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A mixed methods approach towards conceptualizing the influence of training and technology innovation on organizational effectiveness

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Vivian T. Dang

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Dissertation
The Demand for Technical Excellence
A mixed methods approach towards conceptualizing the influence of training and technology innovation on organizational effectiveness

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787-9 at Boeing Field following First Flight on Sept. 17, 2013 by Bob Ferguson.

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For my family…

…BJ

…Mom and Dad (Happy Birthday)

…Grandma

…Kim and Rory

…Finn and Liam

…Phil

…and Ann, I think about you every day.

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I often times have friends and family ask what I will do with my time once I have completed this chapter of my life. I have a huge bucket list of things to do, but they mainly all comprise of spending time with family and friends, and having hobbies. I suppose that is what I will do with my newly found free time…actually have hobbies like a normal human being. Read a book for fun, not journal papers or research papers or any scientific papers. Watch a movie, and I mean really watch a movie and not fall asleep right after the opening credits appear. Part ways with my laptop, as it was almost like I was having an affair with my laptop since I had spent nearly every waking moment on it. Spend quality time with my friends and family, and truly listen and learn something new about them. Travel freely, without ever having any regret of not spending that time working on my doctoral thesis. Sleep and detox from my normal research routine. Yes, this is it…as my good friend recommended to me, go on a Ph.D. detox. Learn how to relax and be happy again.

As for some words of wisdom for this intense process that I have been through and the thousands of hours that I have invested in this endeavor, I have my reservations. And yes, this is my one special spot in my dissertation where I will vent and provide my personal sentiments towards this research process. My thoughts and opinions are strictly from my own personal experience of working full time at an engineering company and pursuing a doctorate at the same time in the evenings after work and throughout the weekends for the past seven years. Hence, *to those who are actually even reading this,* you should take my thoughts with a grain of salt.

To those of you who are planning on pursuing this degree, if you already have a full time career in a field different from your research, walk away now. In fact, *run far away!* If you are a glutton for punishment, go in knowing that the most prevalent sacrifice is your time and your priorities. That may not sound like such a big deal until you have to disappoint family and friends to pursue your own selfish endeavor. You can say farewell to your social life. Bitterness will become a close acquaintance. Your closest family will disappoint you by not understanding the immense stresses involved and will inadvertently introduce more stress in your life at the most inopportune times. That is where anger management comes into play. Easier said than done. Purchase a punching bag, or several. Learn to shut out all of the negativities that will be introduced into your life. Go in knowing that no one will ever comprehend the time involved and mental adversity it takes to do what you do because they are not you. Not their problem. Blah, blah, blah. WTFE.

Pursuing this endeavor is certainly not all rainbows and butterflies, as you can probably sense. You will fail many, many, many times, but it is in those failures that you will learn from and find your way. Just man up, or in this case, woman up and get over it. It is a very humbling experience. I have felt that in those empty, quiet moments in the darkest hours of the night that you come to know yourself and your limits much more intricately. You look at the world around you differently, with both cynicism and gratitude all at the same time. You become a mess of paradoxes, but undeniably, you will come out stronger.

Eventually though, everything does work out and there is a massive payoff at the end. Well, at least in my case. The challenge is to make it to the end and defeat the mental game. In the end, it is definitely all worth it because you then realize that what matters the most in your life is not all of the accomplishments that you have done, but all of the relationships that you have built along the way. You truly know how valuable time is and you will cherish it and appreciate it much more. For me, finding out who truly cares and supports you *no matter what*, is what I have found most rewarding. So for this gratifying culmination, I dedicate this dissertation and all of my time that I had sacrificed for it to those few whom I love and truly care about. You know who you all are. Vivian over and out.

Vivian T. Dang
16 September 2016

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CHAPTER 1
INTRODUCTION

This chapter will establish the importance and significance of managing training changes to align to the technology changes at an aerospace company. Changing the aspect of competencies and managing how and when to offer appropriate training will be highlighted. This chapter will lay the foundation by describing the issue at hand, the main questions needing to be answered to address the issue, and the research approach used to address the research questions. This chapter will conclude with a brief overview of how the research was performed.

1.1 Motivation of the Study

As a Boeing employee having worked in the training organization, technology integration organization, and the structures engineering organization, observations were made regarding the complexities of aligning training to technology innovations. These observations gave motivation towards an independent research to characterize the complexities of training and technology innovation in a large engineering company. Hence, the views expressed in this dissertation are those of the researcher and do not reflect the official policy or position of the Boeing Company.

1.2 Technical Training at the Boeing Company

Every day approximately six million people board airplanes, where approximately 75 percent of the worldwide commercial fleet is Boeing airplanes (Boeing in Brief, 2010). The Boeing Company provides approximately two million hours of instruction each year to over 160 thousand men and women who design, build, test, deliver, and support its airplanes (Boeing, 2009). Because of the scale involved, small effective changes in instruction and workplace learning can have large cumulative impact in terms of increased efficiency, learning curves, and the overall cost of knowledge transfer throughout the enterprise.

During difficult economic times, Boeing faces the same budget cut pressures and layoffs as the rest of the world. In 2009, Boeing cut a total of 10,000 jobs, which equates to about six percent of its workforce (REUTERS, 2009). While training is expensive, the internal training organizations have to work with their reduced budget and resources to develop and deliver the same volume and quality of training. Along these lines, the internal training organizations also have to address the retention of knowledge from those retiring from the company, as well as rapid knowledge transfer to those that are joining the company. With these pressures, it is more important than ever to be very particular in how and when to offer training, and to fully understand the dynamics of offering training in the various disciplines. One area that has been difficult to align training to is the ever changing field of technology.

Technology at Boeing can be found within the areas of IT, learning technologies, novel materials going onto the airplane, communications, as well as many others (Boeing in Brief, 2010). With technologies evolving and changing over time, it is critical for the training to align to these trends to better provide the Boeing workforce with the best training possible. One of the main focuses with Boeing currently is in the advanced materials area, as one of the airplanes driving the company currently is the 787, which is approximately 50 percent composites (Boeing, 2009). Hence, well trained structural engineers are needed more than ever in this area.

1.3 Aligning Training with Technology Innovation

The Boeing Company has several enterprise training curriculums, courses, and initiatives for various kinds of disciplines that require employees to be proficient on (Boeing, 2009). As mentioned in the previous section, one of the main focuses with Boeing currently is in the advanced materials area. Using this technology area in materials sciences as an example, training related within the structures community will be described in this research. To date, there have been several training opportunities for employees working on the structure of the airplane, to take advantage. The challenge is for these employees to know when to take certain training and what curriculum paths they should follow. Curriculum paths within the Boeing Company are career paths recommended by the various organizations within Boeing where lists of competencies and the prerequisite classes to develop and acquire these competencies are made available to employees. Curriculum paths are also called career roadmap or learning maps within the Boeing Company. Another challenge is to have training available when there is a business need that calls for training in a particular technology area.

Technological innovation results in a need for new competencies. Finding the most effective way to align needed training to the changes in technology is a challenge. Offering training too early in a technology lifecycle results in wasted investments. The learners will not have an opportunity to apply what they have learned in the workplace. Offering training too late in a technology lifecycle results in not having a competent workforce. This delays work, as well as places a company behind the rest of their competition. To be able to offer training at the right time during the technology lifecycle would be ideal. An additional challenge is to also identify the appropriate indicators within Boeing that help with mapping out the evolution of technology. This challenge will be discussed in more detail in Chapter 4.

This research will focus on educational considerations and how the technology trends can help predict when to offer courses for various technologies with different maturity levels. This will be done based on observing past models through empirical studies, where two case studies will be analyzed in detail within this research. The case studies explored within this research are intended to be a simplified, conceptualized account of reality, where the overall method developed in the research is tested. It is these conceptual descriptive models that will help give a systematic view of how training and technology innovation interact to affect the organizational effectiveness. Ultimately, the aim of this research is to develop a generalized method that any company comparable to Boeing will be able to use to help create conceptualized models in the context of training, technology innovation, and organizational effectiveness.

1.4 Research Goal and Questions

This research is focused on the previously discussed topics and challenges in a large aerospace corporation. The main goal for this research is to develop a method for conceptualizing the relationships between training (TR), technology innovation (TI), and organizational effectiveness (OE). To achieve this goal, there is one main research question and four sub-questions that will be described in more detail in this section. The main research question is:

<u>What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?</u>

As mentioned in section 1.2, one of the main challenges in organizations is knowing when to offer training when technology changes. One way to address this challenge is to develop a general method showing how to create conceptual models to analyze the relationships between training, technology innovation, and organizational effectiveness. The challenge then is determining how and what kind of data is necessary to gather to study such relationships. Hence, the first research question is:

<u>What key variables are significant for training, technology innovation, and organizational effectiveness?</u>

This first question is intended to analyze the variables that represent each of the three constructs of training, technology innovation, and organizational effectiveness. It is necessary to be able to describe each of these constructs in terms of representative variables as the constructs cannot be measured as is in this current state. As it is the scope of this research to study the relationship between these three constructs, identifying and operationalizing the key variables significant for training, technology innovation, and organizational effectiveness aligns with the goals of this research. This leads into the second research question:

<u>What are the relationships between the key variables?</u>

The second question has a goal of analyzing the relationships between the key variables. Analyzing the significance between the variables, as well as what variable tends to drive the relationship. Conceptual models resulted, where an industry has the opportunity to use the models to help further understand when to offer training when technology changes over time. These conceptual models were based on the research done during the qualitative analysis and quantitative analysis. Once the conceptual models were developed, the models were evaluated by a small panel of subject matter experts (SMEs) to review and compare the viability of the models with what is actually occurring within industry. Hence, the third research question to help address the goal in this research is:

<u>How do the developed conceptual models show when to offer training when technology changes to positively influence organizational effectiveness?</u>

This third question is intended to evaluate the developed conceptual models with a small panel of SMEs. The SMEs evaluated the models with regards to how accurately they depict the current situation and provided context to the case specific operationalized conceptual models. Thereby, the case study phase of this research was completed. This then led to proposing a general method for showing when to offer training to positively influence organizational effectiveness based on the maturity and various types of a technologies. Hence, the fourth research question to help address the goal in this research is:

<u>What general method can be proposed by utilizing the approaches for developing the conceptual models?</u>

This fourth question is intended to develop a general method for showing when to offer training to positively influence organizational effectiveness based on the maturity and type of technology.

Moreover, it is intended that this general method can be used in any large company or organization. For this research, the method is said to be useful if it provides a company a set of guidelines to show how a company could analyze the timing of training for a particular technology. A small panel study will help evaluate this general method with regards to how this method could be used during annual meetings for decision making purposes.

1.5 Research Approach

This section is divided into three sub-sections of Research Philosophy, Research Strategy, and Research Instruments. These sub-sections will describe in detail why a particular research strategy was chosen and what research instruments were used. The research strategy will be described in terms of one blended model in sub-section 1.4.2, which incorporates aspects of three different approaches of design research model (Hevner, March, Park, and Ram, 2004), an inductive-hypothetical research model (Sol, 1982), and an exploratory sequential mixed methods approach (Creswell J. W., 2009).

1.5.1 Research Philosophy

Creswell describes four different worldviews: postpositivism, constructivism, advocacy/participatory, and pragmatism. The accepted approach to research by postpositivists, an individual begins with a theory, collects data that either supports of refutes the theory, and then makes necessary revisions before additional tests are made. Social constructivism, often combined with interpretivism (Mertens, 1998), is typically seen as an approach to qualitative research (Creswell, 2009). The goal of this type of research is to rely as much as possible on the participants' views of the situation being studied. The researcher's intent is to make sense of (or interpret) the meanings others have about the world. According to Creswell, unlike in postpositivism, social constructivism does not begin with a theory, rather inquirers generate or inductively develop a theory or pattern of meaning. An advocacy/participatory worldview holds that research inquiry needs to be intertwined with politics and a political agenda. This philosophical worldview focuses on the needs of groups and individuals in our society that may be marginalized or disenfranchised. The theoretical perspectives may be integrated with the philosophical assumptions that construct a picture of issues being examined, the people to be studied, and the changes that are needed. Creswell describes pragmatism as a worldview arises out of actions, situations, and consequences rather than antecedent conditions like in postpositivism. There is a concern with applications – what works – and solutions to problems (Patton, 1990). The pragmatist researchers look to the *what* and *how* to research, based on the intended consequences – where they want to go with it (Creswell, 2009).

For this research, we are taking a *pragmatism worldview*, where mixed methods approaches will be used for research. In choosing this research strategy, researchers tend to employ sequential, concurrent, and transformative strategies of inquiry (Creswell, 2009). The methods employed are both open-ended and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis. This research follows Creswell's methods in terms of using open-ended questions during interviews conducted to gather data for the qualitative analysis performed in Chapter 4. In addition, quantitative data analysis was used in Chapter 6 to build upon what was found during the qualitative data analysis. This research uses the following practices of research: collects both quantitative and qualitative data; develops a rationale for mixing; integrates the data at different stages of inquiry; presents visual pictures of the procedures in the study; and employs the practices of both quantitative and qualitative research; hence, agreeing with the research strategy outlined by Creswell.

1.5.2 Research Strategy

Quantitative, Qualitative, and Mixed Methods

Two types of research strategies used within quantitative research are survey research and experimental research (Creswell, 2009). According to Creswell (2009), survey research provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. In addition, Babbie (1990) states that survey research includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection, with the intent of generalizing from a sample to a population. Experimental research seeks to determine if a specific treatment influences an outcome (Creswell, 2009). Furthermore, Creswell (2009) explains that this impact is assessed by providing a specific treatment to one group and withholding it from another and then determining how both groups scored on an outcome.

There are several types of qualitative research strategies that include ethnography, grounded theory, case studies, phenomenological research, and narrative research (Creswell, 2009). The main qualitative research strategy used within this particular research is case studies. Case studies are a strategy of inquiry in which the researcher explores in depth a program, event, activity, process, or one or more individuals. According to Stake (1995), cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time.

Creswell (2009) describes that mixed methods strategies are less well known than either the quantitative or qualitative approaches. Three different mixed methods will be described: sequential mixed methods; concurrent mixed methods; and transformative mixed methods. According to Creswell (2009), sequential mixed methods procedures are those in which the researcher seeks to elaborate on or expand on the findings of one method with another method. This may involve beginning with a qualitative interview for exploratory purposes and following up with a quantitative, survey method with a large sample so that the researcher can generalize results to a population. Alternatively, the study may begin with a quantitative method in which a theory or concept is tested, followed by a qualitative method involving detailed exploration with a few cases or individuals.

Concurrent mixed methods procedures are those in which the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem (Creswell, 2009). In this design, the investigator collects both forms of data at the same time and then integrates the information in the interpretation of the overall results.

Transformative mixed methods procedures are those in which the researcher uses a theoretical lens as an overarching perspective within a design that contains both quantitative and qualitative data (Creswell, 2009). Within this lens could be a data collection method that involves a sequential or a concurrent approach.

This research, in general, closely aligns with Creswell's exploratory sequential mixed methods design. Specifically, this research will begin with a qualitative interview approach for exploratory purposes.

The qualitative data analysis resulted in a set of key variables that were significant to the three constructs of this research. The data gathered from operationalizing the variables resulting from the qualitative analysis were then quantitatively analyzed using statistical analysis approaches, specifically correlation analysis. The result of the quantitative data analysis was descriptive conceptual models depicting the relationships between training, technology innovation, and organizational effectiveness. How this research follows Creswell's exploratory sequential mixed methods design will be described in the next sub-section.

This research also uses some aspects of the IS research model similar to Hevner, et. al. In particular, because this research has significant implications towards the business needs, showing relevance is imperative. In addition, showing rigor through extensive literature research is equally important in this research. It is the combination of both the rigor and relevance that feeds into the main research cycle performed in this research, which as described earlier, follows Creswell's exploratory sequential mixed methods approach. The conclusion of this research uses an evaluation to justify the outcomes of the research performed; hence, also aligning to the IS research model (Hevner, March, Park, and Ram, 2004). As it is not within the scope of this research to develop and build artifacts, another research strategy is necessary to explain the conceptual models developed within this research. Hence, this research uses the descriptive portion of the inductive-hypothetical model (Sol, 1982). That is, this research is purely descriptive and not prescriptive in nature, where a descriptive empirical model and three main iterations of the descriptive conceptual models are developed. The process between each of the descriptive and prescriptive models in the inductive-hypothetical model is loosely followed in this research. It is this process and the descriptive nature of the inductive-hypothetical model that replaces the "Design/Build" phase in the IS research model. The combination of Creswell's exploratory sequential mixed methods design, IS research model, and inductive-hypothetical model produces the blended research strategy that is used for this research.

Blended Research Strategy

The exploratory sequential mixed methods design, the IS research framework, and the inductive-hypothetical model, as individual models, lacked the complete framework that is needed for this research. The exploratory sequential mixed methods design and inductive-hypothetical model lacked the relevance in terms of connecting with the business aspect of this research. The IS research framework would be ideal for this research if it had a more robust cycle for developing and building the research. Hence, the combination of Creswell's exploratory sequential mixed methods design, IS research model, and inductive-hypothetical model that produces the blended research strategy is used for this research. This blended strategy tailored for this research is graphically shown in Figure 1-1.

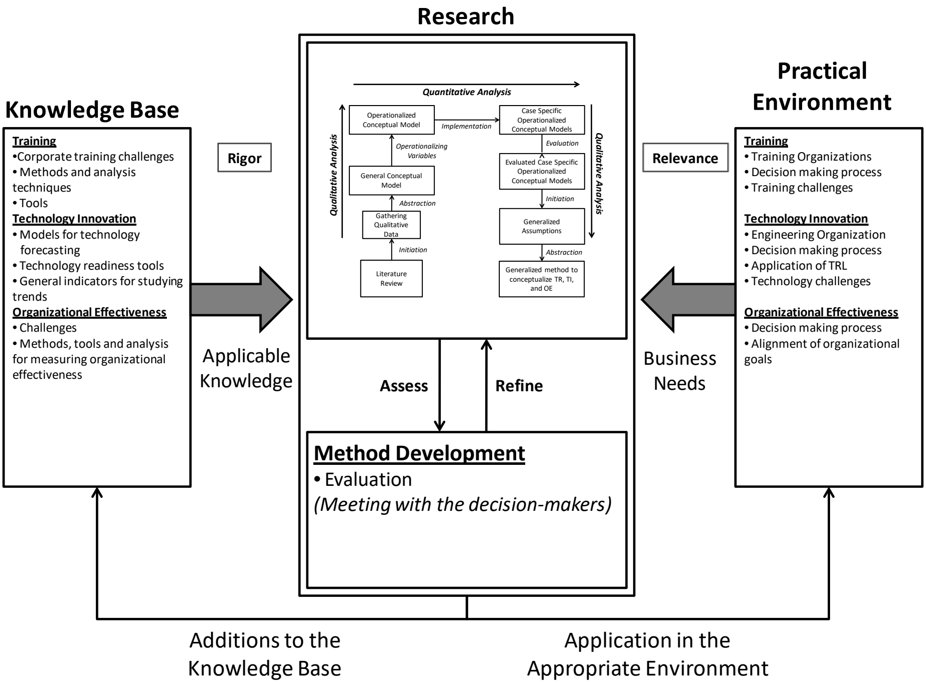


Figure 1-1. Blended research strategy adopted from combination of design-science/behavioral science model (Hevner, 2004), inductive-hypothetical model (Sol, 1982), and exploratory sequential mixed methods research design (Creswell, 2009)

Although the above blended research strategy provides a framework and process for this research, it does not give an indication of *how* the different steps should be carried out. Therefore, the next section will define the instruments that will be used and the function of these instruments throughout this research.

1.5.3 Research Instruments

The research instruments involve the forms of data collection, analysis, and interpretation that researchers propose for their studies (Creswell, 2009). Researchers collect data on an instrument or test or gather information on a behavioral checklist. The choice of methods turns of whether the intent is to specify the type of information to be collected in advance of the study or allow it to emerge from participants in the project. Since this research is focused on mixed methods, there are several different kinds of research instruments used for mixed methods to consider: both pre-determined and emerging methods; both open- and closed-ended questions; multiple forms of data drawing on all possibilities; statistical and text analysis; and across databases interpretation which includes statistical, themes, and patterns interpretation.

As introduced earlier in section 1.5.2, there are five evaluation methods that a researcher can use. For observational method, a researcher can use case studies or field studies for evaluation (Hevner, et.al., 2004; Stake, 1995; Yin, 2003). For analytical methods, static analysis, architecture analysis, optimization, and dynamic analysis can be used for evaluation. For experimental methods, controlled environment, and simulation are used for evaluation. For testing, functional testing and structural testing are used for evaluation. And for descriptive methods, informed arguments and scenarios are used for evaluation.

For this research, two methods of evaluation and instruments were used. They are listed in Table 1-1. For descriptive evaluation model, interviews will be used to gather the necessary data to develop the descriptive conceptual models used within this research. For observational evaluation method, case study was used – study artifact in depth in business environment. This method was used to meet with the decision makers and end-users, where questions regarding usefulness of the general method were furthermore discussed with management.

Table 1-1. Design Evaluation Methods (adopted from Hevner, 2004)

Method	Example
Descriptive	Interviews – Conduct exploratory interviews within various companies to collect data for qualitative data analysis.
Observational	Case Study – Use the results from the exploratory interviews to develop and evaluate findings from quantitative data analysis.

1.5.4 Phased Approach

In the *first phase* of the research, the concepts of TR, TI, and OE were explored and the current situation was described using information from **literature review**. Initial sets of variables resulted from this phase.

In the *second phase* of the research, the concepts of TR, TI, and OE were explored and empirical data were collected. In-depth investigations towards real projects are not yet reported. To gather in-depth information on activities in context of the constructs TR, TI, and OE, an **exploratory interview approach** was chosen. In a limited number of exploratory case studies, semi-structured interviews were held with companies outside of Boeing, as well as within Boeing. Note that practical applications were investigated in chapter three and the knowledge gained from Chapter two and three contributed to the design of the interviews. The exploratory interviews were performed with five companies outside of Boeing, along with seven interviews performed internally at Boeing. The exploratory interviews performed earlier will further be examined in this second phase to help clearly identify the potential relationships between the constructs, as well as any additional variables to consider that are in context of the three constructs. The research in this phase II is qualitatively oriented.

The *third phase* of the research consists of **model development** in terms of operationalizing the variables resulting from the exploratory interview analysis performed in the second phase**.** A general conceptual model representation of the relationships between the three constructs was developed. The aim of this phase is to operationalize the variables for each of the three constructs of TI, TR, and OE. There is a transition from a descriptive conceptual model towards a revised descriptive conceptual model representing the operationalized variables. These transitions aim to set a foundation for the fourth phase to link practice with theory. This in turn, further develops and operationalizes the general conceptual model. Once the general conceptual model is further developed and operationalized, an operationalized conceptual model for this research will become evident. Clearly defining the relationships between the constructs and the relating variables within this research is significant in the development of the conceptual models for this research. In the development of the operationalized conceptual model, the empirical findings from the interviews are confronted with literature findings from Chapter two and three. The interpretation of the general conceptual model resulted in the operationalized conceptual model.

The *fourth phase* of the research consists of **in-depth case studies.** Two cases are studied, representing a mature technology innovation and a technology innovation that is early in the maturity cycle. Based on the theory formulation from the third phase, the revised descriptive conceptual model will be implemented and simulated within the two case studies. This phase focuses on the assumed relationships between the three constructs, as introduced in the first descriptive conceptual model from Phase II. Phase IV has a more explanatory character and is mainly quantitatively oriented. The results from Phase IV will yield a third descriptive conceptual model. The second and fourth phase together is an example of mixed methods approach, but now it is explanatory rather than exploratory. Some of the qualitative findings of Phase II are further explained by means of the quantitative in-depth case studies in Phase IV.

The *fifth* and final phase of the research consists of **method development** to evaluate the descriptive conceptual model. It is investigated to what extent the different aspects of TR contribute to TI, and vice versa, and how the newly developed methodology could help in improving OE at a company. In this final phase of the research, the method developed in this Phase V will be further examined through a small evaluation panel study within Boeing. That is, feedback from the end users (decision makers) will be gathered. The research in this concluding phase is mainly qualitative. The qualitative information explains *how* the descriptive conceptual model could help in improving OE.

In summary, the literature review in the first phase began with observations made from literature review and exploratory interviews. The second phase consisted of the analysis of the exploratory interviews. Model development in the third phase operationalized the variables from Phase II and set the foundation for Phase IV to link practice with theory, which were confronted with literature findings. This resulted in a general conceptual model that generally characterized TI, TR, and OE. The third phase further explored the relationships between TR, TI and OE. Again results are confronted with theory, resulting in the operationalized conceptual model. The fourth phase implemented the Phase III results by means of quantitative in-depth case studies. This resulted in an operationalized conceptual model. In the fifth phase, a method was developed to generalize the approaches followed during Phase I through Phase IV of this research. This method was then evaluated by subject matter experts, resulting in a revised method, thus concluding the research. To strengthen the results, links with literature are established where possible. A summary of the phased approach of this research is shown in Table 1-2 and Figure 1-2.

Table 1-1. Overview of the phased approach of the research

Phase	Chapter	Content	Main Result
Phase I *LITERATURE REVIEW*	Chapter 2 and 3: *Literature review*	What are the key indicators used to characterize technology innovation, training, and organizational effectiveness? What influences engineering companies in determining what technologies to invest in? What influences engineering companies in determing what training is necessary and when to offer? How does technology innovation and training influence organizational effectiveness at engineering companies?	Current situation of characterizing technology innovation, training, and organizational effectiveness *[Addresses research question 1]*
Phase II *EXPLORATORY INTERVIEWS*	Chapter 4: *Exploratory Interviews* *Qualitative Analysis*	How does technology innovation and training influence each other in organizations?	Initial framework to characterize technology innovation, training, and organizational effectiveness *[Addresses research question 1]*
Phase III *MODEL DEVELOPMENT*	Chapter 5: *Model Development* General Conceptual Model Operationalized Conceptual Model	How are technology innovation, training, and organizational effectiveness characterized?	Revised framework containing the operationalization of technology innovation, training, and organizational effectiveness *[Addresses research questions 2]*
Phase IV *CASE STUDIES*	Chapter 6 and 7: *Quantitative Analysis* Case Specific Operationalized Conceptual Model	What framework could be used to characterize the relationships between technology innovation, training, and organizational effectiveness?	Revised framework showing relationships between technology innovation, training, and organizational effectiveness *[Addresses research question 3]*
Phase V *METHOD DEVELOPMENT*	Chapter 8: *Method Development*	How can this framework be used to improve organizational effectiveness?	Method to use this framework to improve organizational effectiveness. Recommendations on application of value improving practices *[Addresses research question 4]*

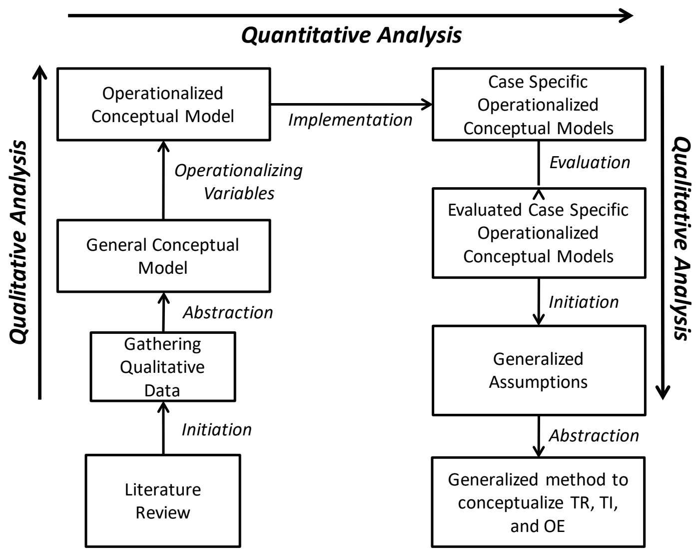


Figure 1-2. Graphical representation of the phased approach of the research

1.6 Dissertation Overview

The thesis is structured into nine chapters, as shown in Figure 1-3. This research begins with the first chapter discussing the pressures that industry is facing with technical training. A problem statement was defined and five research questions were introduced. Three main variables were also introduced within this chapter: Training (TR), Technology Innovation (TI), and Organizational Effectiveness (OE). The research approach was detailed in Chapter 1, which discusses the research philosophy, research strategy, and research instruments.

The second and third chapters provided a literature review, discussing the knowledge base in current literature, and practical knowledge base. These chapters highlighted the current literature and provide examples on the relationship between TR, TI, and OE. The discussion provided in these chapters helped create a foundation for any additional variables that were considered in this research that were in context of the three main variables.

The fourth chapter discussed interviews that were performed, where qualitative data was gathered, quantified, and analyzed. The goal was to thoroughly analyze the qualitative data and address general observations based from findings in Chapter 2 and Chapter 3.

The fifth chapter generalized and operationalized the variables resulting from the qualitative data analysis. A general conceptual model and an operationalized conceptual model were developed, where variables and possible relationships between the variables were confirmed. It was in this chapter that an operationalized conceptual model was introduced based on the general conceptual model from the empirical data gathered in Chapter 4. This chapter also characterized an iterative process towards a method. This iterative process results in the evolution of an operationalized conceptual model. Moreover, this transition aims to link practice with theory by providing a means to measure the variables resulting from Chapter 4 and statistically analyzing the operationalized variables in Chapter 6.

The sixth chapter implemented the operationalized variables from Chapter 5 using detailed case studies. The detailed case studies used the operationalized variables to gather quantitative data, and through the analysis of the quantitative data, an evolved case specific operationalized conceptual model was developed.

The seventh chapter evaluated the case specific operationalized conceptual models that were developed in Chapter 6. A panel of SMEs and managers reviewed the case specific operationalized conceptual models and provided comments.

The eighth chapter developed a method and used a small evaluation panel to discuss embedding the method within Boeing. The method was based on the iterative process of the evolution of the descriptive conceptual models from Chapter 4 through 6. The decision makers at Boeing commented whether this model was effective and how it may fit into the Boeing decision making processes. The goal of this chapter was to develop the method and review with a small group of decision makers. A general method resulted from this chapter.

The ninth chapter concluded this research, making recommendations and giving insight for future studies for this research.

The graphical representation of this research is shown in Figure 1-3.

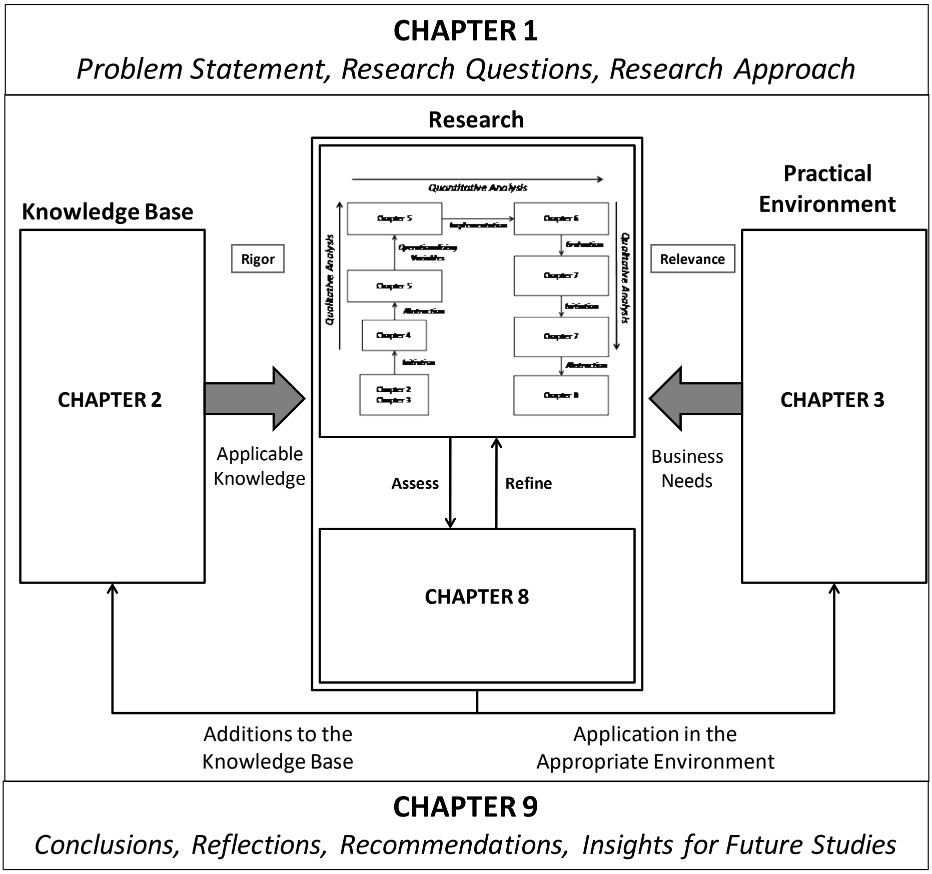


Figure 1-3. Graphical representation of dissertation overview.

CHAPTER 2

THEORY KNOWLEDGE BASE

This chapter is represented as Phase I, shown in Figure 2, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. This chapter will discuss the knowledge base of this research. Current methods, analysis techniques, and tools used for the outlined constructs introduced in chapter one – training (TR), technology innovation (TI), and organizational effectiveness (OE) - are detailed in this chapter. The purpose of this chapter is to build a foundation for this research through detailed study of the knowledge bases found within literature.

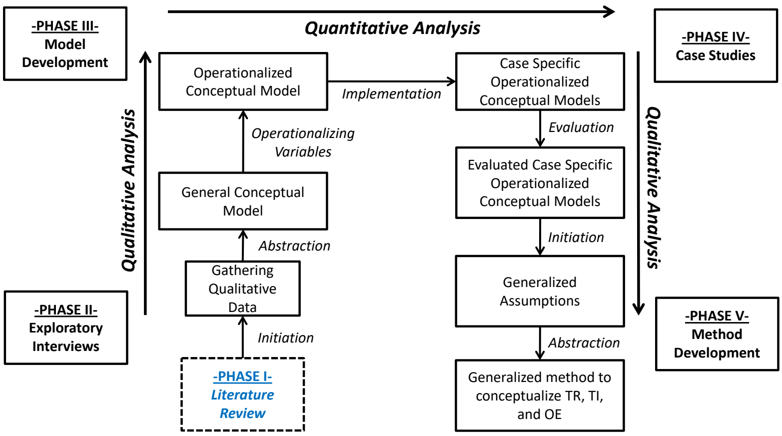


Figure 2. Phase I of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

2.1 Training

Organizations in the United States alone spend about $125 billion on training per year (Patel, 2010). "Training" is the systemic approach to affecting individuals' knowledge, skills, and attitudes in order to improve individual, team, and organizational effectiveness (Aguinis and Kraiger, 2009; Goldstein and Ford, 2002). According to (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012), the term "training" can be thought of as the planned and systematic activities designed to promote the acquisition of knowledge (i.e., need to know), skills (i.e., need to do), and attitudes (i.e., need to feel). These training activities allow organizations to adapt (Salas, Nichols, and Driskell, 2007; Bell and Kozlowski, 2002) innovate (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012), be safe (Allen, Baran, and Cliff, 2010), and reach goals (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). Training has successfully been used to reduce errors in such high-risk settings as emergency rooms (Gaba, 1994; Gaba, 2010; Carayon, 2012), aviation (Endsley and Rodgers, 1996; Jones and Endsley, 2004; Kanki et. al, 2010), and the military (Salas, Wilson, Priest, and Guthrie, 2006; Brock, McManus, and Hale, 2009; Sitzmann, Brown, Ely, and Kraiger, 2009). Salas and Cannon-Bowers (2001) explain that effective training takes place when trainees are intentionally provided with pedagogically sound opportunities to learn targeted knowledge, skills, and attitudes (KSAs) through instruction, demonstration, practice, and timely diagnostic feedback about their performance. Salas et. al. (2012) state that the goal of training is to create sustainable changes in behavior and cognition so that individuals possess the competencies they need to perform a job. These organizations understand that training helps them to remain competitive by continually educating their workforce (Casner-Lotto, 1988; Salas et. al., 2012). In addition, they understand that investing in their employees yields greater results. But it should also be noted that while training can be beneficial to organizations in theory, in practice there are challenges and unforeseen obstacles that may lead to diminished outcomes. Hence, it is important to understand how training is widely used in companies and organizations and how this knowledge relates to this research. To help narrow this down, a few questions need to be addressed: *What are the benefits of training? What are common corporate training challenges? What methods and analysis techniques are used to determine when to offer training and what kind of training to offer? What kinds of tools are used to determine when to offer training and what kind of training to offer? How is training operationalized to ensure organizational effectiveness?* This chapter will aim to discuss and dive deeper into these questions to help provide partial answers to sub-question 1 from Chapter 1: *What key variables are significant for training, technology innovation, and organizational effectiveness?*

2.1.1 Benefits of Training Activities

There is documented evidence that training activities have a positive impact on the performance of individuals and teams (Aguinis and Kraiger, 2009). Aguinis and Kraiger (2009) state that training activities can also be beneficial regarding other outcomes at both the individual and team level (e.g., attitudes, motivation, and empowerment).

Benefits of Training for Job Performance

According to studies performed by Hill and Lent (2006), Satterfield and Hughes (2007), and Kraiger (2002), training-related changes result in improved job performance and other positive changes, which may include acquisition of new skills. In addition, Arthur et al. (2003) conducted a meta-analysis of several effect sizes from various sources and concluded that in comparison with no-training or pre-training states, training had an overall positive effect on job-related behaviors or performance.

In summary, a considerable number of individual studies (Aguinis and Kraiger, 2009; Hill and Lent, 2006; Satterfield and Hughes, 2007; Kraiger, 2002; Arthur et al., 2003) and meta-analytic reviews (Arthur et al., 2003; Salas, Nichols, and Driskell, 2007) provide support for the many benefits of training for individuals and teams. These benefits include performance as well as variables that relate to performance directly (e.g., innovation and tacit skills, adaptive expertise, technical skills, self-management skills, cross-cultural adjustment) or indirectly (e.g., empowerment; communication, planning, and task coordination in teams).

Benefits of Training at an Organization Level

Aguinis and Kraiger (2009) reported several studies regarding the benefits of training at an organizational level. These studies are highlighted in this sub-section. According to Swanson (2001), fewer than 5% of all training programs are assessed in terms of their financial benefits to the organization. Aguinis and Kraiger (2009) comment that the picture changes among companies recognized for their commitment to training. Moreover, Aguinis and Kraiger (2009) point out from Paradise (2007) and Rivera and Paradise (2006) that specifically, the majority of organizations recognized by ASTD for innovative training programs measure training impact at some level of organizational effectiveness. Typical organizational performance measures in this latter sample include productivity improvement, sales or revenue, and overall profitability (Aguinis and Kraiger, 2009). Overall, Aguinis and Kraiger (2009) conclude that research regarding organizational-level benefits is not nearly as abundant as the literature on individual- and team-level benefits. Furthermore, Aguinis and Kraiger (2009) refer to Tharenou et al. (2007), stating that not only have there been relatively few empirical studies showing organizational-level impact, but those studies that have been done typically use self-report data and unclear causal link back to training activities.

Aguinis and Kraiger referred to several studies performed byAragon-Sanchez et al. (2003), Ubeda-Garcıa (2005), and Guerrero and Barraud-Didier (2004) that were conducted in European countries having documented the impact of training on organizational performance. Aragon-Sanchez et al. (2003) investigated the relationship between training and organizational performance by distributing a survey to hundreds of small and medium-size businesses in five different countries. Organizational performance was operationalized as (a) effectiveness, in terms of employee involvement, human resource indicators, and quality, and (b) profitability, in terms of sales volume, benefits before interest and taxes, and a ratio of benefit before taxes/sales. According to Aguinis and Kraiger (2009), results indicated that some types of training activities, including on-the-job training and training inside the organization using in-house trainers, were positively related to most dimensions of effectiveness and profitability.

Aguinis and Kraiger (2009) reported that Ubeda-Garcıa (2005) conducted a study including several Spanish firms with more than 100 employees. According to Aguinis and Kraiger (2009), this study related organizations' training policies (e.g., functions assumed by the training unit, goals of the training unit, nature of training, and how training is evaluated) with four types of organizational-level benefits: employee satisfaction, customer satisfaction, owner/shareholder satisfaction, and workforce productivity (i.e., sales per employee). Furthermore, Aguinis and Kraiger (2009) concluded that the results suggested that training programs oriented toward human capital development were directly related to employee, customer, and owner/shareholder satisfaction as well as an objective measure of business performance (i.e., sales per employee).

Aguinis and Kraiger (2009) reported that Guerrero and Barraud-Didier (2004) administered a questionnaire to over a thousand human resource directors working in large companies and collected financial information from the companies' financial directors or through databases approximately one year later. Moreover, Aguinis and Kraiger (2009) noted that five questions in the survey addressed the extent to which the company implemented training practices, and also included questions about social and organizational performance including work climate, employee attendance, quality of products and services, and employee productivity. Aguinis and Kraiger (2009) concluded that the results showed that some of the variance in financial performance was explained by training (via the mediating role of social and organizational performance).

Aguinis and Kraiger (2009) reported that Alnidawy (2015) conducted a study to identify the training needs on the effectiveness of the training process and improving the individual and organizational performance. Alnidawy (2015) stated that the organizations must work to identify employees and organization training needs accurately. Aguinis and Kraiger (2009) concluded that the results in this study showed that identifying training need had significant impact on the efficiency of the training programs and could improve the individual and organizational performance.

In a study performed by Bapna et. al. (2013), as reported by Aguinis and Kraiger (2009), a panel dataset of small to medium sized IT service firms were used to assess how training enhances human capital, thereby improving firm revenues. Aguinis and Kraiger (2009) stated that this study found an increase in training investments that was significantly linked to an increase in revenue per employee. Moreover, Aguinis and Kraiger (2009) concluded that marginal returns to training were increasing firm size. According to the study performed by Bapna et. al. (2013), it was concluded that, comparatively speaking, large firms benefit more from training.

In summary, there are many studies that have gathered support for the benefits of training for organizations. According to Aguinis and Kraiger (2009) and the various studies described in this sub-section, these benefits were described in terms of improved organizational performance (e.g., profitability, effectiveness, productivity, operating revenue per employee) as well as other outcomes that relate directly (e.g., reduced costs, improved quality and quantity) or indirectly (e.g., employee turnover, organization's reputation, social capital) to performance.

Summary: Identified variables from benefits of training activities

This section aimed to show how training can be beneficial to organizations, and in turn, positively influence organizational effectiveness. The variables that are identified as influencing organizational effectiveness are shown in Table 2-1.

Table 2-1. Identified variables from benefits of training activities

Benefits of Training Activities		
Variables		**References**
Organizational Performance (performance measurement)	profitability	Aragon-Sanchez et. al. (2003)
	effectiveness	Aragon-Sanchez et. al. (2003)
	productivity (e.g. sales per employee)	Swanson (2001); Paradise (2007); Rivera and Paradise (2006); Ubeda-Garcia (2005); Guerrero and Barraud-Didier (2004)
	operating revenue per employee	Swanson (2001); Paradise (2007); Rivera and Paradise (2006); Ubeda-Garcia (2005)
	costs	Swanson (2001); Paradise (2007); Rivera and Paradise (2006); Aragon-Sanchez et. al. (2003); Ubeda-Garcia (2005); Guerrero and Barraud-Didier (2004)
	quality	Aragon-Sanchez et. al. (2003); Guerrero and Barraud-Didier (2004)
	quantity	Aragon-Sanchez et. al. (2003)
	employee turnover	Aragon-Sanchez et. al. (2003); Ubeda-Garcia (2005); Guerrero and Barraud-Didier (2004)
	productivity improvement, sales or revenue, overal profitability	Swanson (2001); Paradise (2007); Rivera and Paradise (2006)
	effectiveness (employee involvement, human resource indicators, and quality)	Aragon-Sanchez et. al. (2003)
	profitability (sales volume, benefits before interest and taxes, ratio of benefit before taxes/sales)	Aragon-Sanchez et. al. (2003)
	employee satisfaction, customer satisfaction, owner/shareholder satisfaction, workforce productivity (sales per employee), business performance (sales per employee)	Ubeda-Garcia (2005)
	work climate, employee attendance, quality of products and services, employee productivity	Guerrero and Barraud-Didier (2004)

2.1.2 Common Instructional Systems Design (ISD) Frameworks used in Training

To better understand the training organization within Boeing, which will be introduced in Chapter 3, methodologies within analysis, course design, delivery methods, implementation, and evaluation will need to be described. Hence, the purpose of this section is to highlight an existing ISD framework and give an example of another variation of this framework to help lead into the discussion in Chapter 3. It is not the intent of this section to go into detail into all of the existing ISD frameworks, as that is out of the scope of this research.

ADDIE (Analysis, Design, Develop, Implement, Evaluate)

There are several ISD frameworks (e.g. CDIO (Conceive, Design, Implement, and Operate), Dick and Carey, Kemp) that are used in training that are variations or have components similar to that of the ADDIE process. Among these frameworks, ADDIE and CDIO will be briefly discussed. The ADDIE model is the generic instructional systems design process traditionally used by instructional designers and training developers (Molenda, 2003). The underlying concepts of ISD can be traced to the model developed for the U.S. Armed forces in the mid-1970s. As Branson (1978) recounts, the Center for Educational Technology at Florida State University worked with a branch of the U.S. Army to develop a model, which evolved into ADDIE, intended for the Army, Navy, Air Force, and Marine Corps. The five phases—Analysis, Design, Development, Implementation, and Evaluation—represent a general guideline for building training (Molenda, 2003; McGriff, 2000; Peterson, 2003). Each of these five phases is briefly described in the following sub-sections, where a summary of these five phases is shown in Figure 2-1.

Throughout this research, as variables that influence the relationship between training and organizational effectiveness, and training and technology innovation become evident, it will be important to recognize where in the ADDIE process these variables directly affect. If it is known *where* in the ADDIE process the variables that are causing an effect on organizational effectiveness, or on technology innovation, then that may help give an indication as to *how* to address the problematic variables. This is important because ultimately, as described in Chapter 1, this research aims to explain how training can help technology innovation to *positively* influence organizational effectiveness.

Analysis Phase

In the analysis phase, a needs assessment or analysis may be performed (Peterson, 2003; McGriff 2000; Tannenbaum, 2002; Tannenbaum and Yukl, 1992; Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012; Goldstein, 1986; Rossett, 1987; Holton III, 1996; Sels, 2002; van Eerde, Tang, and Talbot, 2008; Arthur Jr., Bennett Jr., Edens, and Bell, 2003; Aguinis and Kraiger, 2009; Morano, 1973), although not all organizations perform a needs analysis (Arthur et. al., 2003). In a needs assessment, there are three areas of analysis – organizational, task, and person (Morano, 1973; Holton et. al., 2000; Mcgehee and Thayer, 1961). The analysis phase defines what is to be learned, where the instructional problem is clarified, the instructional goals and objectives are established, and the learning environment and learner's existing knowledge and skills are identified (McGriff, 2000; Goldstein, 1986; Rossett, 1987). This can be thought of as the "task analysis." In addition, the analysis phase identifies who the audience is for the training (person/individual analysis) and ensures that the training aligns to the overall organizational goals (organizational analysis).

Design Phase

The design phase deals with learning objectives, assessment instruments, exercises, content, subject matter analysis, lesson planning and media selection (Goldstein, 1986; McGriff, 2000; Peterson, 2003; Salas et. al., 2012; Aguinis and Kraiger, 2009). These are steps commonly used for the design phase (McGriff, 2000; Peterson, 2003; Goldstein, 1986):

- Documentation of the project's instructional, visual and technical design strategy
- Apply instructional strategies according to the intended behavioral outcomes by domain (cognitive, affective, psychomotor).
- Create storyboards
- Design the user interface and user experience
- Prototype creation
- Apply visual design (graphic design)

Development Phase

The development phase is where the developers create and assemble the content assets that were created in the design phase (McGriff, 2000; Goldstein, 1986; Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012; Aguinis and Kraiger, 2009). Programmers work to develop and/or integrate technologies. Testers perform debugging procedures. The project is reviewed and revised according to any feedback given.

Implementation Phase

During the implementation phase, a procedure for training the facilitators and the learners is developed (Goldstein, 1986; Peterson, 2003; Salas et. al., 2012; Arthur Jr. et. al., 2003; Aguinis and Kraiger, 2009). This is also the phase where the project manager ensures that the books, hands on equipment, tools, CD-ROMs and software are in place, and that the learning application or Web site is functional (McGriff, 2000).

Evaluation Phase

The evaluation phase consists of two parts: formative and summative (Peterson, 2003; Salas et. al., 2012; Kraiger, 2002; Arthur Jr. et. al., 2003; Aguinis and Kraiger, 2009; Bartel, 2000). Formative evaluation is present in each stage of the ADDIE process. Summative evaluation consists of tests designed for domain specific criterion-related referenced items and providing opportunities for feedback from the users (Goldstein, 1986). Historically, organizations and training researchers have also relied on Kirkpatrick's (2004) hierarchy as a framework for evaluating training programs (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). The foundation of this model includes the application of four levels of evaluation: reaction, learning, behavior, and results (Kirkpatrick, 1998). According to Kirkpatrick (1996), the four levels of evaluation can be summed up in this way:

- 1. Level I: Reaction (Smile-sheet evaluation). “Did you like the training?”
- 2. Level II: Learning (Testing). “Did you understand the information and score well on the test?”
- 3. Level III: Behavior (Job improvement). “Did the training help you do your job better and increase performance?”
- 4. Level IV: Results (Organizational improvement). “Did the company or department increase profits, customer satisfaction, and so forth as a result of the training?”

Although the most desired way to apply this model is to use all four levels, this is seldom the case. In fact, in a study by Robinson and Robinson, approximately 150 training professionals were asked to indicate the frequency with which they currently implemented each of Kirkpatrick’s four levels of evaluation in their respected companies (Robinson and Robinson, 1989). Results showed that Level I evaluations were routinely performed; there was a large variation in the frequency of complete Level II evaluations; that, while nearly one-third of the respondents indicated no Level III evaluation, about 70% of the participants do use this level at least occasionally; and that 60% of the respondents do not use any form of Level IV evaluation. To support this study, the 2004 American Society for Training and Development State of the Industry Report indicated the following from a cross section of benchmarking organizations: More than 74% surveyed conduct Level I evaluations; 31% conduct Level II evaluations; 14% conduct Level III evaluations; and less than 10% conduct level IV evaluations (Cohen, 2005). It is argued that evaluation becomes more difficult, complicated, and expensive as it progresses from Level I to Level IV (Kirkpatrick, 1998). From a business perspective, Level IV is the most difficult data to obtain because of the complexity of directly linking training to financial returns (Winfrey, 1999). In summary, Kirkpatrick’s framework remains the basis for much of the evaluation efforts in organizations today (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012).

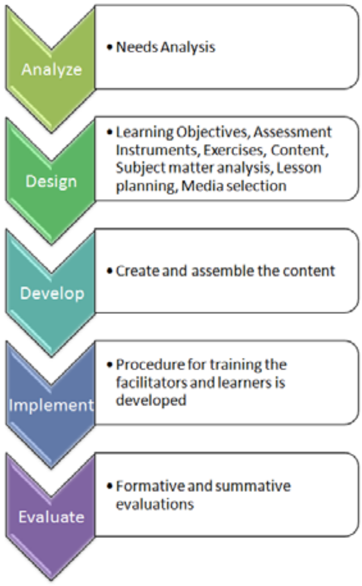


Figure 2-1. The phases of the ADDIE model

CDIO (Conceive – Design – Implement – Operate)

CDIO serves as an ISD process for engineering education in disciplines that build products (Crawley et. al., 2008). According to Crawley et. al. (2008), there are four phases in CDIO – conceive, design, implement, and operate. The conceive stage includes defining customer needs; considering technology, enterprise strategy, and regulations; and developing conceptual, technical, and business plans. The second stage, design, focuses on creating the design, which includes the plans, drawings, and algorithms that describe what product, process, or system will be implemented. The implement stage refers to the transformation of the design into the product, including hardware manufacturing, software coding, testing, and validation. The final stage, operate, uses the implemented product, process, or system to deliver the intended value, including maintaining, evolving, recycling, and retiring the system.

The main difference between the CDIO framework and the ADDIE framework is that ADDIE includes an evaluation phase and CDIO excludes an evaluation phase. In a practical sense, companies evaluate their product, or training, in order to show success or effectiveness (Cairns, 2012; Goldstein, 1986; Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). In terms of training, some level of evaluation is done to ensure that knowledge was transferred and that employees are capable of performing their jobs effectively (Kirkpatrick, 1998). Hence, the evaluation phase is critical in companies and organizations.

Systematic View of Training – The Science of Training

Theoretical contributions from Kozlowski, Brown, Weissbein, Cannon-Bowers, and Salas (2000) and Kozlowski and Salas (2000) have expanded the understanding of training to include both micro and macro perspectives as well as a multidisciplinary view. Researchers now recognize that multiple levels within an organization (i.e., at the levels of the individual, the team or unit, and the organization itself) influence and are affected by training (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). According to Salas, the science of training is rooted in a variety of disciplines; authors who conduct research and publish articles about training have a wide range of educational and experiential backgrounds and perspectives. Moreover, a variety of disciplines (e.g., cognitive science, engineering, systems and industrial/organizational psychology management, education) contribute to the understanding of training effectiveness and the theories that motivate it (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012).

The relationship between training events and organizational characteristics is highlighted in one of the most notable advancements in the science of training – the development of training effectiveness models (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). Earlier training models, like what was explained by Goldstein (1986), described and linked the processes involved in identifying training needs, designing training, and delivering training. However, considerable modern research and theory considers the many factors that may impact the effectiveness of training (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). A framework developed by Cannon-Bowers, Tannenbaum, Salas, and Converse (1991) linked training theory and practice. The framework incorporates three practical questions that should be considered when conducting training: (a) What should be trained? (b) How should training be designed? and (c) Is training effective, and if so, why? Note that in these three main questions, the question of *when* training should be implemented is not explicitly listed, hence the goal of this research to reveal and describe the importance.

Salas et al. (2012), pointed out that successful training is not a one-time event but an iterative process that considers the elements leading up to training as well as important factors after training. Researchers have examined how activities before, during, and after training influence training effectiveness and thus, influencing organizational effectiveness. Studies performed by Grossman and Salas (2011) and Tannenbaum, Mathieu, Salas, and Cannon-Bowers (1991) showed that successful training considers the elements that will influence training beforehand, as well as examines elements within the transfer environment. In this regard, research clearly shows that formal and informal reinforcement is critical for ensuring that trainees will choose to transfer what they have learned outside the formal training environment (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). According to Ford, Quinones, Sego, and Sorra (1992) and Quinones, Ford, Sego, and Smith (1995), students with newly trained behaviors need to be given the opportunities on the job in order to ensure knowledge transfer and be productive. In addition, trainees may be assigned to duties that differ from what they were trained to do or may return to work to find that they do not have ample time to use what they have learned or that the newly learned knowledge of a particular technology is currently not in use by the organization. If opportunities to perform are few and far between, trainees are likely to forget what they have learned and/or to view it as unimportant. Finally, as obvious as it may sound, timing of when training is offered plays a critical role in training effectiveness, where the timing can positively or negatively affect organizational effectiveness. If the technology is not currently ready and/or being used by the organization, then training in that technology will not be effective, as outlined above. To reiterate, trainees will not have the opportunity to transfer the knowledge that they have learned outside of the formal training environment.

Taken together, these studies, along with our observation regarding the timing of training, illustrate the importance of viewing training "as a system" and not a one-time event. This system must take into account what happens before, during, and after training (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). According to Salas and other researchers, this system must promote the application of newly acquired skills to the job. Salas et al., suggested that *what happens in training is not the only thing that matters – a focus on what happens before and after training can be as important. Steps should be taken to ensure that trainees perceive support for the organization, are motivated to learn the material, and anticipate the opportunity to use their skills once on (or back on) the job.* For this research, the above suggestion is considered not entirely complete. In addition, steps should also be taken to ensure that the timing in which training is offered at the right time and coincides with the opportunity to use their knowledge on the job. These steps will help show that the training is effective and that the training strategy positively affects the organizational effectiveness.

The Context in Airplane Design

According to Crawley et. al. (2008), context is the cultural framework, or environment, in which technical knowledge and skills are learned. Based on several current literatures (Casner-Lotto, 1988; Peterson, 2003; Salas et. al., 2012; van Eerde et. al., 2008; Park and Jacobs, 2011; Bartel, 2000), some or all of the components of ADDIE were used for training to be effective, which in turn, helps positively influence organizational performance and effectiveness. Therefore, within the culture of education and training in companies and organizations, the skills that are taught and the approaches that are conveyed should all contain components of the ADDIE process. Since the ADDIE process is a generalized ISD framework, for the purposes of this research, the ADDIE process will also be described in a practical sense, within the context of airplane design.

In airplane design, there is a lifecycle. The process of product lifecycle management (PLM) for the Boeing Company will be described in Chapter 3. In essence, the process of PLM contains components of the ADDIE process, but in the context of airplane design and not instructional systems design. There is an analysis phase, where benchmarking is done to analyze the market, costs, time-to-completion, etc. There is a design phase, where the information found during the analysis phase is taken into account while designing the airplane. When designing the airplane, the FAA requirements are followed, as well as the overall organizational requirements (cost [budget], safety [FAA requirements], performance, and schedule [more so for the commercial side since customers are involved and customers provide the budget]). In the development stage, the parts designed in the design phase are manufactured. The implementation phase is where the parts developed are tested. During the evaluation stage, the data from the tested parts are analyzed and ensured that the developed parts meet the FAA requirements for certification. Once all of the phases are complete, the airplane is then ready for delivery to the customer. It should be noted that all of these phases are repeated for each technology domain, which will be further discussed in Chapter 3. Each of the technology domains may have several stages in which aspects of the ADDIE phases are repeated. For example, in the structures domain, there are three main levels where design, development, implementation, and evaluation is repeated. The three levels are coupon, component, and full-scale. Once the components for all of the technology domains are integrated together, full-scale testing is then performed and analyzed by each domain. Some of these testing include avionics (flight testing), systems, and structures (full-scale fatigue). The details of this process will be described in Chapter 3.

Summary: Variables from common ISD frameworks

The variables of interest in this section are found in Table 2-2.

Table 2-2. Variables from common ISD frameworks

Common ISD Frameworks		
Variables		References
ADDIE/CDIO	need analysis/assessment (budget, training audiences, resources, training program determination, length of training, link to org. goals)	Peterson (2003); McGriff (2000); Tannenbaum (2002); Tannenbaum and Yukl (1992); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Morano (1973)
	development and planning/designing training	Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009)
	delivery/implementation	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009)
	evaluation (including ROI - impact on the organization's mission and operation; transfer of training/knowledge; reduction of error)	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Kraiger (2002); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Bartel (2000)

2.2 Technology Innovation

First, when describing technology innovation in this section, it is necessary to define technology and innovation at an organizational level. According to the Merriam-Webster dictionary, in relation to the engineering field, "technology" generally means the application of scientific knowledge for practical purposes and "innovation" generally means a new method, idea, or product. Researchers (Amabile, 1988; Damanpour and Wischnevsky, 2006; Walker, 2008; Zaltman, Duncan, and Holbek, 1973) have generally defined "innovation" as the development (generation) and/or use (adoption) of new ideas, methods, products, or behaviors. Hence, the term *technology innovation* used throughout this research may be defined as the application of a new method, idea, or product to the scientific knowledge for practical purposes. An example of this in the aerospace industry is the application of nanotechnology as a novel material system towards the structure of an airplane. Moreover, in the above example, nanotechnology is the technology innovation, where the material system is what currently exists in the scientific knowledge in terms of materials; and the application of the new material system towards the structure of an airplane is the practical purpose. The reason for combining these two terms – technology and innovation – is that throughout this research, there is emphasis on the applicability and practicality of the three constructs in a commercial environment. Innovation taken alone does not emphasize on application and technology taken alone does not imply novel technologies; hence, it is the combination of these two terms that best describe the construct *technology innovation* in this research.

2.2.1 Technology Innovation Uncertainties and Challenges in Organizations

Autant-Bernard, Chalaye, Manca, Moreno, and Surinach (2010) states that the framework of technology innovation can be summarized into two uncertainties: (1) *what* kind of innovation is being adopted, and (2) *how* the innovation is being adopted. Cho and McCardle (2009) describe the timing of adoption being affected by the uncertainties of economic dependence outside of the firm that inherently defines cost relationships inside the firm. In addition, according to Van Ittersum and

Feinberg (2010), the two critical uncertainties associated with technology innovation introductions are *whether* and *when* the target market will adopt them. Van Ittersum and Feinburg (2010) further state that one way to reduce these uncertainties is to survey members of the target market about their intentions to adopt the technology. Young, DeSarbo, and Morwitz (1998) argues that the widespread use of intention measures to predict adoption behavior hinges on the belief that intentions are accurate indicators of people's behavior. Moreover, Armstrong, Morwitz, and Kumar (2000) state that intention measures have been shown to be a valuable input in predicting purchase behavior and sales forecasts. Taking the intention measures one step further, Van Ittersum and Feinburg (2010) used timed intent measures to allow for the assessment of both whether and when a technology innovation is most likely to be adopted. That is, timed intent was measured by presenting respondents with multiple time intervals for a specified time horizon for a specific technology innovation. This research aims to study the *when* aspect of technology innovation adoption in more detail and will further describe this uncertainty throughout the upcoming chapters as it relates to training and organizational effectiveness.

2.2.2 Underlying Drivers of Technology Innovation in Organizations

Technology innovations are important drivers of economic progress, productivity growth, long-term performance (Singh, Mathiassen, Mishra, 2015), and competitiveness strategy (Zamora-Torres, 2014). Zamora-Torres used statistical data from an institution for a particular year to select the indicators for their research. The aim of their work was to measure the impact of different variables that affect innovation and technology, as well as the real economy. The variables included high technology products export (US$), high technology products export (% of exp. Of manufacture), patent applications, spending on R & D, and scientific and technological publications.

According to Wejnert (2002), the framework for technology innovation is grouped into three major components: (1) characteristics of the innovation itself; (2) characteristics of innovators that influence the probability of adoption of an innovation; and (3) characteristics of the environmental context. Wejnert (2002) further defines each of the three components into more variables. The characteristics of innovations have two variables consisting of public versus private consequences, and benefits versus costs; characteristics of innovators have six variables consisting of societal entity, familiarity with the innovation, status characteristics, socioeconomic characteristics, position in social networks, and personal characteristics; and environmental context has four variables consisting of geographical settings, societal culture, political conditions, and global uniformity.

Another decision making factor includes timing of technology innovation adoption. In a study conducted by Richardson (2011), factors that were most influential on trainers' decision to adopt the use of a technology innovation were investigated. Among the factors that Richardson (2011) found most influential included timing of technology innovation adoption.

Sawang and Unsworth (2011) studied technology innovation implementation effectiveness in small and mid-size businesses. Their variables included financial resource availability, top management support, implementation policies and practices, implementation climate, implementation effectiveness, and innovation effectiveness. Implementation policies and practices were in terms of policies that support innovation implementation such as training, communication, and assistant program. Implementation climate was in terms of managerial perceptions of the extent to which organizational members support the implementation activities. Implementation effectiveness was in terms of managerial attitude toward implementation process. Innovation effectiveness was in terms of perceived benefits from implemented innovation.

Regarding technology innovation measurement and evaluation, a commonly known approach towards evaluating a technology innovation maturity is the NASA/DoD TRL scale (DoD, 2009). This scale consists of integral values (1–9) that provide ordinal scorings of the readiness of a technology and its integration. Their use is susceptible to inconsistencies in interpretation (Kujawski, 2012). Moreover, according to Kujawski (2012), DoD acquisition programs have been directed to use the TRL scale with no guidance on how to do it or deal with the noted ambiguities.

Summary of the Underlying Drivers of Technology Innovation

The underlying variables that affect technology innovation are summarized in Table 2-3.

Table 2-3. Underlying Drivers of Technology Innovation

Underlying Drivers of Technology Innovation		
Variables		References
Economy/Costs	high technology products export [US$]; high technology products export (% of exp. Of manufacture); patent applications; spending on R & D; and scientific and technological publications; benefits versus costs; societal entity; geographical settings; political conditions	Zamora-Torres (2014); Wejnert (2002)
Technology Innovation Adoption	timing of technology innovation adoption	Richardson (2011)
Technology Innovation Implementation	financial resource availability; top management support; implementation policies and practices - training, communication, and assistant program; implementation climate - managerial perceptions; implementation effectiveness - managerial attitude towards implementation process; and innovation effectiveness - perceived benefits from implemented innovation	Sawang and Unsworth (2011)
Technology Innovation Measurement and Evaluation	technology innovation maturity - TRL	DoD (2009)

2.2.3 Factors between Training and Technology Innovation in Organizations

An issue any manager, or organization, will face when choosing which training practices or new technologies to implement is predicting the timing of returns generated by these investments (McGrath and Percival, 2013). According to McGrath and Percival, the timing is more difficult to estimate and varies greatly depending on the type of returns considered. Returns can be measured in terms revenues, productivity, efficiency, or innovation. Blundell et al. (1999) states that the timing of training is of paramount importance due to strong evidence suggesting, skills obtained through training depreciate at a considerable rate over time and this results in declining returns from the training. McGrath and Percival (2013) suggest that the depreciation of training can occur for a variety of reasons which include technology and organizational developments, shifts in structure of employment and organization, and worker displacement.

2.3 Organizational Effectiveness

In order to begin describing organizational effectiveness, the combination of these two terms need to be defined. The term "organization" that has been used throughout this chapter and for the rest of the research is intended to be in terms of a commercial, for-profit, business environment and not in terms of a non-profit environment. Regarding the term "effectiveness," there are sometimes confusion between what is effective and what is efficient. Corporate University (CorpU) Xchange defines effectiveness and efficiency as (CorpU, 2013):

> *"Effectiveness (alignment and measurement): aligned with business strategy plus measureable impact"*

> *"Efficiency (organization and execution): optimal infrastructure plus cost effective delivery"*

Hence, the difference between effectiveness and efficiency is that the former is based upon alignment and measurement, where alignment means aligning to the overall business strategies and measurement means being able to quantify the impact to the overall business strategies. The latter, that is efficiency, is based upon optimization in terms of cost. Relating back to this research, efficiency may be taken as a subset of effectiveness, meaning measurable impacts to the organization may be affected by the cost and optimization of a product. The cost here may pertain to the costs of training, the costs of technology innovation, and the costs related to the performance of an airplane. To summarize, effectiveness can be measured by how well something can be produced while efficiency is measured by how cheaply something can be produced. Therefore, the term *organizational effectiveness* used throughout this research may be taken as the measureable impacts towards the overall organization. It is the purpose of this section to further define the *measureable impacts* in terms of latent and manifest variables that can be operationalized later in the research, particularly in Chapter 5, when discussing the conceptual model.

2.3.1 Underlying Drivers of Organizational Effectiveness

Finance, Products and Markets, and Human Capital

According to Boudreau and Ramstad (2005), to maintain a competitive advantage, organizations must succeed in three domains: finance, products or markets, and human capital (or their workforce). According to Salas et. al. (2012), worldwide economic cycles tend to create conditions in which obtaining sufficient financing is either equally easy or equally difficult for most organizations of the same size. Moreover, Salas et. al (2012), described that in today's global economy, all organizations can sell to the same markets and product development cycles are such that differences in product innovation are much smaller than in years past. Hence, according to both Huselid and Becker (2011) and Park and Jacobs (2011), it is the human capital in terms of building and maintaining a more capable and better trained workforce that is available to most organizations and is most sustainable.

Human Capital

Effective management of the acquisition and training of human capital is an important key to organizational success (Salas et.al., 2012). According to Delaney and Huselid (1996), effective practices by organizations related to staffing and training were positively related to perceived organizational performance. In addition, in a study performed by Huselid (1995), the use of high-performance work practices predicted employee retention and performance as well as long-term measures of corporate financial performance. Aguinis and Kraiger (2009) also cited multiple studies in several countries that link training practices and policies to measures of organizational effectiveness. The studies described here show that training is a key component in building and maintaining an effective employee workforce, which in turn drives various metrics of corporate well-being and directly effects organizational effectiveness.

Summary of the Underlying Drivers of Organizational Effectiveness

The underlying variables that affect organizational effectiveness are finance, market or product, and human capital. Two of these variables are also considered constructs in this research – product and human capital. The summary of the underlying variables for organizational effectiveness are listed in Table 2-4.

Table 2-4. Underlying Drivers of Organizational Effectiveness

Underlying Drivers of Organizational Effectiveness		
Variables		**References**
Finance	economic cycles; costs	Salas et al. (2012); Boudreau and Ramstad (2005)
Products or Markets	product development cycle; product innovation	Salas et al. (2012)
Human Capital	trained workforce	Salas et al. (2012); Huselid and Becker (2011); Park and Jacobs (2011)

2.3.2 Organizational Effectiveness Cases Based on Literature

Training of Human Capital Affecting Organizational Success

Given the importance and potential impact of training on organizations and the costs associated with the development and implementation of training, it is important that both researchers and practitioners have a better understanding of the relationship between design and evaluation features and the effectiveness of training and development efforts (Arthur et al., 2003). According to Delaney and Huselid (1996), effective practices by organizations related to staffing and training were positively related to perceived organizational performance. Moreover, Huselid (1995) did a study of nearly 1,000 companies, documenting that the use of high-performance work practices (including training) predicted employee retention and performance as well as long-term measures of corporate financial performance. In addition, Aguinis and Kraiger (2009) cited multiple studies in several countries that link training practices and policies to measures of organizational effectiveness.

Causes for Training Strategies to be Ineffective

The suggested causes for training strategies to be ineffective include not thoroughly conducting a TNA and business leaders making uninformed investments in training. In summary, as outlined throughout the studies referenced to in this research, it is suggested that training strategies that are not effective negatively impact an organization. Results of negative impact may include lost development costs for training program, wasted time for people taking the courses, no gain in human performance which sets the organization back competitively to other organizations with a properly trained workforce, etc.

Organizational Innovations Affecting Organizations

An organizational innovation is a structure, practice, or technology new to the organization adopting it (Wang, 2010). For this research, organizational innovations will include technology innovations. Wang (2010) poses the following question: why do organizations adopt innovation? There are two main schools of thought regarding this question: the economic-rationalistic perspective and the institutional perspective (Wang, 2010). According to Melville et al (2004), organizational performance is often measured in terms of financial or economic terms. Moreover, Cyert and March (1992) explains that performance is improved when organizations recognize performance problems and then search and adopt innovations to solve the problems efficiently. Furthermore, Suchman (1995) indicates that the actions of an organization are desirable or appropriate within the organization's socially constructed environment of norms, values, and beliefs, and thereby influences organizational legitimacy and how innovation is diffused. While the debate continues on whether performance or legitimacy drives the diffusion of innovations, Tolbert and Zucker (1983) argue that in its early diffusion of innovations, adopters undertake an innovation to improve performance, and in its later diffusion, most organizations adopt it to pursue legitimacy. Note that according to Rogers (2003), the word diffusion used here refers to the process by which an innovation spreads over time among organizations.

Determinants of Firm Performance and Productivity

In a study performed by Bilgin, Marco, and Demir (2012), determinants for small and medium enterprise performance were explored. In particular, they investigated how training, technology adoption, finance channels and exporting behavior affect the enterprise performance by examining the determinants of the profit per worker. The variables that were examined in this study included formal training program, age of the firm, financing channels, and exports.

2.4 Summary and Discussion

2.4.1 Summary of the Variables

A summary of the variables found within literature are shown in Table 2-5. This does not serve as an all-inclusive list, but rather a baseline of variables to compare and refer to within this research. The findings from this chapter will be confronted in later chapters.

Table 2-5. Summary of variables found in literature for the constructs of TR, TI, and OE

Construct	Variables	References
Training (TR)	productivity improvement, sales or revenue, overal profitability, operating revenue per employee	Swanson (2001); Paradise (2007); Rivera and Paradise (2006)
	effectiveness (employee involvement, human resource indicators, and quality)	Aragon-Sanchez et. al. (2003)
	profitability (sales volume, benefits before interest and taxes, ratio of benefit before taxes/sales)	
	quantity	
	employee satisfaction, customer satisfaction, owner/shareholder satisfaction, workforce productivity (sales per employee), business performance (sales per employee)	Ubeda-Garcia (2005)
	work climate, employee attendance, quality of products and services, employee productivity	Guerrero and Barraud-Didier (2004)
	costs	Swanson (2001); Paradise (2007); Rivera and Paradise (2006); Aragon-Sanchez et. al. (2003); Ubeda-Garcia (2005); Guerrero and Barraud-Didier (2004)
	quality	Aragon-Sanchez et. al. (2003); Guerrero and Barraud-Didier (2004)
	employee turnover	Aragon-Sanchez et. al. (2003); Ubeda-Garcia (2005); Guerrero and Barraud-Didier (2004)
	need analysis/assessment (budget, training audiences, resources, training program determination, length of training, link to org. goals)	Peterson (2003); McGriff (2000); Tannenbaum (2002); Tannenbaum and Yukl (1992); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Morano (1973)
	development and planning/designing training	Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009)
	delivery/implementation	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009)
	evaluation (including ROI - impact on the organization's mission and operation; transfer of training/knowledge; reduction of error)	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Kraiger (2002); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Bartel (2000)
Technology Innovation (TI)	high technology products export [US$]; high technology products export (% of exp. Of manufacture); patent applications; spending on R&D; and scientific and technological publications; benefits versus costs; societal entity; geographical settings; political conditions	Zamora-Torres (2014); Wejnert (2002)
	timing of technology innovation adoption	Richardson (2011)
	financial resource availability; top management support; implementation policies and practices - training, communication, and assistant program; implementation climate - managerial perceptions; implementation effectiveness - managerial attitude towards implementation process; and innovation effectiveness - perceived benefits from implemented innovation	Sawang and Unsworth (2011)
	technology innovation maturity - TRL	DoD (2009)
Organizational Effectiveness (OE)	finance - economic cycles; Products or markets - costs	Salas et al. (2012); Boudreau and Ramstad (2005)
	product development cycle; product innovation	Salas et al. (2012)
	human capital - trained workforce	Salas et al. (2012); Huselid and Becker (2011); Park and Jacobs (2011)

2.4.2 Aligning Knowledge Base to Research

The knowledge base presented in this chapter gives an in depth literature review of training, technology innovation, and how these two constructs relate to organizational effectiveness. Several researchers and studies provided in this chapter show the importance of how training can affect organizational effectiveness. In particular, studies have shown that ineffective training negatively affects organizational effectiveness, while effective training positively affects organizational effectiveness. This relationship is the basis for this research and in providing necessary steps in answering the research questions that were stated in Chapter 1. These relationships will be further investigated within the practical environment in the next chapter. In addition, aligning the knowledge base to this research include the areas of needs assessment, timing, and outside variables (moderators).

Needs Assessment

Subjective information suggests that it is practical to conduct a needs assessment as the first step in the design and development of training (Ostroff and Ford, 1989; Sleezer, 1993). However, according to Arthur, Bennett, Edens, and Bell (2003), in terms of needs assessment, only 6% of the studies in their data set from their meta-analysis study reported any needs assessment activities prior to training implementation. Their results suggested that the training method used, the skill or task characteristic trained, and the choice of training evaluation criteria are related to the observed effectiveness of training programs. Contrary to what Arthur, Bennett, Edens, and Bell had originally expected, which was that implementation of a comprehensive needs assessment would result in more effective training, there was no clear pattern of results for the needs assessment analyses. Nonetheless, these analyses were based on a small amount of data points (Arthur, Bennett, Edens, and Bell, 2003). Moreover, Arthur, Bennett, Edens, and Bell (2003) state that it is conceivable and even likely that a much larger percentage conducted a needs assessment but failed to report it in the published work because it may not have been a variable of interest.

Timing of Training

In current studies (Goldstein, 1986; Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012), the timing of training seems to be implicit, where the TNA explicitly studies the need for training through organizational analysis, task analysis, and person analysis. Once the TNA is complete and the results are analyzed, it is then determined if training is needed or is necessary; how the training the training should be delivered; and to what audience it should be delivered to. The gap in this method is that the timing of the training is not currently explicitly measured and studied. This analysis would most likely fall within an organizational analysis because the timing of training directly affects the organization in terms of both financial and legitimacy. The timing of training becomes particularly critical when trying to improve human capital knowledge in a technology area that is emerging. Determining whether or not the technology is a hype before offering training for the particular technology will directly influence the organizational effectiveness. Hence, explicitly measuring the timing in training is significant for organizational effectiveness.

CHAPTER 3

PRACTICAL KNOWLEDGE BASE

This chapter is represented as Phase I, shown in Figure 3, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. Chapter 2 described the theoretical view point found in current literature. This chapter will describe and discuss technology innovation and training, as well as how training relates to technology innovation and organizational effectiveness in a practical environment. The subsections describing technical training within companies will include a general description of the various training organizations within the practical environment, strategic decision making about technical training, and challenges that companies face with training in general. The subsections describing technology innovation within companies will include a general description of the various technology organizations within the practical environment, strategic decision making about technology adoption, tools used for decision making, and technology challenges faced by companies. The combination of these sections will help in giving an overall view of the practical environment, which will include the variables considered for training, technology innovation, and organizational effectiveness within the practical knowledge base.

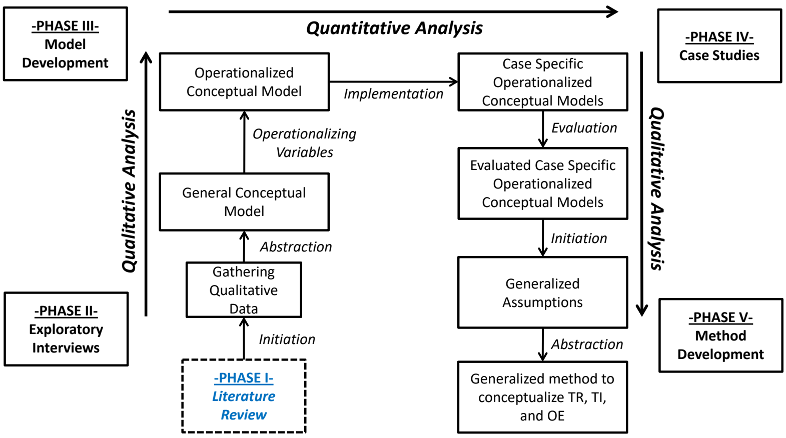


Figure 3. Phase I of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

3.1 Practical Environment

As the goal for this research is to explain how training influences technology innovation to positively affect organizational effectiveness, understanding of the current practical environment is necessary. Once the practical environment is described, this research will aim to build upon the practical environment in more detail.

Annual Benchmarking Studies: Corporate University (CorpU) Xchange

Benchmarking is the process of comparing one's business processes and performance metrics (Courty and Marschke, 2004; Schenk and Hajos, 2000) to industry bests or best practices (Bjornberg, 2002; McCune, 1994) from other industries. Dimensions typically measured are quality (Vorhies and Morgan, 2005), time (Schenk and Hajos, 2000) and cost. According to Vorhies and Morgan (2005), it is in the process of best practice benchmarking where management identifies the best firms in their industry, or in another industry where similar processes exist, and compares the results and processes of those studied (the "targets") to one's own results and processes. In this way, they learn how well the targets perform and, more importantly, the business processes that explain why these firms are successful (Vorhies and Morgan, 2005; Schenk and Hajos, 2000).

According to Courty and Marschke (2004), an important challenge in the design of performance measurement, accountability, and incentive systems is the establishment of relevant benchmark levels of performance, also known as performance standards. Equally as important is determining what area to perform benchmarking studies. Bjornberg (2002) identified a program area to consider reporting best practices are in the area of training and development. Currently the American Society for Training & Development (ASTD) and Corporate University (CorpU) Xchange both perform and provide annual benchmarking reports in the area of training and development. This section provides an example of dimensions used in benchmarking, where the annual benchmarking study that CorpU Xchange performs will be highlighted.

CorpU Xchange is a consortium that partners with the world's leading business and academic organizations to establish new approaches to learning communities that connect people to capture knowledge, solve problems, generate ideas, teach and learn (CorpU, 2013). According to (CorpU, 2013), *"members of CorpU Xchange gain insights into their most pressing challenges through direct collaboration with peers, advice from leading experts and best practice findings from our extensive research library."* This includes annual benchmarking activities (e.g. Learning Excellence and Innovation Benchmarking Study) where several companies participate to learn how their learning organization performance compares to their peers and top performers outside of the company (CorpU, 2013). CorpU Xchange claims that their past participants of the Learning Excellence and Innovation Benchmarking Study report moving major initiatives forward by using benchmarking data to support (CorpU, 2013):

- Identifying gaps in practices that impact effectiveness and efficiency
- Building a business case for major learning initiatives
- Funding decisions for new programs
- Incorporating results into executive level presentations
- Building executive support and advocacy

CorpU identified the most important characteristics of the successful learning organization as 12 operational skill sets that collectively enable a learning function to effectively ***Align***, ***Organize***, ***Measure***, and ***Execute*** (the four quadrants) (CorpU, 2013). Note that these four quadrants are based on their definitions of effectiveness and efficiency, as described at the beginning of this section 2.3. These indicators are listed below (CorpU, 2013):

Align

- Capability Planning (*This dimension provides information on how the learning function fulfills short- and long-term workforce skill requirements needed to execute the enterprise business strategy.*)
- Strategy Integration (*This dimension asks what are the methods the learning function uses to ensure that its efforts align with the strategic needs of the business*)
- Performance Consulting (*This dimension provides information on what methods the learning function uses to ensure performance problems are resolved at their root causes*)

Organize

- Technology (*This dimension analyzes the extent to which the learning function is using technology to gain leverage and increase efficiency across the enterprise*)
- Governance (*This dimension asks what methods the learning function uses to gain agreement on expectation and priorities of senior executives across the enterprise.*)
- Branding (*This dimension asks what methods the learning function uses to promote its value and brand across the enterprise*)

Execute

- Program Design and Delivery (*This dimension asks what methods the learning function uses to deliver programs/initiatives to improve employee and business performance across the enterprise.*)
- Operations (*This dimension identifies what methods the learning function uses to organize its team, allocate its budget, and execute strategy across the enterprise.*)
- Partnerships (*This dimension asks what methods the learning function uses to make decisions on what and to whom (i.e., third party providers) to outsource learning function activities to across the enterprise.*)

Measure

- Personal Outcomes (*This dimension identifies how the learning function measures its impact on individual development across the enterprise*)
- Business Outcomes (*This dimension seeks to understand how the learning function measures the impact of its programs/initiatives on business objectives across the enterprise.*)
- Cultural Outcomes (*This dimension asks the methods the learning function uses to measure the cultural characteristics to back up the statement "our people are our greatest asset" across the enterprise.*)

Results of the Benchmarking Study 2013

In terms of the indicator *align*, the variables relevant to this research are described by CorpU Xchange in terms of the most influential factors the learning leadership team prioritizes for program initiatives. These variables include a governing board setting priorities, a committee of business unit leaders (advisory board) setting priorities, formal business leaders requesting training/support, needs assessment process, ROI analysis, formal portfolio management process, HR leader setting priorities, learning function leaders setting priorities, finance dictating priorities through the budgeting process, and program initiatives not prioritized. The annual benchmarking study found that the top five variables, from the above list, that were the most influential factors for the learning leadership team when prioritizing for program initiatives are formal business leaders requesting training/support

(~25%), learning function leaders setting priorities (~20%), finance dictating priorities through the budgeting process (~10%), needs assessment process (~10%), and a governing board setting priorities (~10%).

In terms of the indicator *organize*, the variables relevant to this research are described by CorpU Xchange in terms of who represents the governing board in the learning function. These variables include top level executives of the learning organization; top level executives from the business units; function leaders (i.e. marketing, sales); other business segment executives; and human resources. The annual benchmarking study found that about 60% of the respondents did not have a governing board in their learning function, while about 25% had other representatives within their governing board that were not listed by CorpU Xchange. Only about 10% of the respondents indicated that the representatives in their governing board were top level executives of the learning organization; top level executives from the business units; and human resources.

In terms of the indicator *execute*, the variables relevant to this research are described by CorpU Xchange in terms of where the responsibility for curriculum development lies in the company. These variables include a central learning function develops one/all curriculum plans for the enterprise; a central learning function develops a curriculum plan for global curriculum areas (i.e. leadership development); individual learning functions develop their own unique curriculum plans; the learning function outsources curriculum development to a third party vendor; and the learning function does not develop curriculum plans. The annual benchmarking study found that the top two variables, from the above list, indicating where the responsibility for curriculum development lies within the company are a central learning function develops a curriculum plan for global curriculum areas (i.e. leadership development) (~50%); and individual learning functions develop their own unique curriculum plans (~50%).

In terms of the indicator *measure*, the variables relevant to this research are described by CorpU Xchange in terms of the methods the learning function uses to measure the effectiveness of its programs/initiatives against business metrics. These variables include an industry standard measurement model (i.e. Kirkpatrick Level 4, Phillips ROI, etc.); anecdotal evidence collected from participants; performance against metrics agreed upon with business leaders; learning is simply valued intrinsically without formal measurement efforts; a measurement strategy that outlines what and how measurement occurs; and the learning function does not measure the effectiveness of the initiatives using business metrics. The annual benchmarking study found that the top three variables, from the above list, indicating the methods the learning function uses to measure the effectiveness of its programs/initiatives against business metrics are anecdotal evidence collected from participants (~85%); performance against metrics agreed upon with business leaders (~35%); and learning is simply valued intrinsically without formal measurement efforts (~35%).

CorpU Xchange Annual Awards for Excellence and Innovation

CorpU Xchange hosts an annual award ceremony, awarding top companies for excellence and innovation (CorpU, 2016). There are awards given out for seven different categories: Alignment, Branding, Leadership, Alliances, Launching, Measurement, and Learning Technology. The award for Alignment is for furthering corporate goals through learning and development efforts; Branding is for developing and implementing innovative communications and branding strategy; Leadership is for implementing high-impact programs targeted to managers, high potentials, and senior executive leadership; Alliances is for making the best use of external providers; Launching is for successfully beginning a new corporate university initiative; Measurement is for creating tools and techniques to measure the value of investment in learning; and Learning Technology is for creating an effective learning environment through the use of technology. 2014 award winners include Hewlett-Packard (HP), The Boeing Company, Raytheon Company, among a few other companies.

Sector Focus

According to the Institute of Engineering and Technology (IET), there are five major sectors: Built Environment, Design and Production, Energy, Information and Communications, and Transport. Built Environment includes areas of building information modeling, future power, heat, and water (IET, 2016). Design and Production includes areas of manufacturing, design, robotics and autonomous systems, and innovation to commercialization. Energy includes areas of energy infrastructure, energy production, energy services, and energy usage. Information and Communications includes areas of connected data, cyber security, digital innovation, and computing. Transport includes areas of autonomous vehicles, energy efficiency, future transport technologies, and intelligent mobility. The qualitative data that was gathered for this research was from five different companies, which cover four of the five major sectors.

3.1.1 Aerospace Companies (Design and Production)

As the world's largest aerospace company and leading manufacturer of commercial jetliners and defense, space and security systems, Boeing supports airlines and U.S. and allied government customers in 150 countries with 12,000 jetliners in service worldwide (Boeing, 2014). The company employs more than 168,000 people across the United States and in more than 65 countries, and leverages the talents of hundreds of thousands more skilled people working for Boeing suppliers worldwide. More than 140,000 employees hold college degrees - including nearly 35,000 advanced degrees - in virtually every business and technical field from approximately 2,700 colleges and universities worldwide.

Boeing is organized into two business units: Boeing Commercial Airplanes and Boeing Defense, Space & Security. Supporting these units are Boeing International, Boeing Capital Corporation, a global provider of financing solutions; the Shared Services Group, which provides a broad range of services to Boeing worldwide; and Boeing Engineering, Operations & Technology, which helps develop, acquire, apply and protect innovative technologies and processes (Boeing, 2014). Boeing has six research and development centers, 16 consortia and 22 joint research centers. Boeing has relationships with more than 50 international universities.

3.1.2 Automotive Companies (Transport)

General Motors (GM) has 212,000 plus employees who work in 396 facilities touching six continents, speak more than 50 languages and touch 23 time zones (GM, 2016). There are 21,000 dealers serving as the face of the new GM in communities around the world. From electric and mini-cars to heavy-duty full-size trucks, monocabs and convertibles, GMs' dynamic brands offer a comprehensive range of vehicles in more than 120 countries around the world.

GM continues to develop innovative technologies to shape the future of the automotive industry (GM, 2016). The innovative technologies are in the areas of vehicle electrification with advancements in batteries, electric motors and power controls. The GM team is also working on a range of high-volume, fuel-saving technologies including direct injection, variable valve timing, turbo-charging, six-speed transmissions, diesel engines, and improved aerodynamic designs.

3.1.3 Oil and Gas Companies (Energy)

Shell is an integrated energy company that aims to meet the world's growing demand for energy in ways that are economically, environmentally and socially responsible (Shell, 2016). Shell is a global group of energy and petrochemical companies divided into five businesses: Upstream, Integrated Gas, Unconventional Resources, Downstream, and Projects & Technology. They operate in over 70 countries, with an average number of 94,000 employees.

Shell operates a global network of 10 R&D centers close to their main markets and production sites. These include three major technology hubs located in India, the Netherlands and the USA. $1.2 billion is spent on research and development annually. Around 5,500 scientists and technical specialists work at these hubs on a broad spectrum of projects, such as turning natural gas into more efficient and cleaner fuels, developing technologies to unlock energy thousands of meters below the sea surface, and improving energy efficiency in our own operations.

3.1.4 Information Technology Companies (Information and Communications)

Dassault Systemes is a scientific company serving science, technology and art for a sustainable society (3DS, 2016). Dassault Systemes is comprised of 12,400 employees located at 53 labs globally. They serve 190,000 enterprise customers from 12 industries in 140 countries. Dassault Systemes has 10 million on premise users and 100 million online users.

Hewlett Packard (HP) produces lines of printers, scanners, digital cameras, calculators, PDAs, servers, workstation computers, and computers for home and small-business use; many of the computers came from the 2002 merger with Compaq. HP as of 2001 promotes itself as supplying not just hardware and software, but also a full range of services to design, implement, and support IT infrastructure (HP, 2016). HP is comprised of 302,000 employees worldwide.

3.2 Training at Companies

It is important to remind the reader here that the term "training" used throughout this research is in terms of technical training (e.g. technology, engineering, etc.) and not human resource training (e.g. "soft training" such as ethics, Lean+, safety, etc.). The definition of training was outlined in Chapter 2 as the planned and systematic activities designed to promote the acquisition of knowledge (i.e., need to know), skills (i.e., need to do), and attitudes (i.e., need to feel or area of emotions such as values) (Salas et. al., 2012).

Boeing invests $150 million in internal learning programs annually in areas strategic to the Boeing business (Boeing, 2014). The internal learning programs and areas strategic to the Boeing business will be explained generally in this section. Specifically, for the scope of this research, the training organizations and training programs will be described in the context of engineering.

3.2.1 Training Organizations

There are several areas of technical training at Boeing from various enterprise training organizations. This is comparable to any other large (i.e. greater than 100,000 employees) engineering company that invests in technology innovation. Structural engineering (analysis and design) of the airplane is one of the main technology domains of aircraft design and manufacturing within Boeing (Frontiers, 2009). Within this area, the material in which airplane parts are made of can be critical to aviation design with regards to sustaining the life of an airplane, which includes weight, reliability, and safety (Frontiers, 2009). The information provided within this chapter will focus on aligning training towards the technology innovation within the structural engineering domain.

The purpose of briefly outlining the training organizations within companies was to highlight the benefits to the enterprise that each of the training organizations provide. As these training organizations provide technical training to the engineers within the structures domain, it is important to recognize the general business drivers. These business drivers may be considered variables for this research when observing the relationship between training and organizational effectiveness. Across the three training organizations, the *general business drivers include timing of when to offer training, alignment to technology domains, rate in which knowledge is transferred, and costs*. It is these business drivers that help create a foundation for how decisions are made about technical training, which will be further discussed in the next sub-section.

Training Needs Assessment

According to several sources (Goldstein, 1986; Rossett, 1987; Morano, 1973; Blanchard and Thacker, 2007), training needs assessment or analysis can be broken into the areas of organizational analysis, job analysis and individual or person analysis, where the results of all three of the analysis are combined for a complete training needs assessment for any given organization.

According to Rossett (1987), the organizational analysis is aimed at short listing the focus areas for training within the organization and the factors that may affect the same. Organizational mission, vision, goals, people inventories, processes, performance data are all studied (Rossett, 1987). According to Rossett (1987), the study gives cues about the kind of learning environment required for the training. Motorola and IBM are examples of companies that conduct surveys every year keeping in view the short term and long term goals of the organization (Rossett, 1987).

According to Rossett (1987), the job analysis of the needs assessment survey aims at understanding the 'what' of the training development stage. Moreover, both Morano (1973) and Blanchard and Thacker (2007) agree that the kind of intervention needed is what is decided upon in the job analysis. Rossett (1987) explained that it is an objective assessment of the job wherein both the worker oriented - approach as well as the task - oriented approach is taken into consideration. The worker approach identifies key behaviors and asks for a certain job and the task - oriented approach identifies the activities to be performed in a certain job (Rossett, 1987). Rossett (1987) concluded that the former is useful in deciding the intervention and the latter in content development and program evaluation.

According to Rossett (1987), the individual analysis is concerned with who in the organization needs the training and in which particular area. Rossett (1987) state that performance is taken out from the performance appraisal data and the same is compared with the expected level or standard of performance. In addition, Rossett (1987) describes that the individual analysis is also conducted through questionnaires, 360 feedback, and personal interviews. Furthermore, according to both Rossett (1987) and Blanchard and Thacker (2007), many organization use competency ratings to rate their managers; these ratings may come from their subordinates, customers, peers, and bosses.

The first step in any training development effort should be a training needs analysis (TNA) – conducting a proper diagnosis of what needs to be trained, for whom, and within what type of organizational system (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). According to Salas, the outcomes of this step are (a) expected learning outcomes, (b) guidance for training design and delivery, (c) ideas for training evaluation, and (d) information about the organizational factors that will likely facilitate or hinder training effectiveness. However, it is important to recognize that training is not always the ideal solution to address performance deficiencies, and a well-conducted TNA can also help determine whether a non-training solution is a better alternative (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). The three components of needs assessment - organizational analysis, task analysis, and individual or person analysis - will be further discussed below.

Organizational Analysis

According to Salas, this step in TNA essentially answers the following questions: What are our training priorities? Is our organization ready to receive and support the training we will provide? Organizational analysis looks at the effectiveness of the organization and determines where training is needed and under what conditions it will be conducted. It helps ensure that the right training is being provided (strategic alignment) and that the environment is properly prepared for the training to succeed (environmental readiness) (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). According to Tannenbaum (2002), the strategic alignment component involves examining key business objectives and challenges, identifying the functions and jobs that most influence organizational success, clarifying the most critical organizational competencies, and establishing overall strategic learning imperatives. Moreover, gaining support from the organization and key stakeholders, as well as having management involvement in the organizational analysis will help with the strategic alignment (Salas et. al., 2012; Noe and Colquitt, 2002). Driscoll (2003) explains that organizational needs are addressed by prioritizing overall training needs and allocating training resources. Not all training requests are equally important (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). This will further be addressed in Chapter 3 in a practical context.

Salas et al. (2012) report that training researchers and designers often overlook this strategic component of TNA and instead begin with a particular training need or program in mind. This is where this research will dive in deeper and look at possible ways to avoid hype, which will be described in more detail in Section 2.2. It is important to periodically conduct a strategic assessment to ensure that resources are allocated properly and that there is a clear alignment between training efforts and organizational needs (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). Moreover, it can be inferred that if there is not a clear alignment between training efforts and organizational needs, then the training strategies will not positively affect organizational effectiveness. Salas further mentions that without this alignment, training can be viewed as a frivolous expense, and leadership and employee support for training may decline. According to Reed and Vakola (2006), linking needs analysis with existing organizational initiatives facilitated change, which ultimately affected the organizational efforts. According to Salas, there has not been a lot of research on the impact of conducting an organizational analysis. For this research, there will be a greater emphasis to study organizational analysis to determine when to offer training in order to positively affect organizational effectiveness.

The second part of organizational analysis examines environmental readiness (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). This involves diagnosing the work environment to identify and remove obstacles to training effectiveness. In both Tracey et al. (2001) and Klein et al. (2006), motivation to learn (Colquitt, LePine, and Noe, 2000; Noe, 1986; Noe and Schmitt, 1986; Quinones, 1997; Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012; Holton III, 1996; Aguinis and Kraiger, 2009) was positively related to measures of trainee satisfaction and learning.

In summary, the organizational analysis should identify environmental impacts, state of the economy and the impact on operating costs, changing workforce demographics and the need to address cultural or language barriers, changing technology and automation, increasing global/world market places, organizational goals, resources available, and climate and support for training. The information needed to conduct an organizational analysis can be obtained from a variety of sources including organizational goals and objectives, mission statements, strategic plans; staffing inventory, succession planning, long and short term staffing needs; skills inventory; annual report; plans for reorganization or job restructuring; and employee attitudes and satisfaction.

Tasks Analysis

Task or job analysis provides data about a job or a group of jobs and the knowledge, skills, attitudes and abilities needed to achieve optimum performance (Goldstein, 1986; Rossett, 1987). Sources for collecting data for a task analysis include job description, KSA analysis, performance standards, job inventory questionnaire, and job inventory questionnaire (Goldstein, 1986; Rossett, 1987).

Individual or Person Analysis

Individual or person analysis analyzes how well the individual employee is doing the job and determines which employees need training and what kind (Tannenbaum and Yukl, 1992). This analysis can lead to better decisions regarding the content and delivery of training, which may influence the relative effectiveness of various training strategies (Salas, Tannenbaum, Kraiger, and Smith-Jentsch, 2012). Sources of information available for an individual include performance evaluation, performance problems, observation, work samples, interviews, questionnaires, attitude surveys, and checklists or training progress charts.

All three levels of needs analysis are interrelated and the data collected from each level is critical to a thorough and effective needs assessment. The purpose of a training needs assessment is to identify performance requirements or needs within an organization in order to help direct resources to the areas of greatest need, those that closely relate to fulfilling the organizational goals and objectives, improving productivity and providing quality products and services (Miller and Osinski, 1996). Moreover, Salas states that TNA is a must and that it is necessary to conduct a systematic and though TNA as it is the first and probably the most important step toward the design and delivery of any training.

Summary: Variables from training needs assessment

A needs analysis essentially provides the information needed for an organization to invest or not to invest in training. Hence, the components from a needs analysis contain variables that are of interest to this research. It should be noted that the training needs analysis is in itself a variable for this research. The variables that are extracted from the needs analysis help provide the topics that are of interest in an organization. In addition, the performance measures or dimensions used in benchmarking studies in the area of training and development help highlight the topics of interest in an organization. Again, it is in these performance measures within benchmarking that allow companies to compare their performance in an area of interest, in this case training and development, to the best practices from other industries in the same area. These variables are listed in Table 3-1.

Table 3-1. Variables for training needs assessment

Training Needs Assessment		
Variables		References
Organizational Analysis	training motivation/motivation to learn/employee motivation	Colquitt, LePine, and Noe (2000); Noe (1986); Noe and Schmitt (1986); Quinones (1997); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Holton III (1996); Aguinis and Kraiger (2009)
	support from the organization/decision makers for authorizing training/senior leaders' and management involvement	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Noe and Colquitt (2002)
Task Analysis	Knowledge, Skilles, and Abilities (KSAs)	Goldstein (1993); Rossett (1987)
Individual/Person Analysis	audience/what kind of training	Tannenbaum and Yukl (1992)

Needs Assessment in a Practical Environment

According to both Rossett (1987) and Blanchard and Thacker (2007), conducting a thorough needs assessment before training is designed and delivered helps set appropriate goals for training and ensure that trainees are ready to participate. However, Kraiger (2003) argues that there continues to be little theoretical or empirical work on needs assessment. Contrary to Kraiger (2003), Baranzini et al. (2001) developed and validated a needs assessment tool for the aviation maintenance industry. In addition, a study performed by Fowlkes et al. (2000) is an example of a theory-based approach to conducting a needs assessment. is a study by Fowlkes et al. (2000) evaluated an event-based knowledge-elicitation technique in which subject matter experts (SMEs) are asked about team situational awareness factors in response to a military helicopter operation. In another study, Colquitt et al. (2000) summarized 20 years of research on factors affecting trainee motivation. According to the meta-analysis from Colquitt et al. (2000), their results showed that training motivation was significantly predicted by individual characteristics (e.g., locus of control, conscientiousness, anxiety, age, cognitive ability, self-efficacy, valence of training, and job involvement) as well as by situational characteristics (e.g., organizational climate).

According to the studies introduced in this sub-section, the benefits of training can be maximized by conducting a needs assessment using experienced SMEs, and to ensure that the trainees are ready and motivated for training. Moreover, according to Casner-Lotto (1988), training readiness can be enhanced by lowering trainees' anxiety about training, demonstrating the value of training before training begins, and making sure employees are highly involved and engaged with their jobs.

Aligning Training Strategy with Corporate Goals: Motorola

Decisions as to what types of training are to be offered are governed by the following considerations (Casner-Lotto, 1988):

- All training must be job-related.
- All training must be applicable throughout the company rather than to specific types of tasks.
- All training must support current corporate strategic goals as identified and communicated by the executive advisory board.
- All training is treated as a dual investment-in people and in the business. Employees are viewed as corporate assets that improve in value when appropriate investments are made with them.

Motorola Training and Education Center (MTEC) was developed for the specific purpose of providing Motorola employees with the skills needed to keep the company competitive. The mission of MTEC is to improve the corporation's productivity, performance, and profitability by developing the kinds of work-force skills that will support the corporation's strategic objectives. MTEC also has the responsibility for monitoring the impact of its programs on the company's bottom line (Casner-Lotto, 1988).

There is a ten-person MTEC executive advisory board that meets twice a year. At the meetings, the executive board looks at the strategic plan of the company and asks in what general directions training is required. Then budget is allocated accordingly in each broad function. The close relationship between the advisory boards and MTEC professional staff is probably essential to the success of a corporate training program and should be carefully studied by any organization contemplating the establishment of its own employee training effort (Casner-Lotto, 1988).

Designing and Delivering Training Cost-Effectively: IBM

IBM uses a systems approach to education. The approach consists of four major steps: (1) a detailed curriculum design for every major job category, based upon defined business requirements; (2) instructional design for each course; (3) course development led by an interdisciplinary professional development team; and (4) delivery of education through a variety of methods, ranging from the traditional classroom to more advanced technological means. The fifth step is measurement and evaluation of training (Casner-Lotto, 1988).

Product excellence is equated with a well-trained work force (Casner-Lotto, 1988). According to Casner-Lotto, several corporations have only recently recognized the value of education and its link to corporate success.

3.2.2 Decision Making about Technical Training

This section will highlight in general the decision making processes that are practiced within the various organizations within Boeing and how these processes play a critical role within the training organization and in how decisions are made when determining funding for training.

Investing in Training - Process and Methods for Developing and Deploying Training

The purpose of this section is to describe the general process necessary for organizations within Boeing to identify, develop, provide, track, and evaluate training needs, materials and resources to develop its workforce to meet ever changing business and technology innovation needs. There is a general process for course development and delivery that the training organizations follow. It follows the ISD framework ADDIE model as described in Chapter 2. The five phases—Analysis, Design, Development, Implementation, and Evaluation—represent a general guideline for building training (Molenda, 2003; McGriff, 2000; Peterson, 2003). Each of these five phases, as described in Chapter 2, is shown again in Figure 3-1.

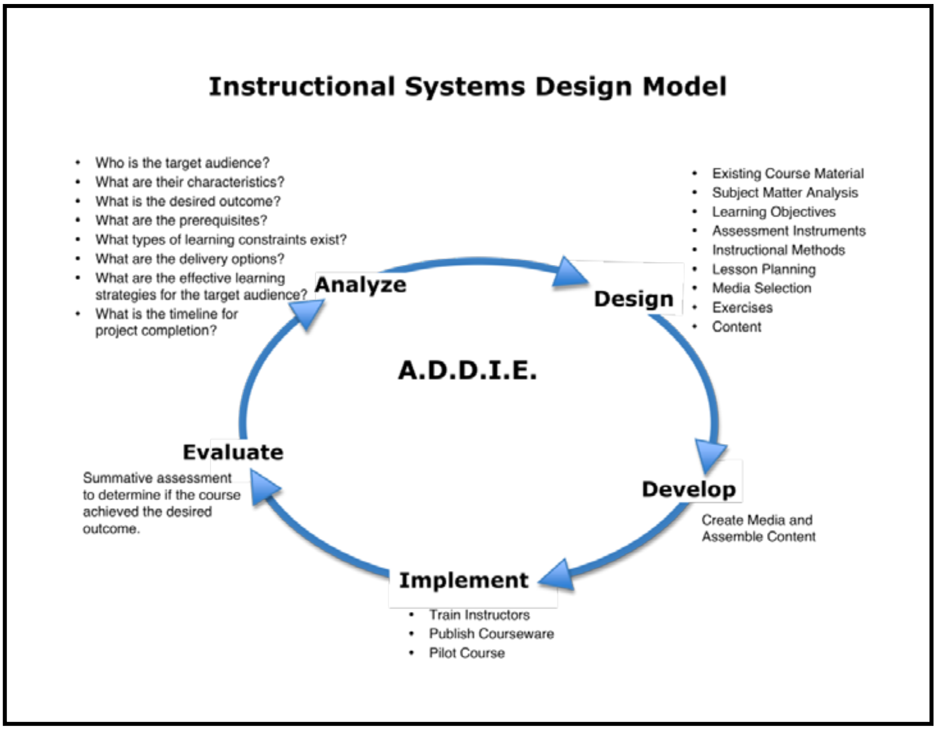


Figure 3-1. The phases of the ADDIE model within Boeing based on Molenda (2003)

Human Capital Investments - Performance Management (PM) and Personal Development Plan (PDP)

"Innovation is inside each team member, and that's why Boeing spends so much time finding the right people to bring on the team."

- The Boeing Company (2012)

As stated by the Boeing Company above, human capital is one of the key factors in the company's success. Finding the right people to bring on the team is important, but equally as important is growing the people from within. At the beginning of each year, employees are asked to define their career goals and detail their development plans. One tool that can help with the planning is the

"70/20/10" model (Frontiers, 2013). This is model is also used within the Shell company. According to Boeing Frontiers (2013), this model was adapted from research conducted by the Center for Creative Leadership on how much time people spend on various types of development. The research found that roughly 70 percent of an individual's development stems from learning from new experiences, such as leading team projects or special assignments. Another 20 percent comes from what is learned from others, which includes formal mentoring, job shadowing, and receiving feedback about job performance. According to the research, only about 10 percent of a person's development comes through formal education, training, and self-study.

The career goals and development plans are discussed between the manager and employee and captured and formally signed in the performance management (PM) and personal development plan (PDP). This process ensures that the manager and organization supports the employee in their personal development, which includes training. It also helps with end of the year evaluation with goals that are measureable.

Summary of variables for decision making in training

Table 3-2 summarizes the variables for decision making in training in a practical environment. The common ISD model that is used in the practical environment is the ADDIE model, first introduced in Chapter 2 of this research.

Table 3-2. Summary of variables for decision making about training in a practical environment

Decision Making about Training		
Variables		References
Analysis	audience; types of learning; delivery options; timeline	Morano (1973); Holton et al. (2000); Mcgehee and Thayer (1961); McGriff (2000); Goldstein (1993); Rossett (1987)
Design	course material; media selection; learning objectives; subject matter analysis; instructional methods	Goldstein (1993); McGriff (2000); Peterson (2003); Salas et al. (2012); Aguinis and Kraiger (2009); Felder, Brent, and Prince (2011)
Development	type of training (e.g. web-based, instructor led, website, etc.)	McGriff (2000); Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009)
Implement	training instructors (SMEs)	Goldstein (1993); Peterson (2003); Salas et al. (2012); Arthur Jr. et al. (2003); Aguinis and Kraiger (2009)
Evaluate	reaction; learning; behavior; results	Peterson (2003); Salas et al. (2012); Kraiger (2002); Arthur Jr. et al. (2003); Aguinis and Kraiger (2009); Bartel (2000); Kirkpatrick (1998); Robinson and Robinson (1989); Cohen (2005); Winfrey (1999)

3.2.3 Corporate Training Challenges

In order to understand how training influences organizational effectiveness, an understanding of the corporate training challenges is necessary. It is through the challenges that companies face, where there is then a need for companies to work on understanding and addressing the challenges.

There are five critical training challenges that have been identified by Work in America Institute (Rosow, 1988):

- Coordinating training strategy and corporate strategy
- Implementing continuous-learning and employee-involvement strategies as an effective response to change
- Encouraging manufacturer-user cooperation as a means of stimulating more creative and profitable applications of new technology

- Improving the cost-effectiveness and quality of training for new technology
- Linking continuous learning with employment security practices

Training in corporations encompasses much more than formal classroom or seminar instruction organized by the training department (Casner-Lotto, 1988). Training also refers to a variety of less formal but equally valuable means of learning: role modeling, coaching, rotational assignments, on-the-job training, self-instruction, and so on.

Aligning Training Strategy with Corporate Goals

Organizations that have successfully linked training strategies to the corporate strategy of the firm find that the quality of training improves and the results more closely support corporate goals (Hickey, 1988; Casner-Lotto, 1988; Plous, Jr., 1988; Rubin, 1988; Scalpone, 1988). Casner-Lotto (1988) identifies three issues related to aligning training strategy with corporate goals: budgeting, evaluation, and accurate exchange of information between corporate and training strategists.

Continuous Learning for All Employees

Constant change in technology, products, markets, jobs, and competition has necessitated a continuous learning approach toward training, which is fundamentally different from conventional training (Hickey, 1988; Casner-Lotto, 1988; Rubin, 1988). General Electric's Continuing Engineering Education Program has an advisory council of engineers, technical managers, and marketing representatives who ensure that the course curriculum meets business needs and reflects the latest trends in various technological fields (Hickey, 1988).

Manufacturer-User Training Partnerships

The relationship between the manufacturers and users of new technology presents a host of opportunities for learning on both sides (Casner-Lotto, 1988; Hemmens, 1988; Gutchess, 1988; Sickler, 1988; Scalpone, 1988). According to Casner-Lotto (1988), from the initial contracting to the design, building and testing, implementation, and training for new technological systems, a genuine learning partnership can lead to applications and innovations that far exceed the expectations of either user or manufacturer/vendor.

Designing and Delivering Training Cost-Effectively

According to Casner-Lotto (1988), driven by the pressures to compete, some leading U.S. companies are putting more and more of their resources into the design and delivery of high-quality, cost-effective training for new technology. There are several innovative approaches that have enhanced cost-effectiveness (Casner-Lotto, 1988; Hamburg, 1988; Scalpone, 1988; Gutchess, 1988; Stackel, 1988). A "systems approach" to training, pioneered by IBM, organizes the educational process into discrete, manageable steps and has resulted in improved decision making and training delivery (Casner-Lotto, 1988).

In addition, a study performed by Saks and Burke-Smalley (2014), bridged the gap between micro-training research on the transfer of training and macro-training research on training and firm performance by testing the relationship between transfer of training and firm performance. The results from this study indicated that transfer of training was positively related to firm performance and mediated the relationship between training methods and firm performance. The results also suggested that among the three training methods of on-the-job, classroom, and computer-based, on-the-job training was the most strongly related to transfer of training and firm performance (Saks and Burke-Smalley, 2014).

Combining Continuous Learning and Employment Security

Employers that are committed to the continuous upgrading and training of their employees and to providing some degree of employment security have found that these two practices, in combination, represent a powerful strategy for improving the competitiveness and long-term growth of the firm (Morano and Leonardi, 1988; Hemmens, 1988; Smith, 1988; Feurey, 1988; Casner-Lotto, 1988). Three aspects of employment security in which continuous learning and training are important elements are explored in the cases: the cost-effectiveness of retraining for new technology as against hiring already-trained recruits (Feurey, 1988); managing the redeployment of employees from old to new jobs (Casner-Lotto, 1988); and enhancing the success rate of retrainees by bringing them into contact with the new work unit as early as possible (Morano and Leonardi, 1988).

Summary: Corporate Training Challenges Variables

Researching the training challenges that companies face establishes the need for companies to work on understanding and improving the training challenges. In trying to understand and improve the training challenges that companies encounter, the question to be answered is what are the variables that are considered for companies to recognize when they are encountering a training challenge? The answer to this question will help to operationalize the training variable used in this research.

Based on the five critical training challenges that Rosow (1988) had identified, steps needed to improve training challenges within companies include aligning training strategies with corporate goals, provide continuous learning for all employees, aligning training for manufacturers and users of new technology, design and deliver training cost-effectively, and combining continuous learning and employment security. Rosow (1988) had also given several case studies for each of the identified training challenges. These case studies helped provide a list of corporate training challenges variables shown in Table 3-3.

Table 3-3. Summary of corporate training challenges and variables from Casner-Lotto (1988)

Corporate Training Challenges		
Variables		**References**
aligning training strategies with corporate goals	quality of training	Hickey (1988); Casner-Lotto (1988); Plous, Jr. (1988); Rubin (1988); Scalpone (1988)
	budgeting	
	evaluation	
	accurate exchange of information between corporate and training strategists	
provide continuous learning for all employees	advisory council to ensure that the course curriculum meets business needs and reflects the latest trends in various technological fields	Hickey (1988); Casner-Lotto (1988); Rubin (1988)
	forecasting areas of job growth and decline	
aligning training for manufacturers and users of new technology	training advisory board	Casner-Lotto (1988); Hemmens (1988); Gutchess (1988); Sickler (1988); Scalpone (1988)
	in-house group of instructors (industry-experienced personnel, familiar with theory and applications as well as with training techniques)	
	hands-on training	
	identify specific training needs	
design and deliver training cost-effectively	design delivery	Casner-Lotto (1988); Hamburg (1988); Scalpone (1988); Gutchess (1988); Stackel (1988)
	cost	
	quality of training	
combining continuous learning and employment security	cost-effectiveness of retraining for new technology as against hiring already-trained recruits	Morano and Leonardi (1988); Hemmens (1988); Smith (1988); Feurey (1988); Casner-Lotto (1988)
	managing the redeployment of employees from old to new jobs	
	enhancing the success rate of retrainees by bringing them into contact with the new work unit as early as possible	

3.2.4 Training Challenges Companies Face

The intent of this research is not to cover every aspect of training for new technology, but rather to explore only the most challenging issues regarding training that are difficult to solve. The challenging issues that Boeing faces are very similar to those that other companies face. These include: aligning training and organizational effectiveness; improving the cost-effectiveness and quality of training for new technology; implementing continuous-learning and employee-involvement strategies as an effective response to change; and having a clear process to follow when aligning training to the proper technology needs (Rosow, 1988).

Aligning training strategy and corporate goals

According to Rosow (1988), "Organizations that have successfully linked training strategies to the corporate strategy of the firm find that the quality of training improves and the results more closely support corporate goals."

A training challenge within Boeing is gaining full support from the senior management on effectively aligning technical training with business/organizational needs. With a large corporation of more than 165,000 employees, the challenge is to succinctly communicate the same message out to everyone and have every organization interpret this message the same way. For example, some organizations may think that since nanomaterials are ready to be implemented in their department and meets their needs, that nanomaterials is ready for the entire airplane. The challenge is in determining how to align training to these dynamics audiences, meet everyone's needs, and remain cost effective. This challenge aligns closely with the three issues related to the linkage of corporate and training strategies as described by Rosow (1988). The three issues are: budgeting, evaluation, and mechanisms of linkage.

Improving the cost-effectiveness and quality of training for new technology

It has been observed within Boeing that innovation and research in emerging technologies is driven by funding and the economy. When the money is flowing, more and more money is dumped into these technology areas and this helps drive the training needs. Managers create an environment where there are opportunities for their employees to dive in emerging technology areas and become more trained in that area. This forces the training organization to develop training to meet the current technology needs in an ad hoc way, which compromises the quality of training. But when money is tight, reduction in funding is performed and unfortunately, most of the novel ideas are set aside. The higher priorities are then addressed to fit the current business environment needs and these needs are strictly driven by cost and schedule. This lowers the need for training in the area of emerging technologies, where without funding from the stakeholders, there is no urgency to neither improve on the current curriculum nor continue it. Hence, when money is tight, for training to continue in an area of emerging technologies, there needs to be a strong business reason, linkage, and plan for developing it.

Implementing continuous-learning

In today's corporate environment, the success of the business is directly related to its ability to manage change. These changes in technology, products, and competition have forced most companies to embrace continuous learning. The goal of continuous learning is to encourage everyone in the organization to become actively and continuously involved in expanding their skills (Rosow, 1988). Rosow (1988) describes continuous learning as being an everyday part of the job rather than being confined to the classroom. Moreover, continuous learning is where employees learn skills of others in their work unit as well as those related to their own jobs and also understand how their work unit relates to the rest of the business. Continuous learning is evident in a company when the employees teach, and learn from, one another (Rosow, 1988).

While the idea of continuous learning is ideal in most major companies, no one company has completely adopted the continuous learning model (Rosow, 1988). Within Boeing, it is a challenge to implement continuous learning. There are many opportunities to do so, with mentoring programs, as well as rotational programs, but the difficulty is for management to prioritize the appropriate time for their senior engineers to participate in programs that promote continuous learning. These engineers have opportunities to learn every day in their working environment, but to pass along their knowledge to the younger engineers is difficult. Simply finding some time in their hectic schedule to be able to capture their knowledge for the future generation is near impossible. The bottom line is that while continuous learning is important to Boeing, this company is an engineering company that has deadlines with producing airplanes for customers. They need their senior engineers to be applying their knowledge directly to their statement of work in order to meet these deadlines. Hence, the majority of the top level engineers are over-worked and over-booked.

Processes in aligning training to the proper technology needs

One of the training challenges that Boeing faces is the ambiguity and generalization in processes of aligning training to the proper technology needs in the various departments. As introduced in the above section, the main challenge lies within the very first step of identifying requirements and needs. Currently, there is not a clear process in determining training for an emerging technology and identifying when to offer the appropriate training as to be effective and beneficial to the customers.

3.3 Technology Innovation at Companies

As described in Chapter 2 as one of the underlying drivers of organizational effectiveness, effective management of acquiring and training human capital is a significant key to organizational success (Salas et. al., 2012). Training is a key component in building and maintaining an effective employee workforce, which is conducive to technology innovation and directly effects organizational effectiveness.

"Innovation at its very core comes from within the people on our team. It's all the great ideas, the background, the experience base, the education, the training, the places they live. All of that brings to people potential solutions that they're carrying around with them."

-John Tracy, Chief Technology Officer (Boeing, 2012)

3.3.1 Engineering Best Practices

According to Gartner (2009), when a company decides to invest in a technology innovation, there is some due diligence that needs to be done. Benchmarking studies are performed, as described earlier in this chapter. Business cases and strategies are developed. Budget, staffing, and technology readiness are also considered. Prototype testing may be necessary. Once technology is shown to be applicable, the findings are presented to stakeholders and business leaders. The organization then decides whether or not to invest in the technology innovation. The next section will discuss decision making about technology adoption and integration further.

3.3.2 Decision Making about Technology Adoption and Integration

Technological improvements occur regularly in both materials and manufacturing processes (detail, assembly and installation). The process flow at Boeing begins with discovery to applicability and then technology ready to production ready. Incorporating new technology on any program can be challenging whether it is a "new" airplane or an existing airplane. To successfully develop and incorporate new technology, strict processes and rules should be followed to ensure the technology is ready to perform. The technology gated process highlights three key steps: technology ready, application ready and production ready.

Boeing requires a method to ensure that technologies have reached Technology Readiness and Application Readiness when they are adopted into a business unit or product platform. Their method establishes maturity stages and readiness categories and defines exit criteria for assessing whether a technology has reached technology and application readiness. For Boeing, technologies relate to hardware, software, technical processes, materials, business processes, and the like. The method applies whether Boeing creates the technology through its internal research and development activities, or acquires the technology by purchase or licensing of rights from another party (Boeing, 2009).

Similar to the TRL process as presented from DoD (2009), from conception to application, the developmental path of a technology follows general stages of maturity. The five progressive stages of maturity in technology development are:

1. *Discovery.*
2. *Feasibility.*
3. *Practicality (Successful completion of this stage results in achievement of the technology readiness milestone).*
4. *Applicability (Successful completion of this stage results in achievement of the application-readiness milestone).*
5. *Preparation for production use (successful completion of this stage results in achievement of production readiness).*

Stage characteristics describe attributes of a technology as it matures toward production implementation. The key requirements of an internal Boeing document are focused on completion of the practicality and applicability stages. At the end of the practicality stage, the technology has reached technology readiness. In the next stage of maturity, the technology applicability is developed to the point where a technology user can commit a specific technology to production.

3.4 Organizational Effectiveness at Companies

3.4.1 Decision Making within Organizations

Strategic planning is a way to identify long-term goals and to direct the organization toward fulfilling those goals (Pisano, 2012). Strategic planning involves: Assessing the current business environment; Defining the organization's purpose mission; Deciding what you want the business to look like in one to five years; and Mapping out a course of action to take the organization from the current to its desired position. Benefits may include improved financial conditions, labor relations, human resource development & training, internal communications, distributor and/or supplier relationships, public relations, advertising, promotions, efficiency, productivity and organizational structure, enhanced products and services, achieved and maintained superior customer service, increased utilization of technology that improves operations, increased in revenues, enhanced products and services.

According to the leadership within the structures technology domain, the key variables that need to be addressed in order to remain competitive are: build and design quality; airplane performance; reliability and maintainability; delivery discipline; and world-class support. The last variable in this list – competitive pricing – can be attained by effectively addressing the previously mentioned key variables. That is, if there is less rework needed to build and design and airplane, less repair, on-time delivery, and efficient support to the customers, then all of the costs associated with the aforementioned could be rolled into the total cost of the airplane; hence, reducing the cost and in turn Boeing can offer more competitive pricing (Boeing, 2009). According to the structures leadership team, one of the main keys to reduce costs of Boeing airplanes for customers is to reduce the amount or percentage of engineering rework rate. It is the combination of all of these key variables that help drive the success of the company from an aerospace company point of view.

3.4.2 Measurements for Best Practices for Companies

According to Pisano (2012), organizations thrive when their strategies are aligned to the realities of the environment or the broader organizational context in which they operate. An R&D organization needs to have a strategy that is aligned with the broader business strategy of the organization in which it operates. A strategy should help drive alignment between the business and the various organizations (Kaplan, 2012). Hence, top R&D spenders may indicate some companies that invest heavily in technology innovation. Table 3-4 lists the top R&D spenders according to Booz & Co.

Table 3-4. Top 10 R&D Spenders 2010-2014 (Booz & Co, 2016)

Top 10 R&D Spenders 2010-2014					
Ranking	*2010*	*2011*	*2012*	*2013*	*2014*
1	Roche	Roche	Volkswagen	Volkswagen	Volkswagen
2	Microsoft	Pfizer	Toyota	Samsung	Samsung
3	Nokia	Volkswagen	Novartis	Roche	Intel
4	Pfizer	Novartis	Roche	Intel	Microsoft
5	Toyota	Microsoft	Pfizer	Microsoft	Roche
6	Volkswagen	Merck	Microsoft	Toyota	Novartis
7	Novartis	Toyota	Samsung	Novartis	Toyota
8	Johnson & Johnson	Samsung	Merck	Merck	Johnson & Johnson
9	Boeing	Nokia	Intel	Pfizer	Google
10	GlaxcoSmithKline	GM	GM	Johnson & Johnson	Merck

3.5 Discussion

This section will summarize the variables and indicators commonly used in practical environments. In addition, there will be discussion about how the practical environment knowledge base aligns with the scope of this research. The information from this chapter is intended to provide some background for the qualitative analysis performed in Chapter 4.

3.5.1 Summary of Variables and Indicators in Practical Environments

A summary of the variables found within literature are shown in Table 3-5. This does not serve as an all-inclusive list, but rather a baseline of variables to compare and refer to within this research. The findings from this chapter will be confronted in later chapters.

Table 3-5. Summary of variables in practical environments

Construct	Variables	References
Training (TR)	training motivation/motivation to learn/employee motivation	Colquitt, LePine, and Noe (2000); Noe (1986); Noe and Schmitt (1986); Quinones (1997); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Holton III (1996); Aguinis and Kraiger (2009)
	support from the organization/decision makers for authorizing training/senior leaders' and management involvement	Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Noe and Colquitt (2002)
	Knowledge, Skilles, and Abilities (KSAs)	Goldstein (1993); Rossett (1987)
	audience/what kind of training	Tannenbaum and Yukl (1992)
	audience; types of learning; delivery options; timeline	Morano (1973); Holton et al. (2000); Mcgehee and Thayer (1961); McGriff (2000); Goldstein (1993); Rossett (1987)
	course material; media selection; learning objectives; subject matter analysis; instructional methods	Goldstein (1993); McGriff (2000); Peterson (2003); Salas et al. (2012); Aguinis and Kraiger (2009); Felder, Brent, and Prince (2011)
	type of training (e.g. web-based, instructor led, website, etc.)	McGriff (2000); Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009)
	training instructors (SMEs)	Goldstein (1993); Peterson (2003); Salas et al. (2012); Arthur Jr. et al. (2003); Aguinis and Kraiger (2009)
	reaction; learning; behavior; results	Peterson (2003); Salas et al. (2012); Kraiger (2002); Arthur Jr. et al. (2003); Aguinis and Kraiger (2009); Bartel (2000); Kirkpatrick (1998); Robinson and Robinson (1989); Cohen (2005); Winfrey (1999)
	quality of training	Hickey (1988); Casner-Lotto (1988); Plous, Jr. (1988); Rubin (1988); Scalpone (1988)
	budgeting	
	evaluation	
	accurate exchange of information between corporate and training strategists	
	advisory council to ensure that the course curriculum meets business needs and reflects the latest trends in various technological fields	Hickey (1988); Casner-Lotto (1988); Rubin (1988)
	forecasting areas of job growth and decline	
	training advisory board	Casner-Lotto (1988); Hemmens (1988); Gutchess (1988); Sickler (1988); Scalpone (1988)
	in-house group of instructors (industry-experienced personnel, familiar with theory and applications as well as with training techniques)	
	hands-on training	
	identify specific training needs	
	design delivery	Casner-Lotto (1988); Hamburg (1988); Scalpone (1988); Gutchess (1988); Stackel (1988)
	cost	
	quality of training	
	cost-effectiveness of retraining for new technology as against hiring already-trained recruits	Morano and Leonardi (1988); Hemmens (1988); Smith (1988); Feurey (1988); Casner-Lotto (1988)
	managing the redeployment of employees from old to new jobs	
	enhancing the success rate of retrainees by bringing them into contact with the new work unit as early as possible	
	budgeting, evaluation, mechanisms of linkage	Rosow (1988)
	cost, quality	
	employees teach - SME involvement	
	needs assessment	
Technology Innovation (TI)	budget, staffing, technology readiness	Gartner (2009); DoD (2009)
Organizational Effectiveness (OE)	cost, quality	Boeing (2009); Kaplan (2012); Pisano (2012); Booz & Co (2016)

3.5.2 Aligning Practical Environment Knowledge Base to Research

The variables from this chapter and Chapter 2 provide a general baseline to begin the research study in Chapter 4 through Chapter 6. As there was no conclusive evidence from literature describing the relationships that are significant between the three constructs of this research, additional studies are necessary. Hence, exploratory interviews from five different companies will be performed in Chapter 4 to further define the key variables that are significant for training, technology innovation, and organizational effectiveness.

CHAPTER 4

QUALITATIVE DATA ANALYSIS: EXPLORATORY INTERVIEWS

This chapter is represented as Phase II, shown in Figure 4, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. The goal of this chapter is to substantiate the assumed relationships between the three research constructs of training, technology innovation, and organizational effectiveness. In addition, this chapter addresses the relevance and business needs, as outlined in the research strategy from Chapter 1. The interviews highlighted throughout this chapter give a practical viewpoint and are used to expand the general observation that training and technology innovation interact in the prediction of organizational effectiveness.

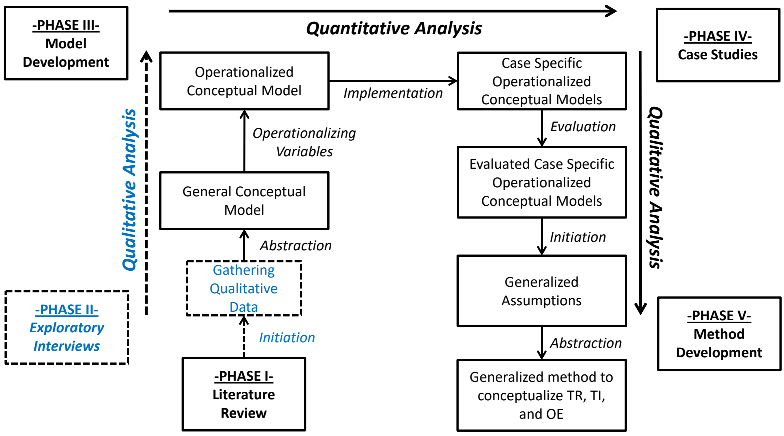


Figure 4. Phase II of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

4.1 Motivation for Practical Cases

The motivation for the interviews is to support the relationships between the constructs that have been observed through current literature and research. Specifically, the observations include the relationships between the main constructs that need to be further described in detail from a practical relevance as introduced in the blended research strategy from Chapter 1. The aim for this chapter is to provide additional insight into the first research sub-question from Chapter 1: *What key variables are significant for training, technology innovation, and organizational effectiveness?*

4.2 General Observations and Exploratory Questions

The three main general observations based upon current literature described in Chapter 2 and 3 are listed below, along with nine exploratory questions (EQ) that need to be addressed through interviews to help add relevance to the research, as described in the research framework from Chapter 1. In order to validate the observations, open interviews in the context of the three main constructs in the research were conducted with several companies to help provide insight to the EQs below. Section 4.6 will further expand on the three general observations described in this section by reporting what was concluded during the qualitative data analysis of the practical cases from the industry perspectives.

General observations TR-OE (GO TR-OE):

Training (TR) has a positive effect on organizational effectiveness (OE).

The main interest in further analyzing GO TR-OE is to optimize the relationship between TR and OE. The answers to the EQs below aim to confirm whether there is a relationship between TR and OE and provide the information necessary to support the general observation GO TR-OE. Furthermore, additional variables may surface, where comparisons to the variables that have been described in the previous chapters will be discussed. It will be through the analysis of the interview data where the answers to the questions below will be addressed.

EQ1. For what aspects of organizational effectiveness does training play a role?

The answer to this EQ aims to confirm that there is a relationship between TR and OE. The answer to this EQ will also provide additional variables to consider or to confirm the variables that have been discussed in the previous chapters. The process of determining the additional variables will be through the qualitative and quantitative data analysis, which will be described later in this chapter.

EQ2. How do you align training to organizational goals?

The answer to this EQ aims to provide the methods and processes for aligning training to organizational goals, which in turn, influences organizational effectiveness. This information will be used to describe the relationship between TR and OE.

EQ3. How does the training leadership team participate in the strategic planning process for the enterprise?

The answer to this EQ aims to help provide the requirements needed for TR to have a positive effect on OE. Understanding the requirements needed for TR to have a positive effect on OE will help determine how the conceptual model for this research can be validated and tested.

General observation TI-OE (GO TI-OE):

Technology Innovation (TI) has a positive effect on organizational effectiveness (OE).

The main interest in further analyzing GO TI-OE is to optimize the relationship between TI and OE. An additional interest for analyzing this general observation is to determine whether TR plays a role in optimizing the TI and OE relationship. The general observation of the relationship between TI and OE is from inductive reasoning based on literature in Chapter 2 and 3. Deductive reasoning of this general observation of the relationship between TI and OE aims to provide support the existence of TR in the interaction between TI and OE; thereby, necessitating the next general observation TI-TR-OE.

The answers to the EQs below aim to confirm whether there is a relationship between TI and OE and provide the information necessary to support the general observation GO TI-OE. Furthermore, additional variables may surface, where comparisons to the variables that have been described in the previous chapters will be discussed. It will be through the analysis of the interview data where the answers to the EQs below will be addressed.

> *EQ4. For what aspects of organizational effectiveness does technology innovation play a role in?*
>
> The answer to this EQ aims to confirm that there is a relationship between TI and OE. Specifically, this EQ aims to show (1) whether TR exists in the relationship between TI and OE; and (2) if TR does exist, whether TR plays a mediating role or moderating role in the relationship between TI and OE. Moreover, the process of analyzing the common variables between TI and OE may provide additional variables to consider or to confirm the variables that have been discussed in the previous chapters. The process of determining the additional variables will be through the qualitative and quantitative data analysis, which will be described later in this chapter.
>
> *EQ5. How do you align technology innovation to organizational goals?*
>
> The answer to this EQ aims to provide the methods and processes for aligning technology innovation to organizational goals, which in turn, influences organizational effectiveness. The interest here would be to observe whether TR plays a role in the process of aligning technology innovation to organizational goals. This information will be used to further describe in relationship between TI and OE, and what variables influence this relationship.
>
> *EQ6. How does the technology function leadership team participate in the strategic planning process for the enterprise?*
>
> The answer to this EQ aims to help provide the requirements needed for TI to have a positive effect on OE. Understanding the requirements needed for TI to have a positive effect on OE will help determine how the conceptual model for this research can be validated and tested.

General Observation TI-TR-OE (GO TI-TR-OE):

From Chapter 2 and 3, there is an expectation that Technology Innovation (TI) and training (TR) interact with each other to affect Organizational Effectiveness (OE), but literature provides little information regarding this interaction.

The main interest in further analyzing GO TI-TR-OE is to confirm the relationship between TI and TR. Moreover, an additional interest is to analyze how to optimize this relationship to positively influence OE. The answers to the EQs below aim to confirm whether there is a relationship between TI and TR. Additionally, the answers to the EQs aim to also confirm if the relationship between TI and TR affects OE. The answer to these EQs will provide the information necessary to support the general observation GO TI-TR-OE. Furthermore, additional variables may surface, where comparisons to the variables that have been described in the previous chapters will be discussed. It will be through the analysis of the interview data where the answers to the EQs below will be addressed.

EQ7. For what aspects of technology innovation planning process does training play a role in?

The answer to this EQ aims to confirm the relationship between TI and TR. Specifically, this EQ aims to show how TR affects TI.

EQ8. For what aspects of training planning process does technology innovation play a role in?

The answer to this EQ aims to confirm the relationship between TI and TR. Specifically, this EQ aims to show how TI affects TR, and if TI drives TR.

EQ9. How does the relationship between TI and TR affect organizational effectiveness?

The answer to this EQ aims to confirm that there is a relationship between TI and TR, and that this relationship has an effect on organizational effectiveness. Furthermore, the answer to this EQ aims to provide a basis for a preliminary conceptual model for this research. This EQ corresponds directly to the main research question from chapter 1: *How can the relationship between training and technology innovation influence organizational effectiveness from being reactive to proactive when technology changes?*

4.3 Methods for Gathering Qualitative Data

4.3.1 Interview Design

The interview design aims to gather qualitative data through 14 interviews. The analysis of the qualitative data will be used to support the relationships between the three main constructs of training, technology innovation, and organizational effectiveness, stated earlier as GO TR-OE, GO TI-OE, and GO TI-TR-OE in Section 4.2. The main result of this chapter is a two-fold: (1) to list additional key variables that are considered for each construct, and (2) to confirm the existence of the relationships between the constructs. The information resulting from this chapter will be combined with the findings from Chapter 2 and 3 to create a conceptual model, which will be elaborated in Chapter 6.

All of the interviews are recorded and transcribed. The interviewees were all asked to review the information quoted or paraphrased from them to ensure accuracy. All of the interview questions were intended to be open questions to support the general observations GO TR-OE, GO TI-OE, and GO TI-TR-OE. Hence, the interview questions were in the context of the three main constructs of this research.

4.3.2 Interview Company Selection

The main research question and goal of this research is in terms of general engineering companies. Hence, data from different engineering companies are collected and analyzed to align to this research. The most accessible data that can be collected is from the engineering company in which the researcher is currently employed. In this case, the engineering company is the Boeing Company. Data from different engineering companies are collected and used to compare against the interview data collected from the Boeing Company. Throughout the rest of this research, the Boeing Company will be referred to as "Boeing" and engineering companies that are not Boeing will be referred to as "Non-Boeing." The non-Boeing interview data was collected from Shell, Hewlett Packard (HP), Dassault Systemes, and General Motors. The analysis of the data collected from both Boeing and non-Boeing was used to illustrate the relationships between the three constructs. It is also of interest to analyze whether Boeing and non-Boeing interviewees are different in terms of their discussions of the three constructs. The general criteria for the selection of these companies used in this chapter were briefly described in Chapter 1.

In short, the companies highlighted in this chapter were selected based upon the size of the company, comparable to Boeing; having engineering, research and technology departments; and having internal training departments to help provide the technical training necessary to the engineering community. These groups of companies highlighted in this chapter have the above characteristics. It was not the intent of this chapter to interview and research every single company that has the above characteristics. The intent of this research phase is to interview a few selected companies to help provide answers to the questions listed earlier to support the general observations in Section 4.2. Again, all three of the general observations and corresponding questions are related to the constructs within this research, as the analysis approach is exploratory and not testing specific hypotheses. Hence, for this research, the number of companies being interviewed is not critical. The data collected from the interviews will also draw attention to the key variables that are considered when influencing organizational effectiveness.

4.3.3 Interviewee Selection

The audience for the interviews was chosen based upon the three main constructs of the research. That is, the categories are of people who are SMEs or managers in the area of technology innovation, training, or organizational effectiveness. Note that all three constructs are in the context of engineering, meaning technology innovation is in the area of engineering, training is technical training in the area of engineering and the audience being engineers, and organizational effectiveness is in the context of engineering companies and organizations.

All interviewees were chosen to address and align to at least one of the constructs of this research, although most interviewees were able to speak to more than one construct. That is, although an interviewee's function specializes directly in one construct, the interviewee may have indirect experience in other constructs as well. Training managers were expected to provide discussions rich in both TR and OE, which in turn provides the data necessary to support GO TR-OE. Engineering managers were expected to provide discussions rich in both TI and OE, which in turn provides the data necessary to support GO TI-OE. Training SMEs were expected to provide discussions rich in TR. Engineering SMEs were expected to provide discussions rich in TI. Analyzing the two groups of training SMEs and engineering SMEs provides the data needed to support the TI-TR relationship, which in turn provides the data necessary to support GO TI-TR-OE. Additionally, since all managers consist of training managers and engineering managers, and all non-managers consist of training SMEs and engineering SMEs, the analysis of managers and non-managers aims to provide the data necessary to support GO TI-TR-OE.

Relationships between the constructs are necessary to analyze to provide the reasoning to support the three general observations. Hence, analyzing the differences between the interviewees functions are of interest to this research. To analyze the relationships between the constructs, the interviewee functions are divided into groups of interest and sets of interest. The groups of interest and sets of interest relating to specific EQs and general observations are shown in Table 4-1. There are a total of 11 groups of interest and six sets of interest.

Table 4-1. Groups of interest and sets of interest as relating to EQs and general observations

Group of Interest	Set of Interest	Description	Which EQ Addressed	Which General Observation Addressed
General - All 14 Interviews	All 14 interviews	General overview of all three constructs taking into account all 14 interviews	EQ1-EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
Boeing (7 Interviews)	Boeing and non-Boeing	Boeing interviews which include managers, engineering SMEs, and training SMEs	EQ1-EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
non-Boeing (7 Interviews)		non-Boeing interviews which include managers, engineering SMEs, and training SMEs	EQ1-EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
Managers (5 Interviews)	Managers and non-Managers	Managers only from both Boeing and non-Boeing	EQ1-EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
non-Managers (9 Interviews)		non-managers from both Boeing and non-Boeing	EQ1-EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
Training SMEs (4 Interviews)	Training SMEs and Engineering SMEs	Training SMEs from both Boeing and non-Boeing	EQ1-EQ3; EQ8	GO TR-OE, GO TI-TR-OE
Engineering SMEs (7 Interviews)		Engineering SMEs from both Boeing and non-Boeing	EQ4-EQ6; EQ7	GO TI-OE, GO TI-TR-OE
Engineering SMEs not involved in training (3 Interviews)	Engineering SMEs not involved in training and Engineering SMEs involved in training	Engineering SMEs from both Boeing and non-Boeing, which does not include managers and who are NOT directly involved in developing or teaching training courses	EQ4-EQ6; EQ7	GO TI-OE, GO TI-TR-OE
Engineering SMEs involved in training (4 Interviews)		Engineering SMEs from both Boeing and non-Boeing, which does not include managers and who are directly involved in developing or teaching training courses	EQ1-EQ6; EQ7, EQ9	GO TR-OE, GO TI-OE, GO TI-TR-OE
Engineering Manager (3 Interviews)	Engineering manager and Training manager	Engineering manager from both Boeing and non-Boeing	EQ4-EQ6; EQ7, EQ9	GO TI-OE, GO TI-TR-OE
Training Manager (2 Interviews)		Training Manager from both Boeing and non-Boeing	EQ1-EQ3; EQ8, EQ9	GO TR-OE, GO TI-TR-OE

Table 4-2 shows the list of interviewees as they correspond to the functions and the three constructs. There were a total of seven interviewees within Boeing and seven interviewees outside of Boeing. The list of interviewees within Boeing discussed and related to the same number of constructs as the interviewees outside of Boeing.

Table 4-2. List of interviewees and their functions as they relate to the three constructs of this research

	Function	Training	Technology Innovation	Organizational Effectiveness
Interviewee 1 [I1]	Training Manager	x		x
Interviewee 2 [I2]	Engineering Senior Manager	x	x	x
Interviewee 3 [I3]	Training SME	x		x
Interviewee 4 [I4]	Engineering Senior Manager	x	x	x
Interviewee 5 [I5]	Engineering SME		x	
Interviewee 6 [I6]	Engineering SME	x	x	
Interviewee 7 [I7]	Training SME	x		x
Interviewee 8 [I8]	Engineering SME	x	x	x
Interviewee 9 [I9]	Engineering SME	x	x	
Interviewee 10 [I10]	Engineering SME	x	x	
Interviewee 11 [I11]	Engineering SME		x	
Interviewee 12 [I12]	Engineering Manager		x	x
Interviewee 13 [I13]	Engineering SME		x	x
Interviewee 14 [I14]	Training Manager	x		x

As shown in Table 4-2, most of the interviewees fall into two construct categories and play two different roles within the organization. For example, a training manager will be able to give perspective from the training construct point of view as well as the organizational effectiveness point of view. An engineering SME *may* also have participated by mentoring or formally teaching and developing a course and transferring knowledge. This engineering SME would be able to give perspective from a technical point of view as well as a training point of view. There are those that were interviewed that were only able to give perspective from one construct point of view, and some that were able to give perspective from all three constructs point of view. So depending on the person being interviewed, the questions were tailored based on their subject of expertise.

4.3.4 Interview Protocol

The interview protocol was followed during every interview. The interview protocol included an introduction to the research, purposes of the interview, description of transcripts taken from the recorded interview, description of the confidentiality, and the list of interview questions based upon the function (e.g. training SME, manager, subject matter expert, etc.) of the person being interviewed. The interview questions will be described in further detail in the next section.

Every person being interviewed was given a brief introduction of the research, which included the main goals of the research study. The purpose of the interview was described for each person being interviewed and the goals of the interview were based upon the function of the person being interviewed.

Every interview was recorded with the permission of the person being interviewed. The purpose of having the interviews recorded was to have an accurate account of the interview and to provide the person being interviewed with a transcript of the interview. An accurate transcript was critical in the analysis of the data collected during the interview. All of the data collected during the interview that was presented in the thesis was reviewed and approved by the person being interviewed. The intent of the recorded interview was to report accurate information with the given permission of the person being interviewed.

Each person being interviewed had the opportunity to choose to be anonymous or to be referenced to by name and/or title in this research. All direct quotes and references to the person being interviewed were approved by the person being interviewed.

4.3.5 Interview Questions

Each person being interviewed had a set of interview questions (IQ) that were addressed during the interview. The interview questions were based upon the audience and function (e.g. training SME, manager, subject matter expert (SME), etc.) of the person being interviewed. This approach was followed so that there will be an evenly distributed amount of data addressing each of the three constructs of Organizational Effectiveness, Technology Innovation, and Training within the context of this research, as shown earlier in Table 4-2. Again, as stated earlier in the chapter, all of the interview questions were intended to be open questions in the context of the three main constructs of this research.

The purpose of the interviews is to further describe the general observations described in Section 4.2. Hence, the interview questions correspond to each of the general observations and the related questions listed for each of the three general observations. Below is the general list of interview questions. Again, each interview was tailored to the interviewee's function at the company. The complete set of general interview questions that were used for each interview based on the function of the interviewee can be found in Appendix 4A.

IQ1. What do you perceive as the main organizational goals for training or technology innovation?

The purpose of this question is to identify the variables that are related to training and technology innovation as it relates to organizational effectiveness. This question corresponds directly to GO TR-OE and GO TI-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ2 and EQ5.

IQ2. How does the training or engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?

The purpose of this question is to identify the variables that are related to training and technology innovation as it relates to organizational effectiveness. This question corresponds directly to GO TR-OE and GO TI-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ2, EQ3, EQ5, and EQ6.

IQ3. How does the training or engineering organization know when a new technology is being considered by the other organizations?

The purpose of this question is to identify the variables that are related to training and technology innovation as it relates to organizational effectiveness. This question corresponds directly to GO TR-OE and GO TI-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ1 and EQ4.

IQ4. How does the company manage the adaptation of its training programs to new technological developments and innovations?

The purpose of this question is to identify the variables that are related to training and technology innovation as it relates to organizational effectiveness. This question corresponds directly to GO TI-TR-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ9.

IQ5. What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?

The purpose of this question is to identify the variables that are related to training and technology innovation as it relates to organizational effectiveness. This question corresponds directly to GO TI-TR-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ7 and EQ8.

IQ6. Think of a successful training or technology innovation program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?

The purpose of this question is to identify the variables that are related to training and technology innovation as it positively relates to organizational effectiveness. This question corresponds directly to GO TR-OE and GO TI-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ1, EQ2, EQ3, EQ4, EQ5, and EQ6.

IQ7. Think of an unsuccessful training or technology innovation program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?

The purpose of this question is to identify the variables that are related to training and technology innovation as it negatively relates to organizational effectiveness. This question corresponds directly to GO TR-OE and GO TI-OE in section 4.2. Moreover, depending on the function of the interviewee, this questions aims to provide the data necessary to support EQ1, EQ2, EQ3, EQ4, EQ5, and EQ6.

4.4 Methods for Addressing Exploratory Questions

The interview questions were open in nature and provided data from the 14 interviewees to analyze. To optimize the data, the goal is to address several sub-EQs (listed and described in Appendix 4B) that align directly to the nine EQs that support the general observations in Section 4.2. Hence, the main purpose for analyzing the data from the interview questions is to provide the answers to the EQs in Section 4.2, thereby, providing the deductive reasoning to support the general observations GO TR-OE, GO TI-OE, and GO TI-TR.

There are a total of six sets of interest that are combinations of the groups of interest that will be analyzed, where the combination of groups of interests will be compared. A correlation analysis will be performed for each set of interest to describe the relationship between the groups of interest. The correlation analysis will also be performed for each set of interest in terms of the individual constructs of this research. Moreover, the correlation analysis will be performed for each of the most significant variables in terms of the group of interest and individual construct. Individual constructs refer to each of the three constructs of OE, TI, and TR. The analysis of the individual constructs will aim to provide explanation for the relationships between the constructs. This approach will provide the necessary information to be able to perform deductive reasoning to support the three general observations of GO TR-OE, GO TI-OE, and GO TI-TR-OE. Detailed discussions of the conclusions will be described in section 4.5.3.

The general design for addressing the EQs is divided into three phases of analysis. The first two phases will use a mixed methods approach, using both quantitative and qualitative analysis to address the sub-EQs. Phase three is simply a summary phase to conclude the analysis, and thereby providing the information necessary for addressing the nine EQs.

The first phase begins with investigating the most significant variables for the group of interest and set of interest. The quantitative analysis being performed is a correlation analysis to statistically describe the relationship between the two groups of interest. The qualitative analysis consists of the direct quotes or accounts taken from the interviews to further describe the most significant variables between the groups of interest.

The next phase investigates the most significant variables relating to the constructs individually for each group of interest and set of interest, respectively, as shown earlier in Table 4-1. The quantitative analysis being performed is a correlation analysis to statistically describe the relationship between the two groups of interest in terms of the three individual constructs. The qualitative analysis consists of the direct quotes or accounts taken from the interviews to further describe the most significant variables between the groups of interest in terms of the three individual constructs. The strength and direction of the relationships are also determined through correlation analysis.

The final phase of analysis involves summarizing the most significant variables from phase one and two; thereby providing a summary table of the most significant variables for the entire set of interest. The summary tables from each set of interest will be compared and discussed in both Section 4.5.3 and Section 4.6 when addressing the EQs, and drawing and verifying conclusions, respectively. The details of the analysis will be further described in detail in Section 4.6. The analyses of the interview data to address all nine of the EQs followed this three-phased approach for consistency.

4.5 Analysis of Interview Data

4.5.1 Qualitative Data Analysis (QDA) Approach

According to Miles and Huberman (2014) and Saldana (2013), the qualitative data analysis approach consists of three main activities: data condensation (which includes coding), data display (which includes designing matrix and network displays, as well as methods of displaying and analyzing qualitative data), and drawing and verifying conclusions, as will be described in section 4.5.1, 4.5.2, and 4.5.3, respectively. Because this research includes elements of each of the three main activities described by Miles and Huberman, the analysis of the 14 interviews will follow this QDA approach.

There are many computer-assisted qualitative data analysis software (CAQDAS) to help with the qualitative data analysis. These include AnSWR, ATLAS.ti, HyperRESEARCH, MAXQDA, NVivo, QDA Miner, Qualrus Transana, and Weft QDA (Saldana, 2013). For this research, the ATLAS.ti software toolkit was used.

4.5.2 Coding Process

According to Saldana (2013), a code in qualitative analysis is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data. In this research, the data consists of interview transcripts. Saldana (2013) states that the reverberative nature of coding – comparing data to data, data to code, code to code, code to category, category to category, category back to data, etc. – suggests that the qualitative analytic process is cyclical rather than linear. Hence, according to Saldana (2013), there are coding cycles involved in the analysis of qualitative data. Saldana (2013) defines First Cycle methods are those processes that happen during the initial coding of data and are divided into seven subcategories: Grammatical, Elemental, Affective, Literary and Language, Exploratory, Procedural, and Themeing the Data. Saldana (2013) describes Second Cycle methods to be a bit more challenging because they require such analytic skills as classifying, prioritizing, integrating, synthesizing, abstracting, conceptualizing, and theory building.

The portion of data to be coded during First Cycle coding processes can range in magnitude from a single word to a full paragraph to an entire page of text (Saldana, 2013). The coding in this research ranges from a sentence to a full paragraph in the interview transcript. For this research, exploratory and elemental methods will be used during the First Cycle coding. Saldana (2013) defines exploratory method as *"Open-ended investigation and preliminary assignments of codes to the data before more refined coding systems are developed and applied. This method can serve as preparatory work before more specific First Cycle or Second Cycle coding methods."* Saldana (2013) defines elemental method as *"Foundation approaches to coding qualitative data. It is basic but focused filters for reviewing the corpus to build a foundation for future coding cycles."* Saldana (2013) lists five possible coding techniques used for elemental methods: structural coding, descriptive coding, in vivo coding, process coding, and initial coding. This research uses initial coding during the First Cycle coding, where Saldana describes initial coding as *"the first major open-ended stage of a grounded theory approach to the data. The initial coding technique breaks down qualitative data into discrete parts, closely examines them, and compares them for similarities and differences."*

In Second Cycle coding processes, the portions coded can be the exact same units, longer passages of text, analytic memos about the data, and even a reconfiguration of the codes themselves developed in during the First Cycle coding (Saldana, 2013). This research moves towards reconfiguring the codes developed in the First Cycle coding, where a ***full manual review*** of the first coding cycle takes place to ensure that the portions of the interview transcript are coded in context. Examples of this will be shown later in this section. Saldana (2013) lists six possible coding techniques to use during the Second Cycle coding: pattern coding, focused coding, axial coding, theoretical coding, elaborative coding, and longitudinal coding. This research uses focused coding during the Second Cycle coding. Saldana (2013) defines focused coding technique as *"follows in vivo, process, and/or initial coding. This technique categorizes coded data based on thematic of conceptual similarity, as well as searches for the most frequent or significant initial codes to develop the most salient categories in the data corpus."*

Charmaz (2001) describes coding as the "critical link" between data collection and their explanation of meaning. According to Miles and Huberman (2013), the coding process is part of the analysis. The next few sub-sections will further describe the methods and coding used within this research during the First Cycle coding through the Second Cycle coding.

Choosing the Variables

Before describing the first and second cycle coding process, there was exploratory work that was completed during the data condensation. The raw transcript data was sifted through and sorted by the words that interviewees used to describe a certain idea within the context of the construct that is being considered. ATLAS.ti has a function called Word Cruncher, where this feature offers word "crunching" capabilities for a simple quantitative content analysis. For this research, this feature was used to create word count tables for each of the 14 interviews. The word count table from ATLAS.ti gave a count of every single word in the transcript, where an example snapshot is shown in Table 4C-

1 in Appendix 4C. The raw data, or list of words, from ATLAS.ti word cruncher was then filtered and sorted from the highest count to the lowest count. An extra column was created to list the common coding category for each relevant word from the raw data, where an example snapshot is shown in Table 4C-2 in Appendix 4C. Relevant in this context means a word at first observation or go through that might relate and be synonymous to the research in terms of training, technology innovation, and organizational effectiveness.

A combined list of the common coding categories for all 14 interview transcripts was created in a table or summary list, where an example snapshot is shown in Table 4C-3 in Appendix 4C. This summary list was then filtered by alphabetical order by coding category, where an example snapshot is shown in Table 4C-4 in Appendix 4C. Each coding category was then separated and analyzed, listing the key words from the raw data that related to or was synonymous to the coding category. Note that the key words are direct words used from the interviewees. There were no additional words added as this would misrepresent the raw data. This list of related words was then used to theme or "code" the interview transcripts. Moreover, these coding categories in combination with the corresponding related words from the raw data created the units of analysis for this research. The units of analysis will be further described in the next section. From this exercise, ***35 common coding categories***, which can also be referred to the latent and manifest variables within this research, surfaced from across the 14 interview transcripts. A summary of the 35 variables, with the corresponding words from the raw data and coding category type, can be found and defined in Table 4C-5 in Appendix 4C.

Units of Analysis for Coding the Interview Transcripts

ATLAS.ti provides a feature to code the interview transcripts by defining a code and searching the transcript by words corresponding to the code. For this research, the code and the groups of words corresponding to the code is referred to as a "unit of analysis." There were a total of 35 units of analysis used to code each of the 14 interview transcripts. The units of analysis were created using the summary of the 35 variables and the total corresponding words from the raw data. Table 4D-1 in Appendix 4D shows the exact syntax used within ATLAS.ti as the units of analysis for coding the 14 interview transcripts.

First Cycle Coding of the Interview Transcripts

In ATLAS.ti, there is an auto coding feature that allows for user to input their defined code, along with the corresponding words relating to that word that the user would like to be searched and coded. The user has the option to code the interview transcript by Exact Match, Word, Sentence, Single Hard Return, Multiple Hard Returns, and All Text. For the First Cycle coding, this research used initial coding of the interview transcripts by sentence. An example can be seen in Figure 4C-6 in Appendix 4C. The coding categories were named directly in the transcript in the margin as a code, directly relating to the quotation, where the quotation in this first cycle coding was defined as being a sentence.

Second Cycle Coding of the Interview Transcripts

In the Second Cycle coding of the interview transcripts, manual coding was performed by revising previous sentence by sentence structural coding to focused coding in the context of the three constructs or certain idea/latent variable/manifest variable. The reason for the Second Cycle coding was to ensure that the quotations from the interview transcripts being coded during the First Cycle coding was within context of the three constructs being discussed during the interview. For example, within a paragraph after First Cycle coding where every sentence is coded, it is not necessary that the code in the first sentence is being related to the code in the last sentence of the paragraph. This would be inaccurate since the two codes should be connected to be in correct context of each other. This is why Second Cycle coding is critical for the accuracy of this research. An example of what this coding looks like is shown in Figure 4-1. Once the Second Cycle coding was complete, co-occurrence tables and frequency count tables were created and analyzed.

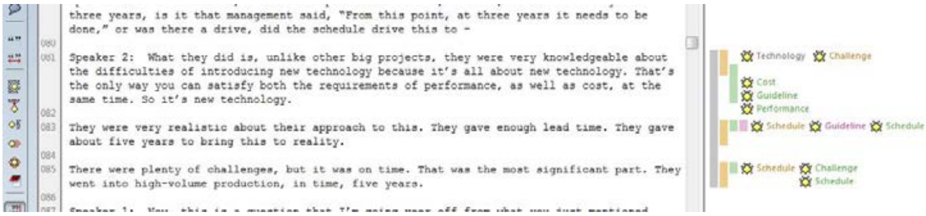


Figure 4-1. Example of second cycle coding in ATLAS.ti

4.5.3 Observations from Data Analysis

This interview study was exploratory in nature, as there was minimal current information showing the relationships between the three main constructs shown in a practical manner, as to add relevance to this research as outlined in the research strategy in Chapter 1. Answering sub-EQs will in turn address the main EQs for each general observation GO TI-OE, GO TR-OE, and GO TI-TR-OE from Section 4.2. Sub-EQ1 through sub-EQ45, which were first introduced earlier in this chapter in Section 4.3.5, will be addressed in this section by using the data collected for occurrence frequency and co-occurrence frequency.

Occurrence Frequency

In Atlas.ti, the occurrence frequency counts single quotations. The software counts the number of times a code is used in the interview transcript. If a single quotation is coded twice by the same code, this would count as a single occurrence for that code. The occurrence frequency helps give information regarding specific individual variables and individual groups of interest. The occurrence frequency data was not intended to be used to describe specific relationships in this research, such as relationships between the three constructs or the groups of interest.

Co-occurrence Frequency

In Atlas.ti, the co-occurrence frequency does not count single quotations, it counts co-occurrence events. If a single quotation is coded by two codes, this would count as a single co-occurrence. Because this research is mainly interested in the relationships between the three constructs and the possible latent and manifest variables associated with them, it would not be accurate to use a code frequency count (also known as the occurrence frequency) when analyzing the relationships between the variables, as this would misrepresent certain codes that are being described in the context of another. Hence, the co-occurrence frequency data was used when analyzing relationships between constructs and groups of interest.

Quantitative Data Statistical Analysis Methods

The statistical quantitative data analysis that was used in this chapter was correlation analysis. As reiterated through this chapter, the intent and interest was to describe the relationships between the three constructs. The interest was to know if two variables are related to each other, where if the change in one variable brings about a change in the other variable, they were said to be correlated. Again, correlations only describe the relationship/association and the strength of the relationship (Field, 2013) – they do not prove the cause and effect (direction of the arrow), which was not the interest of this chapter. This will be analyzed later in the research.

The data sets used in this research are all categorical variables, and more specifically ordinal variables. The quantitative values for each qualitative variable can be ranked in sequence. The X and Y scatter plots shown in Appendix 4E all show that there was a monotonic relationship between the variables being compared. Hence, Spearman's rank-order correlation was used for this research. Again, Spearman's correlation was used to test for a rank order relationship between two quantitative variables when concerned that one or both variables is ordinal (rather than interval) and/or not normally distributed or when the sample size is small (Field, 2013). Thus, it was used in the same data situation as a Pearson's correlation, except that it was used when the data are either importantly non-normally distributed, the measurement scale of the dependent variable is ordinal (not interval or ratio), or from a too-small sample. There were assumptions that were made when choosing Spearman's rank-order correlation. The first assumption was the two variables being compared were ordinal variables. The second assumption was there was a monotonic relationship between the variables.

Regarding the correlation coefficient values that lie between -1 and +1, the correlation coefficient is a commonly used measure of the size of an effect; values of +/-0.1 represent a small effect, +/-0.3 is a medium effect, and +/-0.5 is a large effect (Field, 2013). However, according to Field (2013), interpreting the size of correlation within the context of the research rather than blindly following the benchmark above is recommended (Taylor, 1990; Hemphill, 2003). Hence, for the context of this research, which aims to determine the most statistically significant variables, the below criteria was followed in describing the Spearman's rank-order correlation coefficient:

- ***Exactly –1.*** *A perfect downhill (negative) relationship, representing a perfect correlation*
- ***–0.70.*** *A strong downhill (negative) relationship, representing a large correlation effect*
- ***–0.50.*** *A moderate downhill (negative) relationship, representing a medium correlation effect*
- ***–0.30.*** *A weak downhill (negative) relationship, representing a small correlation effect*
- ***0.00*** *No relationship*
- ***+0.30.*** *A weak uphill (positive) relationship, representing a small correlation effect*
- ***+0.50.*** *A moderate uphill (positive) relationship, representing a medium correlation effect*
- ***+0.70.*** *A strong uphill (positive) relationship, representing a large correlation effect*
- ***Exactly +1.*** *A perfect uphill (positive) relationship, representing a perfect correlation*

Ranking Criteria and Approach to Determining Most Significant Variables

Ranking criteria was set up to determine and examine the most significant variables when analyzing the occurrence frequency and co-occurrence frequency data. Note that the ranking criteria and approach to determining the most significant variables to consider for further study in this research was specific to this research. Before determining and examining the most significant variables, assumptions regarding the data need to be considered. The main assumption taken here was that if the number of occurrence or co-occurrence was low (i.e. closest to 0), then the variable was not statistically significant. Below are two assumptions that were considered when ranking the data:

> *A1. The greater the number of occurrence frequency, the more significant the variable is for the group of interest.*

> *A2. The greater the number of co-occurrence frequency, the more significant the variable is for the individual construct, combined construct, group of interest, and set of interest when examining the relationships between the variables.*

Hence, when transforming the occurrence frequency and co-occurrence frequency data, Spearman's rank-order correlation method was used to determine the most significant variables. The specifics of Spearman's rank-order correlation were described in the previous section. For the occurrence frequency and co-occurrence frequency data, values closest to the numeric value of 1 represented the most significant variable and the values closest to the numeric value of 35 represented the least significant variable. Once the ranking was completed, the most significant variables were considered for the conceptual model development.

The approach in determining the most significant variables depended on two scenarios: (1) the analysis of one individual construct, two groups of interests, or two groups interest with respect to individual constructs, and (2) the analysis of one group of interest. There was a four-step process in determining the most significant variables for the individual construct, two groups of interests, or two groups interest with respect to individual constructs,: (1) ranking of the variables, (2) omitting the variables that were not significant, (3) determining the ranking difference between the two variables, and (4) color-coding the variables. There was a one-step process in determining the most significant variables for one group of interest: ranking of the variables. The details of these two scenarios will be described in the next few paragraphs.

Because the goal of this chapter is to further study the most significant variables and not all 35 variables, it was necessary to omit several variables and recommend that those variables be studied further in future research. When comparing individual constructs, two groups of interest, or two groups of interest with respect to individual constructs, the ranking criteria for examining the most significant variables involved omitting the least significant variables. Similar to interpreting the size of correlation within the context of the research rather than blindly following a benchmark, it was necessary to also interpret the range of frequency data values within the context of this research because of the nature of how the occurrence and co-occurrence frequency data was obtained. It is likely that the occurrence and co-occurrence frequency data is different from research to research. Again, the occurrence and co-occurrence frequency data is highly dependent on how the interview was conducted in the context of the research and how the interviewees responded. For the reasons described above, the ranges of the occurrence and co-occurrence values used for this research aligned with the goals of this chapter in choosing the most significant variables to further study.

For occurrence and co-occurrence frequency data, any variables with occurrences and co-occurrences value of 10 and less are considered not significant and are omitted. There were instances when all of the data for a specific construct or group of interest had occurrences and co-occurrences value of 10 and less. In these cases, the conclusion was made that the entire set of variables was not significant. Moreover, if this was the case when a comparison was being made between the groups of interest or individual constructs, then the conclusion was made that there was not enough conclusive data to be able to perform an accurate comparison analysis between the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs.

The ranking difference was determined when comparing the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs. The ranking difference value was used to analyze whether the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs agreed on the ranking of a variable. The ranking difference between the ranking data of the variables was then color-coded for ease of analysis and was used for the purposes of this research only. Ranking difference value of 0 to 0.5 (color-coded green) represented no difference in the ranking between the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs being analyzed. Therefore, the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs were the same in their ranking of the variable. The absolute ranking difference value of 1 to 2 (color-coded yellow) represented little difference in the ranking between the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs being analyzed. Therefore, the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs were almost the same in their ranking of the variable. The absolute ranking difference value of 2.5 to 5 (color-coded orange) represented some differences in the ranking between the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs being analyzed. Therefore, the individual constructs, two groups of interest, or two groups of interest with respect to individual constructs had some differences in their ranking of the variable. The absolute ranking difference value of 5.5 or more (color-coded red) mean that there was a difference in the ranking between the two groups of interest or the constructs being analyzed. Therefore, the two groups of interest or constructs were not the same in their ranking of the variable. The main trend analyzed here was the closer the ranking difference was to 0, the greater confidence there was in the two groups of interest or individual constructs agreeing on the ranking of a particular variable. This analysis was important when determining the most significant variables for two or more constructs or groups of interest. The most significant variables for two groups of interest or individual constructs that were considered for the conceptual model development for this research were those variables that were colored *green and yellow*.

When only one group of interest was being analyzed, no ranking difference was determined because there were no comparisons being made between groups of interest. The similar ranking criteria for comparing individual constructs, two groups of interest, or two groups of interest with respect to individual constructs was used. For occurrence frequency data, variables with occurrence value of 10 and less were considered not significant and were omitted. The main difference when analyzing one group of interest versus two groups of interest or constructs was that the co-occurrence frequency data was not being considered. Co-occurrence frequency data was only used when comparing individual constructs, two groups of interest, or two groups of interest with respect to individual constructs. The most significant variables for only one group of interest was determined by considering the variables with ranking values from *1 through 5*.

Observations from the Data Analysis

As mentioned earlier in this chapter, the data analysis for each set of interest follow a three phase process. Observations from the data analysis will be reported using this three phase process to be consistent with the data analysis. For each set of interest, the most significant variables and the most significant variables as related to one of the three constructs will be described and supported with both quantitative data analysis (from Appendix 4F) and qualitative data analysis from the interviews. It is critical that the most significant variables be further defined and described in context to the individual and combined constructs because the variables may be viewed differently depending on the individual constructs and combined constructs. The correlation strength comparing each group of interest will also be described. As described earlier, phase three of the analysis aimed to provide a summary of the most significant variables. The summary table of the most significant variables can be seen in Table 4-3 and 4-4. When describing the data analysis observations for each set of interest, Table 4-3 and 4-4 will be referred to frequently. All of the detailed statistical analysis can be found in Appendix 4F.

Table 4-3. Summary Table of Most Significant Variables for Groups of Interest

Group of Interest	Most Significant Variables	Most Signifcant Variables relating to TR	Most Significant Variables relating to TI	Most Significant Variables relating to OE
All 14 interviewees	Training, Schedule, Guideline, Organizational Effectiveness, Technology	Guideline, Schedule, Organizational Effectiveness, Audience, Success	Training, Schedule, Guideline, Audience, Organizational Effectiveness	Training, Success, Management, Schedule, Guideline
Boeing	Training, Schedule, Organizational Effectiveness, Guideline, Success	Organizational Effectiveness, Audience, Success, Guideline, Schedule	Schedule, Training, Guideline, Organizational Effectiveness, Audience	Training, Success, Schedule, Management
Non-Boeing	Training, Schedule, Guideline, Technology, Organizational Effectiveness	Schedule, Guideline, Audience, Organizational Effectiveness	Training, Schedule, Guideline, Audience	Training, Management, Success, Guideline
Manager	Training, Schedule, Organizational Effectiveness, Guideline, Management	Organizational Effectiveness, Schedule, Guideline, Management, Success	Schedule, Training, Indicator, Audience, Research, Organizational Effectiveness	Training, Success, Management, Schedule, Guideline
Non-Manager	Training, Schedule, Guideline, Cost, Technology	Guideline, Audience, Schedule, Success, Teaching	Training, Guideline, Schedule, Audience, Organizational Effectiveness	Training, Success, Management, Cost, Technology
Training SME	Training, Organizational Effectiveness, Guideline, Schedule, Management	Organizational Effectiveness, Guideline, Schedule, Success, Measurement	Organizational Effectiveness, Training, Guideline, Schedule, Audience	NA
Engineering SME	Training, Schedule, Guideline, Technology, Cost	Guideline, Audience, Schedule, Success, Technology	Training, Schedule, Guideline, Cost	NA
Engineering SME involved in TR	Training, Schedule, Technology, Guideline, Cost, Management	Audience, Guideline, Teaching, Success, Challenge, Technology	Training, Schedule, Guideline, Audience, Cost	NA
Engineering SME not involved in TR	Training, Schedule, Guideline, Cost, Technology	Schedule, Guideline, Organizational Effectiveness, Cost, Success	Decision Making, Guideline, Schedule, Training	NA
Training Manager	Organizational Effectiveness, Training, Guideline, Schedule, Management	Organizational Effectiveness, Schedule, Success, Guideline, Management	Training, Organizational Effectiveness, Schedule, Success, Guideline	Training, Success, Management, Schedule, Guideline
Engineering Manager	Schedule, Technology, Training, Audience, Guideline, Decision Making	Schedule, Audience, Guideline, Technology, Management	Schedule, Research, Training, Indicator, Audience	Training, Audience, Schedule, Technology

Table 4-4. Summary Table of Most Significant Variables for Sets of Interest

Set of Interest	Most Significant Variables	Most Significant Variables relating to TR	Most Significant Variables relating to TI	Most Significant Variables relating to OE
All 14 interviewees	Training, Schedule, Guideline, Organizational Effectiveness, Technology	Guideline, Schedule, Organizational Effectiveness, Audience, Success	Training, Schedule, Guideline, Audience, Organizational Effectiveness	Training, Success, Management, Schedule, Guideline
Boeing and non-Boeing	Audience, Management, Schedule, Training, Teaching, Market Need, Customer, Guideline, Organizational Effectiveness, Decision Making, Technology	Challenge, Management, Measurement, Audience, Guideline	Schedule, Guideline, Training, Audience	Training, Success, Management
Manager and non-Manager	Decision Making, Schedule, Training, Market Need, Measurement, Success, Performance, Technology, Guideline, Audience	Market Need, Schedule, Success, Cost, Technology, Guideline	Audience, Organizational Effectiveness, Schedule, Training	Success, Training, Management
Training SME and Engineering SME	Teaching, Guideline, Training, Management, Performance, Audience, SME, Schedule	Schedule, Success, Decision Making, Guideline, Cost	*no variables that fit the ranking criteria because the highest co-occurrence value was less than ten*	NA
Engineering SME involved in TR and Engineering SME not involved in TR	Schedule, Training, Cost, Success, Guideline, Performance, Challenge, Technology	*no variables that fit the ranking criteria because the highest co-occurrence value was less than ten*	*no variables that fit the ranking criteria because the highest co-occurrence value was less than ten*	NA
Training Manager and Engineering Manager	Measurement, Training, Indicator	Schedule	*no variables that fit the ranking criteria because the highest co-occurrence value was less than ten*	*no variables that fit the ranking criteria because the highest co-occurrence value was less than ten*

All 14 Interviewees

As shown in Table 4-3 and 4-4, the most significant variables in general for all 14 interviewees are Training, Schedule, Guideline, Organizational Effectiveness, and Technology. It was expected that Training, Organizational Effectiveness, and Technology were found to be among the most significant variables across all 14 interviewees as the interviews were in context of the three constructs of TR, TI, and OE. Hence, the main significant variables to expect and consider from the analysis for all 14 interviewees are ***Schedule and Guideline***.

The most significant variables relating to TR in general for all 14 interviewees are Guideline, Schedule, Organizational Effectiveness, Audience, and Success. Again, it was expected that Schedule and Guideline are among the most significant variables, but in terms of TR, Audience is also one of the most significant variables. The Schedule and Guideline variables will be described in the next paragraphs. The variable 'Audience' in the context of companies is referring to the human capital. A non-Boeing manager states that *"investing in human capital, training is a very important part of every company [I4, 4:23]."* According to a training SME at Boeing, assessing the audience means *"understanding the needs of what is the current level of skill in the workforce that is being looked at, where is the ideal level of skill and knowledge, are there any gaps in between the two that need to be addressed, and if there are, then what is the best method to do that [I3, 7:7]."* Moreover, analyzing the target audience can help in determining whether or not training is necessary. A training SME at Boeing comments *"It [the needs assessment] is constantly being looked at to make sure that we are asking the right questions and this analysis really looks at what the target audience is, what are the objectives of the course, when the learner gets done with the training program, what are the key things that should be happening, should they be able to recite something, should they be able to comprehend something or take action on something, so what is the level of knowledge that you are looking for. And that can help drive whether or not training is the right answer [I3, 7:6]."* The needs assessment as described by the training SME at Boeing helps provide *who* the target audience is, but not necessarily *how* to target the audience for training. A training manager at Boeing helps give some insight and an approach regarding this, *"Overall, I go back once again to that localized kind of learning capability. Because one size doesn't fit all, the closer you are to the consumers of any given learning solution, the better solution you're going to have. That's a very important concept in this whole university construct we created. The closer you are to the end consumer of your learning solution, the more effective your solution should be [I1, 9:5]."* Hence, investing in human capital, knowing who the audience is and how to target the audience in a company contributes to the effectiveness of TR.

The variable 'Schedule' was also determined to be among the most significant variables in relation to TR. Schedule in context to TR at companies can have a few meanings, but all relating to time. One meaning for the variable 'Schedule' is the time required to keep course materials up-to-date. According to [I10], *"the third methodology on keeping this material up-to-date is that we use lots of subject matter experts for teaching itself [I10, 13:59]."* Another meaning for the variable 'Schedule' is the timing in which the course is being offered, which directly relates to when to offer training and the schedule in which the course needs to be delivered. An engineering SME described training in terms of timing as, *"'just in time' learning [I13, 15:118]."* This same engineering SME, shared that his company uses the 70:20:10 learning framework, which was based off of the learning framework originating from research done by Morgan McCall and his colleagues at CCL in the 1990s (Lombardo and Eichinger, 1996). According to Lombardo and Eichinger, '70' refers to experimental learning, where learning and developing is through day-to-day tasks, challenges and practice; '20' refers to social learning, where learning and developing is with and through others; and '10' refers to formal learning, where learning and developing is through structured modules, courses and programs. According to this engineering SME, "Just in time" learning refers to the '20' from the learning framework and includes wikis, portals, and content from the internal company website that were developed by the SMEs within the company. The engineering SME further defined the 70:20:10 learning framework as, *"So, recognizing that only about 10 percent of competence is built by formal training, 70 percent is on the job, and 20 percent is informal [I13, 15:28]."* Moreover, sometimes formal training is not the answer to addressing the competency needs, *"I remember a lady saying that the answer to a competence need is rarely a training course. So, you should always think twice, 'Do we need a formal training course for this [I13, 15:39]?'* An engineering SME also gives an example of informal learning through a community of practice company website, *"And as a new hire if you come in or if you are new to the group and they say you are going to design the leading edge of [Airplane X] you can go to the community of practice and pull up a page and you can see everything that has to do with the leading edge. Then the new hire has an idea for that…what if we did this instead [I6, 5:160]."*

The variable "Schedule" is also tied with company guidelines for having a skilled workforce; hence, the time it takes to train the workforce or the human capital at a company is also used to define 'Schedule' in this research. According to a training manager, *"We do tie our training very closely to our competence frameworks, and we do have a drive to reduce the time - what we call "the time to autonomy," trying to get them up to competence more quickly, through both training and on-the-job learning [I14, 14:14]."* 'Schedule' in this context, translates to training development time, delivery time, and implementation time in order to efficiently and effectively transfer knowledge to the workforce.

The variable 'Guideline' in terms of TR refers to the processes that a company follows to ensure a skilled workforce. These processes tend to be outlined in documents at the company where every organization uses as a reference. This is done so that the development, delivery, and implementation of TR are consistent and common across the company. A training SME comments, *"It is not that what they are doing is bad, but I think that would free them up to do more of the engineering work if they are probably more passionate about and more valuable to the company for. It also allows us to get a more common approach to training; so rather than 12 different groups with each having a slightly different version of a specific training, if we can get all 12 of those groups to get to a more common training to when something needs to be adjusted or it helps keep errors from happening in random groups, if we can get everything more common, we can keep a more level status on what's going on in making sure everybody is doing things the right way across the board [I3, 7:25]."* Hence, having guidelines and following common processes help towards improving the effectiveness of training, moreover, improving the overall organizational effectiveness by reducing time in correcting errors. It is interpreted that the time it takes for an employee or a group within the organization to correct errors directly translates to overhead costs in companies, since employees are paid for their time in doing work. Therefore, whenever the variable 'Schedule' is mentioned or discussed, it is in reference to time, and time is directly related to cost at companies, whether implicitly or explicitly.

The most significant variables relating to TI in general for all 14 interviewees are Training, Schedule, Guideline, Audience, and Organizational Effectiveness. Since the interview questions were in context of the three constructs, it is expected that TR and OE are among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Schedule, 'Guideline,' and 'Audience' were the most significant variables relating to TI.

The variable 'Schedule' in terms of TI refers to, in a broad sense, meeting the deliverable date in terms of delivering the product to the market. In order to meet the deliverable time, the life-cycle time of a technology, as well as the technology readiness level is evaluated. There are review decision gates that companies follow to determine that a product is ready to move to the next stage in its life-cycle. An engineering SME comments regarding delivery of a product, *"…we were three years late to deliver our product…[I6, 5:68]."*

The variable 'Guideline' in terms of TI refers to the processes that a company follows to ensure that the workforce is producing quality-controlled products that align and comply with the government and external customer guidelines. According to an engineering SME, *"…what's amazing is if you know if you have a process that allows the real issues to come out and you have the resources, the leadership, the business systems in place to work the issues, then it is amazing how much you can get done in a very quick amount of time [I5, 6:11]."* It may be interpreted that the guidelines and processes are in place to help with efficiency within the workforce. Hence, the variable 'Guideline' can be indirectly related to 'Schedule,' and since 'Schedule' is time and time is directly related to cost in a company, 'Guideline' can be interpreted as being indirectly related to the variable 'Cost.' The reasoning behind this explanation is to explain why the variable 'Cost' does not appear everywhere in the conceptual model as expected. It may be due to the fact that since 'Cost' is so widely known in companies, regardless of the function an employee, the interviewees tend to indirectly refer to cost by discussing other variables that are directly or indirectly related to 'Cost.'

The variable 'Audience' in terms of TI refers to the engineers within the company, as well as the suppliers outside of the company who are directly involved with the engineers at the company to help produce a certain product. This is due to the context of this research and the interviewees were chosen to fit the context of this research as described earlier in this chapter.

The most significant variables relating to OE in general for all 14 interviewees are Training, Success, Management, Schedule, and Guideline. Since the interview questions were in context of the three constructs, it is expected that TR is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Management,' 'Schedule,' and 'Guideline' were the most significant variables relating to TI. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was successful in the context of the construct being discussed.

The variable 'Management' in terms of OE refers to the leadership support and the business point of view within an organization. According to a training manager, "***Understanding the organization, taking that piece of it, means you know what the leadership support is, what the managers will support in regards to any learning innovation or solution you might bring in; you know***

what the makeup of the individuals that make up that organization are, the skills that you have in that organization, the level of skill with that organization [I1, 9:20]." An engineering SME further comments that *"The manager is key to it…management's involvement is very, very important [I8, 13:80]."* The 'it' in the quote refers to the effectiveness of the organization. Without management support, the organization will not be effective. A training manager agrees that, *"If you don't have that support up front, you will fail [I14, 14:11]."* Hence, the variable 'Management' refers to the leadership support throughout the organization, and in the context of this research, the organization is analyzed in terms of TI and TR. Management in terms of TI and TR will be discussed later in this section.

The variable 'Schedule' in terms of OE refers to meeting business deadlines and deliverables set by the customers. These sometimes occur during meetings annually. A manager comments, *"We meet once or twice a year, and they help us with our projects and what are our investments, and that's how the evaluations go [I4, 4:22]."* The variable 'Schedule' in terms of OE also refers to having a trained workforce and plan to transfer knowledge in case of staffing changes. A manager commented regarding learning drivers, *"…learning drivers will never end because it's new tools, new technologies, new processes, staffing changes, demographics of your population (like our demographics were 40-50% of all workforce could retire in five years); other initiatives that are being sent from the larger BC organizations or from in the enterprise. All of those things I just mentioned are learning drivers that will continually come at an organization [I1, 9:3]."*

The variable 'Guideline' in terms of OE refers to the standard tools and process that companies follow in order to certify their products prior to delivery to the market. An engineering manager comments, *"Then we are using our own certification tool, which by the way is also used externally for our customers [I2, 5:9]."*

An additional analysis that was performed for set of interest "All 14 interviewees" that was not performed for the rest of the sets of interest, due to the small number of interviews, was statistical comparison of the constructs to determine whether common variables were the same for each of the combined constructs of TI-TR, TI-OE, and TR-OE. For all three combinations of combined constructs, there was a moderate (+/- 0.50) positive relationship, where the relationship was neither weak nor strong.

The most important variables for both TI and TR are Schedule, Cost, Audience, Success, Market Need, Organizational Effectiveness, Management, and Guideline. Since the interview questions were in context of the three constructs, it is expected that OE is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Schedule,' 'Cost,' 'Audience,' 'Market Need,' 'Management,' and 'Guideline' were the most significant variables relating to TI and TR. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was successful in the context of the construct being discussed.

The variable 'Schedule' in terms of TI-TR refers to the development time, delivery time, the implementation time, and the recurring time it takes to keep the training material up-to-date. In terms of development time, an engineering SME commented, *"The training material itself has been quality checked a number of times by various subject matter experts [I10, 13:131]."* In terms of delivery time, an engineering SME commented that, *"I think the timing could have been better for anything that we try to teach our partners as well [I6, 5:5]."* Moreover, as technology innovation continues to evolve constantly, it is necessary that the timing of the training for the engineers is aligned. An engineering SME agrees, *"The other thing with* *training that's really critical, that's very well known, is that it has to be the right content at the right time [I9, 8:68].”* In terms of keeping the material up-to-date, an engineering SME comments, *“…the third methodology on keeping this material up-to-date is that we use lots of subject matter experts for teaching itself [I10, 13:59].”*

Narrative 1. Case highlighting business-driven training needs

In a company, when managers require that the workforce take training, then there is full support from management in terms of funding and resources to develop, deliver, implement, and evaluate the training. When the courses are not required, the funding and resources become more challenging to obtain, as well as having the audience participate in the courses become more challenging. An engineering SME further explains in the dialogue below:

First of all, the composite courses could not have been developed earlier because we just didn't have any - we actually developed and learned about those as we went further in the program. So, we couldn't have done the same things earlier. But, one thing you have to keep in mind is that these courses were required courses and were on hours, and everybody had to take them. The certificate programs are totally voluntary and were off hours. And, when you talk about off hours, management cannot require anybody to take off hours, so it's completely optional.

- [I9, 8:156]

Hence, when the business is driving the training needs, full support from the localized level management leads to training being developed, delivered, implemented, and evaluated on schedule to support the business. Therefore, for training to be successful, management support from all levels is essential.

Narrative 2. Case highlighting successful TI-TR relationship

One of the key factors for a successful TI-TR relationship is having localized training. Meaning, within a company, when training is directly integrated with the technology organization, engineering SMEs become directly involved in the training process formally and informally. An engineering SME comments below:

So, the training became this integral part of the Technology Center, and that had extremely positive results because your experienced engineers, subject matter experts, and the young engineers are sitting next to each other.

- [I10, 13:11]

Narrative 3. Case highlighting timing of training and technology need

In this case, the higher level business was what was driving the technology need, which in turn was driving the training need. The business promises their customers in the market a product, where a schedule gets committed whether the workforce is ready or not ready for it. This becomes challenging because with following a schedule, the workforce is in need to become quickly skilled in the product, as well as the partners who help support the building of the product. The challenge is that the business or high level management expects the workforce to become quickly skilled while trying to follow a tight schedule in developing and delivering the product to meet the market need. In this case, the management did not make the training mandatory, so the workforce needs to come up with the funding necessary to develop the training, but also the time necessary to send their workforce to the training. If the higher level business decision were made with input from the training and technology organizations prior to making any promises to the market, the preparation for getting the workforce skilled for developing and delivering the product would be more efficient and effective. An engineering SME elaborates below:

I think the timing could have been better for anything [with training] that we try to teach our partners as well. I think what happened was the schedule gets committed based on selling the product and regardless of whether you are ready or not, you go for it. I think that even if we had the training, we would not have had the time to take out [of the daily work schedule] to do it. It would've been one of those, 'well that's great, but if we don't have time for that, then we can't take it because we need to hurry and keep on designing this product.' I think the training ahead of time [would work if the organization was more prepared for it]. Which is kind of what we did on [Program X], we spent a little bit of time up front dealing with this sort of thing. It definitely played a major role I think [to the success of Program X].

-[I6, 5:165]

The variable 'Cost' in terms of TI-TR refers to the funding needed for training. Funding is in terms of resources needed for the development, delivery, implementation, and evaluation of training. The variable 'Audience' in terms of TI-TR refers to the engineering workforce and suppliers. An engineering SME provides an example of the various kinds of audiences to consider.

Narrative 4. Case showing how management drives engineering to develop localized training

In this case, there was a direct management push to the engineering SMEs to develop a training program. The training was developed without the rigor of a typical training program that is developed from the training organization, but the engineers needed to quickly gain the skills necessary to be able to design, develop, and deliver the product. So, the management made the decision to have engineering SMEs develop the training program and train the engineers and partners/suppliers. An engineering SME elaborated below:

When we started the [Project X] program, our management brought me in to develop composite training. The manager who was in charge of the [Project X] engineering program called me in and asked me to develop a training program. I set up the meetings where I brought all of the composite folks from the enterprise to [our location], and to talk about their know-how and how they can contribute to our education program. So, all of the [program X] guys went through the [program X] course during the duration of the program, and all of the [program Y] guys went through the [program Y] course. And that included all of [this company's] people who were

> *mostly metal types, and also a lot of our partners. Everybody had to go through the program and it was absolutely critical because there's no way we could have designed and built [the product] - those people in the room couldn't do it, so we needed to train a large group of people. So, we took the best know-how company and shared it with large group of people working on the program, and that increased the capability dramatically. Basically, we shared everything that we knew with everybody working on the program. But in this case, training was critical to the success of the program. Our program wasn't 100 percent successful, but if we didn't have training, [the program] would have been really in trouble. The program could not have happened without the training. This was extreme, I think. We always had training on all of the programs, but it was never as badly needed as it was in this case.*
>
> *-[I9, 8:1-20]*
>
> Hence, in this extreme case, where training was needed badly to the point where the management believed that the time should not be wasted by going to the training organization, the engineering organization developed the training internally without the help of the training organization. As pointed out by the engineering SME, the program was not 100% successful, but without it, the program would have failed. Moreover, in this case, although training did help the program, it may have been developed more efficiently and effectively if there was more diligent planning ahead of time by the business leaders, especially regarding the lack of communication with the training organization.

The variable 'Market Need' in terms of TI-TR refers to engineering skill set that is needed within the company. This includes new employees, knowledge transfer from expert to novice engineers, and current engineers learning a new skill set. Market need is determined by performing a training needs analysis to help identify any gaps in skills within the workforce. Furthermore, to identify the skill gaps, there is also a technology assessment that is performed to better understand what technologies the company is planning on investing in. A senior manager explains, *"I think innovations and technologies that we invest in come out from the need and what we see outside of the company. What are the technology trends that are driving today's world and could drive the future, as well as ideas that, at the moment, we don't know how they will be integrated into products and services, like nanotechnology research we're doing. So, exploring science in general, as well as creating new products and services with existing technologies and things that we're developing in [company] Labs. And then integrating new technologies into new products [I4, 4:28]."*

The variable 'Management' in terms of TI-TR refers to management or leadership support within the organizations. It is the high level OE that provides the funding or overhead dollars to the engineering organization, which in turn provides funding to the training organization to develop the needed training for the engineering workforce. The high-level management also gives direction to the managers in which they manage. An engineering SME elaborates, *"There were managers pushing it [the project] because that's really the direction given by their management [I8, 13:88]."* The variable 'Guideline' in terms of TI-TR refers to processes that an organization follows in order to provide training for their workforce. Whether training comes from an enterprise training organization, localized training group, or training centers, they all follow a common general guideline loosely based off of the ADDIE model. An engineering SME remarks about aligning closely to OE goals, *"I think the part about 'does it closely aligned to organizational goals,' I think one of them was* **learn how to use composite,** *the other was* **robust, safer, lighter, less expensive***, it was clearly more robust from a damage standpoint is definitely lighter; less expensive, probably not [I6, 5:32]."* This leads to the next relationship between construct TI and OE.

The most important variables for both TI and OE are Training, Indicator, Schedule, and Guideline. Since the interview questions were in context of the three constructs, it is expected that TR is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Schedule' and 'Guideline' were the most significant variables relating to TI and OE. The variable 'Indicator' was simply used as an indicator for the researcher that the interviewees was giving an example of an indicator of decision making within the company.

The variable 'Schedule' in terms of TI-OE refers to the time it takes for a technology innovation to mature and become application ready. It is when the technology innovation is in production when it effects the business or OE. For the business, TI can affect the OE by having the product ready for the market and ready to be sold to the customers. On time delivery translates to cost and profit for the company. An engineering SME comments regarding the decisions made from management, *"In terms of innovation, regarding whether it was a good time to use composites or when to use composites or not, from what I remember from [Program X], it was really more about that it was decided that we were going to use them. And we're going to find a way no matter what. So in some respects there are probably areas that we maybe should not have use composites but it was before we were going to learn how to use this new material, it was almost like a management edict or corporate edict - that we were going to try this out and make it work [I6, 5:55]."*

The variable 'Guideline' in terms of TI-OE refers to the processes and guidelines necessary for a technology innovation to be certified for market use. Once the technology is ready for market use, the company can begin making profit, which translates to cost performance. The processes include review boards. An engineering SME, *"The oversight board is called the decision review board, and each one of the managers of a division has that decision review board meeting at least once a year, and they go over the programs they need to get next year or soon to be executed programs [I11, 11:20]."* In addition, the engineering SME added with regards to decisions being made on technology maturity, *"I was just working on what they call the technology maturation plan, which is a description of the new integrated division, and that goes to the decision review board and is distributed to the various vice presidents to get an understanding of what's in the R&D program, how it's valued, where we're going with the deployment schedules and such [I11, 11:22]."* An engineering SME comments regarding requirements, *"For handling some of the existing criteria requirements. You know the criterion requirements for their product does not change. It is just the way you meet them that changes. So this is one the key things [I5, 6:25]."*

Narrative 5. Example regarding high-level management in terms of guideline and TRL

This case highlights how biased and subjective TRL can be in terms of the decision making process of determining the level of maturity in a certain technology within a company. TRL is very dependent on the people who are responsible for the decision making, and these people may be directly involved in supporting the business needs of the company. An engineering SME explains:

It's [TRL] open to a lot of interpretation - no matter how tight they tried to describe the various maturity gates, business needs are very strong, and so what that means is that there is a lot of bias in the outcome of the evaluation for an activity to support business needs. There's also a lot of conservative type of behavior by the people who have to implement it. The closer you get to the person, who has to hand the keys over to the customer, the more conservative they get about implementing a technology. For example, the sales engineer that might be the very first person to go and talk to a customer might say that it's [the product] going to be a self-levitating airplane and [but in reality] it's [the product] barely production ready. And the technology development, who might be an expert at superconductive magnets or something, might say 'yes, I think that will work.' By the time you get to the certification engineer, they are thinking, 'what were you guys thinking?' TRL is very biased and subjective depending on whom you talk to. No matter how objective they tried to make the criteria, it [TRL] is still very subjective. - [I5, 6:44]

The most important variables for both TR and OE are Market Need, Decision Making, Technology, Challenge, and Schedule. Since the interview questions were in context of the three constructs, it is expected that TI is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Market Need,' 'Decision Making,' and 'Schedule' were the most significant variables relating to TR and OE. The variable 'Challenge' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a challenge in the context of the construct being discussed.

The variable 'Market Need' in terms of TR-OE refers to the need to fill the skill gaps within the workforce. The business side of the company, OE, needs the workforce to be skilled and updated on the latest technology innovation in order for the organization to be effective. Without a skilled workforce, the efficiency and accuracy of the work needing to be completed would be stalled.

The variable 'Decision Making' in terms of TR-OE refers to the steps taken to decide on whether training is necessary or not for the workforce or engineering community. The decisions may be made with a review board as a senior manager pointed out, *"Well, the board is telling for instance, that we should train 205,000 people on a given technology. That's the decision of the board. It's a [business] decision. How exactly it will happen? It will be planned by the training department. They will plan classes, they will recruit trainers, and they will organize the whole process in detail. So, for instance, the board would decide to train a certain amount of people within six months. And how that will happen in detail will be decided the HR department…because that's where the training department is. And with the individual managers of the involved people, the trainees, because we have to make sure that the training is not disruptive of production activities. But there is something you should be aware of, that it is mandatory in European companies to provide proof of our corporation to spend a certain percentage of production time being education - in training. It is mandatory to maintain a volume of these during the year, that is for training [I2, 5:79-80]."* In addition, a training SME explains the training decisions that are made based on alignment to the business, *"So just recently I built a strategic alignment chart that is for my customer base and that has become a template for the other strategic business partners in my particular work group. It is something that we just don't naturally think about, but as I have found from working with my customer base, they are very appreciative because in their minds they can start thinking about how a trainee does align to the business and how it does make it different [I7, 12:2-3]."* Moreover, this training SME states, *"So one of the things that I have done as a strategic business partner and when I come into an organization, any organization that I support, the first thing that I take a look at is what are their business goals and objectives. Because I really want to understand - the training projects that we are working on, where do they align in the business and where are we moving the needle on the business goals and objectives.* ***We have the business discussion and then we have the training discussion. Because I think that you are really missing with both if you just talk about training and you don't talk about the business*** *[I7, 12:29-30, 59]."*

Narrative 6. Decision making within a company regarding training ultimately leads to failure

There are times when companies make bad cost-related decisions. An example is when the existing workforce is too expensive. The executives who have the power to make the business decisions will try to find a way to reduce the workforce to help reduce the overhead costs. The following story from an engineering SME will explain how reducing the workforce with the existing workforce may lead to failure.

What happened was there's a tremendous need for analysis people at this company. Basically, they're the people that can do finite element modeling (FEM), who can understand the problem, formulate it, use FEM, solve it and form appropriate conclusions, define design direction. What they found was it's not easy to find people who have those skills. Those people, obviously, they're in high demand. The attrition rate was also high. So one option would have been, "Hey, just pay these guys better," and give them incentives to stay. So they decided to go down another route, and at the executive level - and this is primarily driven by the lack of knowledge on what it takes to be able to do complex analyses. Somehow or other, an executive was convinced that, with the appropriate training, ***<u>any</u>*** *designer will be able to do FEM.*

There are a lot more designers than there are FEA people because the skill set required for being a designer in the auto industry is - it's not as involved as the in-depth FEA skills, where typically you need a Master's or PhD. Most of the designers, they have four-year degrees, some were even two-year technical degrees. The goal was to make sure that every designer can also do FEM. So, despite the objections of the analysis community, the FEM community, they decided to go ahead, and it's interesting to see how the objections were overruled. So the objections were basically that designers cannot do FEM. However, the management viewed it as, "Oh, these FEM guys want job security, so they don't want anybody else doing that job." So the FEM committee backed off, and they started this process. There was a massive rollout. They picked on a vendor, and these vendors actually have a finite element analysis (FEA) product, but what they're trying to do is they're always trying to maximize revenue. They're trying to find new uses for the product, and there are only so many FEA experts or people trained to do FEA. So they wanted to widen their customer base, and they hit upon this idea, "Hey, here's a company that wants to expand to designers. Let's meet their demand because it's going to result in us expanding our business."

The vendor that is selling them came up with this formal course, and every designer needed to take that course. Once they took that course, they were supposed to start doing their own FEMs themselves, and here is the interesting twist to it. It took a lot of effort because the designers, probably this fact was overlooked, that you need better computers to run analysis software than what the designers typically use. So their computers had to be upgraded. All of the designers. Then the software had to be installed on all their systems. So there was a delay. Finally, they started going about it, and as you can expect, they started running into problems, right from day one. So it's mostly about, "How do I do this? How can I do that?"

Yes, but this is one of the interesting cases where something good came out of some bad decisions. So, all the designers had to go through their training course, and it was a refresher course. It was pretty detailed, and I'm sure they learned a lot of stuff in this course, but the problem is this, it's a "refresher." It does not have the rigor of a university class, where you stay up half the night to do an assignment.

So then, slowly, one by one, the designers completed this class and they were still running into *issues. Nothing has changed. This is where dying a natural death comes into play. The natural death was started when the executive was championing this effort retired. This is how the corporate world works. This, I think, is a very interesting study about how training - what helps and hurts, if it's not guided properly. So the executive retired. All of a sudden, the management chain lost interest, but nobody wants to declare it a failure. That's where the natural death comes in. So, "Hey, Designer, you are having problems? That's okay, let the FEM guy do it."*

-[I8, 13:150-159]

The decision made to have training in this story lead to failure because at the end, training the current workforce directly impacted the business in a negative manner because there was not enough skilled resources to perform the deliverables set forth by the business. Also, the management did not realize that there are certain skills that cannot be trained or transferred, where certain knowledge is learned through college education and not learned overnight. Hence, the moral of the story is to assess the workforce to see what skills are needed and what cannot be replace and gradually improve. In this case, analysts have a complete different skill set than designers, and this kind of skill set cannot be replaced. Hence, when a company does try replacing a skill set that cannot be replaced, the company ends up wasting time and money, and then starting back at square one. This situation happens when business is driven only by cost without regard for following standard guidelines within the company.

Narrative 7. Case highlighting the elements of success for a training program

When developing a training program, management support is key to the success of the training program. The main point is that the direct alignment to the business needs and the training needs is critical to the success of a training program. If the management can support both sides, then the training program can be successful. A training manager highlights the elements of success for a training program:

An unsuccessful one [training program example] would be one that was really done in a vacuum without the input from the business; and not just input on "we want this training course," but input on, "Okay, then you need to supply us with a subject matter expert or two and to work with us through the development of this course to make sure that we're covering the subjects we need to cover, and that it's covered in a way that you feel, and we feel, from a learning and adult learning theory standpoint, is proper, and that you support that on an ongoing basis." "If you don't have that support, up front, you will fail. You won't get the SMEs' time to help you develop the course. You don't get the quality of the course coming out. To me, it's making sure that the course is what the business really wants and that you work with them through every stage of that development process to make it successful.

- [I14, 14:116]

The variable 'Schedule' in terms of TR-OE refers to the time it takes for the workforce or engineers to be skilled enough to efficiently and accurately do their job. It has to be determined what kind of training is most effective and efficient in transferring the knowledge necessary for the workforce. This is in terms of total training hours and the total number of engineers that are trained. A training manager comments, *"Well, I think, for us the main organizational goals are to provide training and development* *that rapidly brings our technical staff up to appropriate competence levels for the work that they're doing and the disciplines that they support [I14, 14:13]."*

Again, statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between the combined constructs of TI-TR, TI-OE, and TR-OE. The relationships are neither weak nor strong. The details of the quantitative analysis performed for the combined constructs can be found in Appendix 4F. Conceptually, the most significant variables for the three constructs of TR, TI, and OE, as well as the combined constructs of TI-TR, TI-OE, and TR-OE is shown in Figure 4-3.

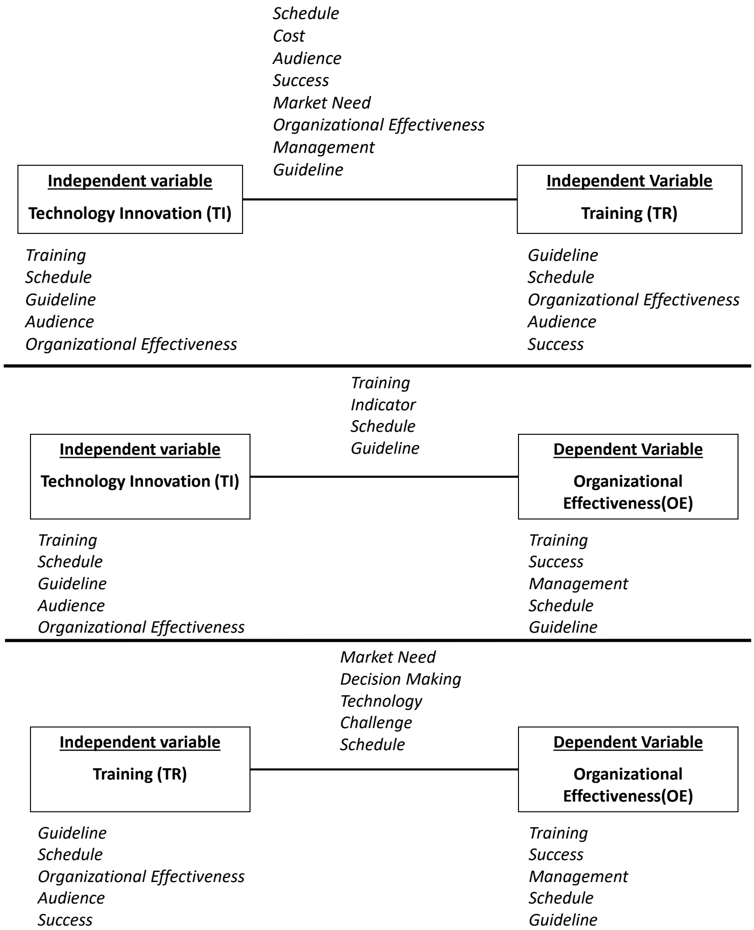


Figure 4-3. The most significant variables for the three constructs of TR, TI, and OE, and the combined constructs of TI-TR, TI-OE, and TR-OE for the set of interest 'All 14 Interviewees'

Several of the variables that are listed for each of the construct TR, OE, and TI as the most important variables are not of direct interest for this research. Specifically, for the construct TR, the variables 'Success' and 'Organizational Effectiveness' will not be considered. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. These success stories will be highlighted throughout Section 4.5.3 to validate a specific observation. The variable 'Organizational Effectiveness' in terms of TR was meant to validate that the relationship between the constructs of OE and TR does exist for this set of interest. For the construct OE, the variables 'Training' and 'Success' will not be considered. The variable 'Training' in terms of OE was meant to validate that the relationship between the constructs of OE and TR does exist for this set of interest. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. For the construct TI, the variables 'Training' and Organizational Effectiveness' will not be considered. Both of these variables in terms of TI were meant to validate that the relationship between the constructs of OE and TI, and TR and TI does exist for this set of interest.

Several of the variables that are listed for each of the combined construct TI-TR, TI-OE, and TR-OE as the most important variables are not of direct interest for this research. Specifically, for the combined construct TI-TR, the variables 'Success' and 'Organizational Effectiveness' will not be considered. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. The variable 'Organizational Effectiveness' in terms of TI-TR was meant to validate that the relationship between all three of the constructs OE, TI, and TR does exist for this set of interest. For the combined construct TI-OE, the variables 'Training' and 'Indicator' will not be considered. The variable 'Training' in terms of TI-OE was meant to validate that the relationship between all three of the constructs OE, TI, and TR does exist for this set of interest. The variable 'Indicator' was used as a key word in the interview to indicate what specific variables were used as indicators during the decision making process or an indication of success or failure. For the combined construct TR-OE, the variables 'Technology' and 'Challenge' will not be considered. The variable 'Technology' in terms of TR-OE was meant to validate that the relationship between all three of the constructs OE, TI, and TR does exist for this set of interest. The variable 'Challenge' was meant to be an indicator for this research that the interviewee had some challenge stories in context to the specific construct or combined construct.

Conceptually, the most significant variables that are *considered* for this research in context of the set of interest "All 14 Interviewees" can be seen in Figure 4-4 as they relate to the three main constructs of this research.

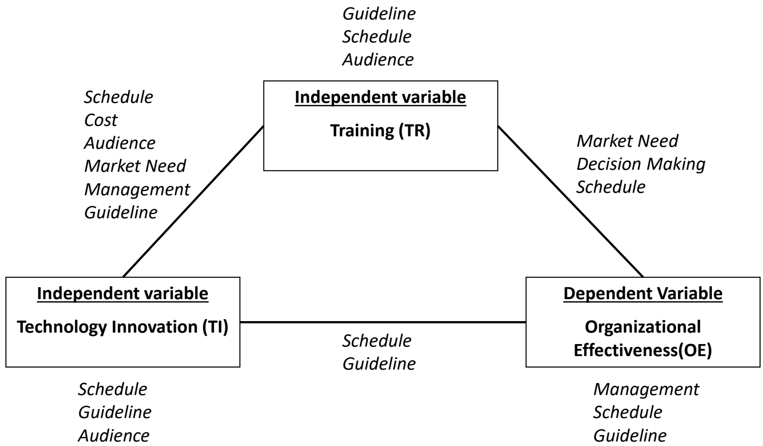


Figure 4-4. The most significant variables that are considered for the three constructs of TR, TI, and OE, and the combined constructs of TI-TR, TI-OE, and TR-OE for set of interest 'All 14 Interviewees'

Boeing and non-Boeing

As shown in Table 4-3 and 4-4, the most significant variables in general for Boeing and non-Boeing are Audience, Management, Schedule, Training, Teaching, Market Need, Customer, Guideline, Organizational Effectiveness, Decision Making, and Technology. It is expected that Training, Organizational Effectiveness, and Technology are found to be among the most significant variables for Boeing and non-Boeing as the interviews were in context of the three constructs of TR, TI, and OE. Hence, the main significant variables to consider from the analysis for Boeing and non-Boeing are ***Audience, Management, Schedule, Teaching, Market Need, Customer, Guideline, and Decision Making***. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Boeing and non-Boeing.

The most significant variables relating to TR for Boeing and non-Boeing are Challenge, Management, Measurement, Audience, and Guideline. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Boeing and non-Boeing with regards to variables relating to TR. It is through the open interview process that the interviewees mentioned the variables 'Management,' 'Measurement,' 'Audience,' and 'Guideline' and these were the most significant variables relating to TR for Boeing and non-Boeing. The variable 'Challenge' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a challenge in the context of the construct being discussed.

The variable 'Management' in terms of TR for Boeing and non-Boeing refers to the management and leadership support needed for TR to be successful. An engineering SME comments, *"Regards to management and TR, "The manager is key to it. In the two examples that I gave you, good management/bad management. I mean, that clearly defined the direction in which things were headed [I8, 13:167]."* In addition, a training manager agrees, *"If you don't have that support, up front, you will fail [I14, 14:11]."* In relation to management and understanding the organization, a training manager elaborates, *"Understanding the organization, taking that piece of it, means you know what the leadership support is, what the managers will support in regards to any learning innovation or solution you might bring in; you know what the makeup of the individuals that* *make up that organization are, the skills that you have in that organization, the level of skill with that organization [I1, 9:20].”*

Narrative 8. Case where management forcing TR to be successful by making it a requirement

There are occasions within a company where training is driven by the business needs. The success of training in these cases is biased as management at all levels is deeply involved in terms of funding and resources. Cases of when training courses are made mandatory for engineers to take are extreme cases, as it is expensive for the business to decide to do this. In reality, most training is not made mandatory within companies, but rather as a personal development, where it is the responsibility of the workforce to find a balance between working and taking the training course. For the organizations to develop training that is not required, obtaining full support in terms of funding and resources from the business becomes more challenging, as the funding is prioritized to other business needs. An engineering SME comments:

The certificate programs are totally voluntary and they're off hours. But, one thing you have to keep in mind is that [Program X] courses were required courses and were on hours, and everybody had to take them. And, when you talk about off hours, management cannot require anybody to take off hours, so it's completely optional.

- [I9, 8:41, 69-70]

Narrative 9. Case highlighting management driving training need and loses interest

There are cases where the high level business drives the training without realizing the amount of due diligence and work involved. Instead of working with the training organization to assess the workforce and develop the training, the business sometimes chooses to rely only on the engineering SMEs to develop the training on top of their normal work statement, with the expectation of getting both major tasks completed efficiently. In some cases, this initiative from the management may be successful if the management was involved and supportive for the entire project. There are cases where initiatives like this are initiated and the management either loses interest mid-way through the project, leave the company, or retires. The challenge then is relying on the next management to support and continue on with the previous initiative. An engineering SME explains a case where the senior manager retires shortly after initiating a training project:

What ended up happening was the management/senior management asked the FEM people to come up with a course [to train the designers the skills of the FEM workforce]. Obviously, the management people know that the FEM people are really tied up. So the involvement of the subject matter experts in FEM was, "Come up with an outline for a course, and we will contract with the university, a nearby university. The natural death [of this training project] was started when the executive who was championing this effort retired. All of a sudden, the management chain lost interest, but nobody wants to declare it a failure. That's where the natural death comes in because instead of continuing the initiative of training all of the designers, the management reverted back to the original FEM SMEs to complete the work.

- [I8, 13:91-94,122,134]

The variable 'Measurement' in terms of TR for Boeing and non-Boeing refers to the evaluation that takes place after the training is complete to measure the effectiveness of training. The variable 'Audience' in terms of TR for Boeing and non-Boeing refers to the workforce, suppliers and engineers being trained. The variable 'Guideline' in terms of TR for Boeing and non-Boeing refers to the training analysis, development, delivery, implementation, and evaluation standard guidelines and processes set forth by the company to optimize the workforce skillset. The workforce skillset are defined at companies as competencies. An engineering SME comments, *"In our competence framework, we have three proficiency levels: awareness, knowledge and skill [I13, 15:35]."* Both 'Audience' and competence are directly related as an engineering SME adds, *"And also the competence. And sometimes, that covers quite a few different job roles; because - we had a situation where we had too many competencies, or it was thought we had too many descriptions. And so they've been rationalized. But now some of them are quite heavy and actually cover different roles. So, you have to be clear on your audience, but also clear on the outcomes - which areas of the competence definition are you addressing [I13, 15:33]?"* Hence, if the competency framework is considered a 'Guideline' to define the workforce skillset, and 'Audience' refers to the workforce, then 'Guideline' and 'Audience' are influenced by each other. The engineering SME further comments regarding training, *"I still think the success criteria are to really understand the audience, to understand the competence or the sub-area of competence that you're addressing, and then to think about the delivery - how are you going to deliver the course [I13, 15:8]."* Furthermore, a training SME explains, *"Who is the audience that really needs to understand and learn this knowledge? It is really about trying to understand what is the desired performance outcome, who is the audience that needs to know it and what is the content [I7, 12:8-9]."*

The most significant variables relating to TI for Boeing and non-Boeing are Schedule, Guideline, Training, and Audience. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Boeing and non-Boeing with regards to variables relating to TI. Since the interview questions were in context of the three constructs, it is expected that TR is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Schedule,' 'Guideline,' and 'Audience' were the most significant variables relating to TI for Boeing and non-Boeing.

The variable 'Schedule' in terms of TI for Boeing and non-Boeing refers to the time it takes for a technology innovation to mature and be application ready and market ready for the customers. The variable 'Guideline' in terms of TI for Boeing and non-Boeing refers to standard processes that a company follows to determine the maturity of a technology innovation. An engineering SME comments, *"if you have a process that allows the real issues to come out and you have the resources, the leadership, the business systems in place to work the issues, then it is amazing how much you can get done in a very quick amount of time [I5, 6:11]."*

The variable 'Audience' in terms of TI for Boeing and non-Boeing refers to the engineering workforce, as well as the suppliers working alongside the engineers.

Narrative 10. Case of audience for TI and using engineering SMEs to develop and teach the training course

In most cases at companies, engineering SMEs are encouraged to develop the training and teach the training courses to ensure that consistent knowledge is transferred between the skilled and novice workforce. The engineering SMEs can more accurately convey the engineering concepts to their fellow engineers, as compared to a non-engineering lecturer or an outsourced lecturer. The engineering SMEs can provide practical examples to convey certain engineering principles to the workforce. An engineering SME comments:

In fact, that's how I started teaching, because I wanted to learn this stuff better. And, one thing that might be interesting is that I taught the entire course myself for many years. So, I brought around 40 instructors to teach the same course. Because, not only people taking the course were learning, but the teachers were learning, so we're all learning together. So, we pulled all of the capabilities of the company and, in terms of organizational effectiveness, we had a large number of folks to train. And that included all of the [this company's] people that were mostly metal types, and also a lot of our partners. So, those courses were offered in Japan. We did them in Japan, we did them in Italy, and we did them in Texas.

- [I9, 8:95-102,144]

The most significant variables relating to OE for Boeing and non-Boeing are Training, Success, and Management. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Boeing and non-Boeing with regards to variables relating to OE. Conceptually, the most significant variables for the three constructs of TR, TI, and OE are shown in Figure 4-5. Since the interview questions were in context of the three constructs, it is expected that TR is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Management' was the most significant variables relating to OE for Boeing and non-Boeing. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a success in the context of the construct being discussed.

The variable 'Management' in terms of OE for Boeing and non-Boeing refers to the leadership making the business decisions within the company. A training manager comments, *"But at the director level, and the director says, "I'm going to identify these courses, based on business needs, based on issues that I see in my business, and I'm going to say that I'm going to target that this much of that content is delivered to this many people, and these are the type of people that need each of these courses [I1, 9:19]."*

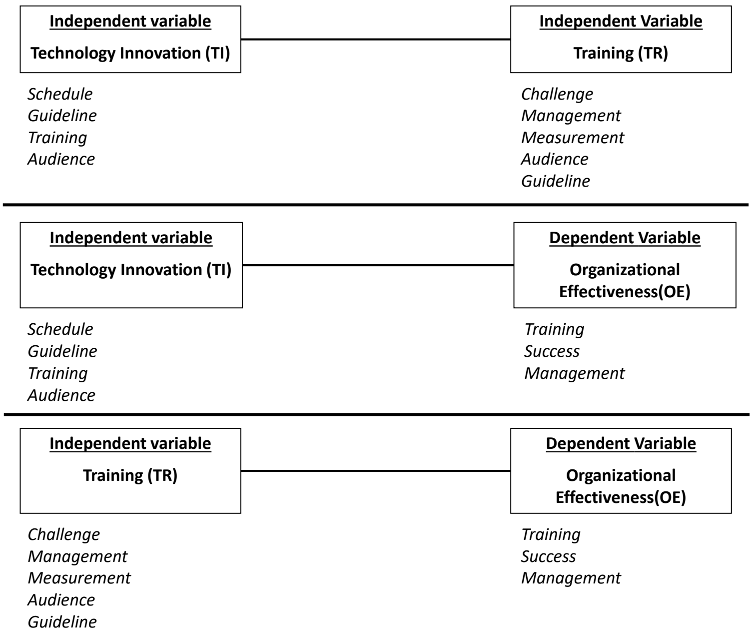


Figure 4-5. The most significant variables for the three constructs of TR, TI, and OE for the set of interest 'Boeing and non-Boeing'

Several of the variables that are listed for each of the construct TR, OE, and TI as the most important variables are not of direct interest for this research. Specifically, for the construct TR, the variable 'Challenge' will not be considered. The variable 'Challenge' was meant to be an indicator for this research that the interviewee had some challenge stories in context to the specific construct or combined construct. For the construct OE, the variables 'Training' and 'Success' will not be considered. The variable 'Training' in terms of OE was meant to validate that the relationship between the constructs of OE and TR does exist for this set of interest. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. For the construct TI, the variable 'Training' will not be considered. The variable 'Training' in terms of TI was meant to validate that the relationship between the constructs of TI and TR does exist for this set of interest.

Conceptually, the most significant variables that are *considered* for this research in context of the set of interest "Boeing and non-Boeing" can be seen in Figure 4-6 as they relate to the three main constructs of this research.

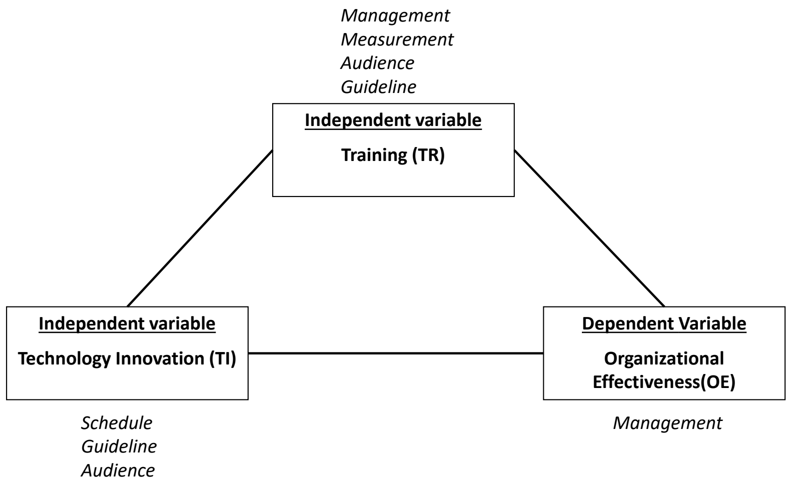


Figure 4-6. The most significant variables considered for the three constructs of TR, TI, and OE for the set of interest 'Boeing and non-Boeing'

The most significant variables for Boeing are similar to non-Boeing in general and across all three constructs. Since the obtained values for Spearman's correlation of 0.864 (in general), 0.748 (in relation to OE), 0.840 (in relation to TI), and 0.924 (in relation to TR) is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Boeing and Non-boeing interviewees. Because there is a rank order relationship between the variables in the population represented by Boeing and Non-boeing interviewees, the most significant variables mentioned by the Boeing and Non-boeing interviewees are similar. This result confirms that the conceptual model to be developed can be used by organizations both internal and external to Boeing.

Manager and non-Manager

As shown in Table 4-3 and 4-4, the most significant variables in general for Managers and non-Managers are Decision Making, Schedule, Training, Market Need, Measurement, Success, Performance, Technology, Guideline, and Audience. It is expected that Training and Technology are found to be among the most significant variables for Managers and non-Managers as the interviews were in context of the three constructs of TR and TI. Hence, the main significant variables to consider from the analysis for Managers and non-Managers are ***Decision Making, Schedule, Market Need, Measurement, Success, Performance, Guideline, and Audience***. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Managers and non-Managers.

The most significant variables relating to TR for Managers and non-Managers are Market Need, Schedule, Success, Cost, Technology, and Guideline. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Managers and non-Managers with regards to variables relating to TR. Since the interview questions were in context of the three constructs, it is expected that TI is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Market Need,' 'Schedule,' 'Cost,' and 'Guideline' were the most significant variables relating to TR for Managers and non-Managers. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a success in the context of the construct being discussed.

The variable 'Market Need' in terms of TR for Managers and non-Managers refers to filling in the skills gap within the workforce. The variable 'Schedule' in terms of TR for Managers and non-Managers refers to the time it takes for an engineer to become autonomous in their job. The training involved is in terms of the time for assessment, development, delivery, implementation, and evaluation.

The variable 'Cost' in terms of TR for Managers and non-Managers refers to the overhead costs and resources that are needed to assess, develop, deliver, implement, and evaluate training. A training SME explains, *"We do try to stay away from that [formal training] because that is very expensive and so we've really gone more towards developing virtual classroom models that can be deployed throughout the world. So in my mind, that is what I constantly hear from my customer base, is that all of those things can contribute to an increase in quality, reduction in cost, and greater productivity for the company [I7, 12:18-19]."*

The variable 'Guideline' in terms of TR for Managers and non-Managers refers to the standard process for accessing, development, delivery, implementation, and evaluation of training. An example that a training SME explained regarding accessing if training is needed was, *"Sometimes when customers are describing 'I need a training course,' they'll say, "I need a training course." Sometimes we realize that it is really not training. It is just information that they would like to distribute to their employees. So people get confused between what is training and what is communication [I7, 12:100]."* In terms of following guidelines, or streamlining processes, and helping reduce 'Cost,' a training SME comments, *"For the particular organization that I support, my attention to evaluation, a lot of the organizational goals right now for training is around common processes and tools. [Organization] is a new organization that was formed five years ago. It is all about streamlining and creating efficiency. A lot of the training that I am helping to develop right now is around getting to common. What I hear from the leaders in [organization] is that it is about reducing safety - reducing safety risks and/or hazards, reducing redundancies, reducing re-work. All of those things contribute to greater quality and reduced cost; greater productivity. In my mind, that is what I constantly hear from my customer base, that all of those things can contribute to an increase in quality, reduction in cost, and greater productivity for the company [I7, 12:91, 93]."*

The most significant variables relating to TI for Managers and non-Managers are Audience, Organizational Effectiveness, Schedule, and Training. Statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between Managers and non-Managers with regards to variables relating to TI. Since the interview questions were in context of the three constructs, it is expected that OE and TR are among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Audience' and 'Schedule' were the most significant variables relating to TI for Managers and non-Managers.

The variable 'Audience' in terms of TI for Managers and non-Managers refers to engineering workforce and suppliers needing training. According an engineering SME, *"Everybody who joins the company gets a contract with his supervisor, and there the learner objectives for the first three and then for another three years are clearly defined [I10, 13:67]."* The variable 'Schedule' in terms of TI for Managers and non-

Managers refers to the time it take for a technology innovation to mature and become application ready and ready for market.

The most significant variables relating to OE for Managers and non-Managers are Success, Training, and Management. Statistically, the Spearman's rank-order correlation value indicates a strong (+/-0.70) positive relationship between Managers and non-Managers with regards to variables relating to OE. Conceptually, the most significant variables for the three constructs of TR, TI, and OE are shown in Figure 4-7. Since the interview questions were in context of the three constructs, it is expected that TR is among the most significant variables. It is through the open interview process that the interviewees mentioned other variables, where 'Management' was the most significant variables relating to OE for Managers and non-Managers. The variable 'Management' in terms of OE for Managers and non-Managers refers to the leadership making the business decisions within the company. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a success in the context of the construct being discussed.

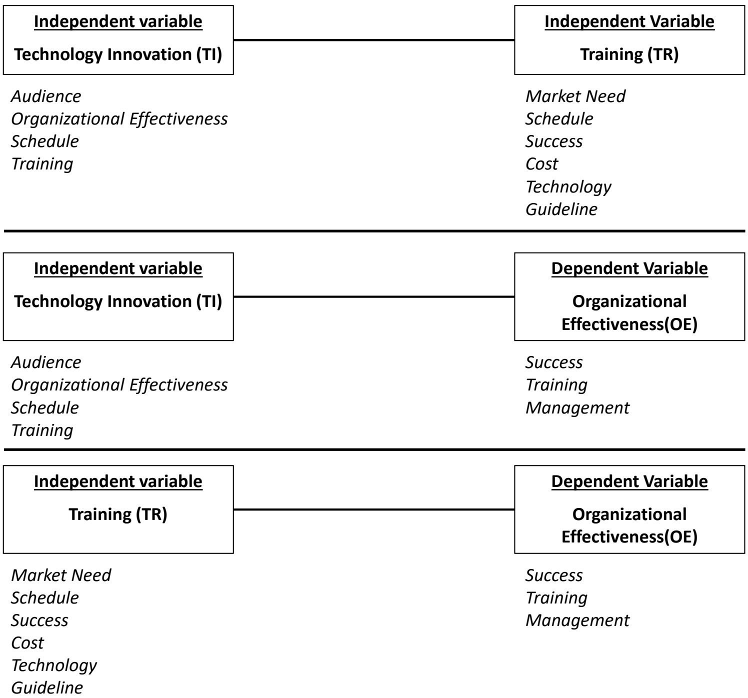


Figure 4-7. The most significant variables for the three constructs of TR, TI, and OE for the set of interest 'Manager and non-Manager'

Several of the variables that are listed for each of the construct TR, OE, and TI as the most important variables are not of direct interest for this research. Specifically, for the construct TR, the variables 'Success' and 'Technology' will not be considered. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. The variable 'Technology' in terms of TR was meant to validate that the relationship between the constructs of TI and TR does exist for this set of interest. For the construct OE, the variables 'Training' and 'Success' will not be considered. The variable 'Training' in terms of OE was meant to validate that the relationship between the constructs of OE and TR does exist for this set of interest. The variable 'Success' was meant to be an indicator for this research that the interviewee had some success stories in context to the specific construct or combined construct. For the construct TI, the variables 'Organizational Effectiveness' and 'Training' will not be considered. Both of these variables in terms of TI were meant to validate that the relationship between the constructs of OE and TI, and TR and TI does exist for this set of interest.

Conceptually, the most significant variables that are *considered* for this research in context of the set of interest "Manager and non-Manager" can be seen in Figure 4-8 as they relate to the three main constructs of this research.

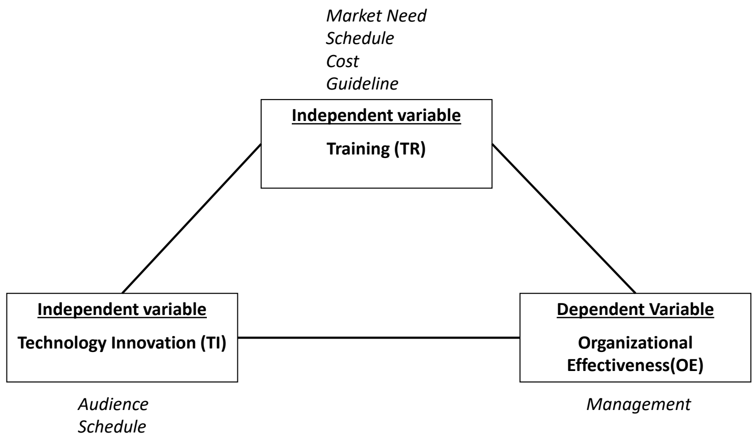


Figure 4-8. The most significant variables considered for the three constructs of TR, TI, and OE for the set of interest 'Manager and non-Manager'

The most significant variables for Managers are similar to non-Managers in general and across all three constructs. Since the obtained values for Spearman's correlation of 0.845 (in general), 0.902 (in relation to OE), 0.615 (in relation to TI), and 0.861 (in relation to TR) is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship in the population represented by Managers and non-managers. Because there is a rank order relationship in the population represented by Managers and non-managers, the most important variables mentioned by the Managers and non-managers are similar. This result confirms that the conceptual model to be developed can be used by both Managers and non-managers.

Training SME and Engineering SME

As shown in Table 4-3 and 4-4, the most significant variables in general for Training SMEs and Engineering SMEs are Teaching, Guideline, Training, Management, Performance, Audience, SME, and Schedule. It is expected that Training and Technology are found to be among the most significant variables for Training SMEs and Engineering SMEs as the interviews were in context of the three constructs of TR and TI. Hence, the main significant variables to consider from the analysis for Training SMEs and Engineering SMEs are ***Teaching, Guideline, Management, Performance, Audience, SME, and Schedule***. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Training SMEs and Engineering SMEs.

The most significant variables relating to TR for Training SMEs and Engineering SMEs are Schedule, Success, Decision Making, Guideline, and Cost. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Training SMEs and Engineering SMEs with regards to variables relating to TR. It is through the open interview process that the interviewees mentioned the variables 'Schedule,' 'Decision Making,' 'Guideline,' and 'Cost' were the most significant variables relating to TR for Training SMEs and Engineering SMEs. The variable 'Success' was simply used as an indicator for the researcher that the interviewees was giving an example within the company that was a success in the context of the construct being discussed.

The variable 'Schedule' in terms of TR for Training SMEs and Engineering SMEs refers to the time it takes for assessing, development, delivery, implementation, and evaluation of training. Schedule also refers to the time it takes to prepare and teach a training course, which falls under delivery of training. An engineering SME states, *"So, the challenge is, you want the training ready for when the product gets rolled out [I13, 15:11]."* Another engineering SME states, ***"The other thing with training that's really critical, that's very well known, is that it has to be the right content at the right time [I9, 8:68]."*** Additionally, 'Schedule' refers to the time it takes for the workforce to become skilled. An engineering SME remarks, *"The measure of effectiveness is how quickly from coming into your role do you achieve autonomy - for a graduate, for example. For somebody fresh from university who's full of knowledge, full of theory, now they have to put that theory into practice [I13, 15:90]."*

The variable 'Decision Making' in terms of TR for Training SMEs and Engineering SMEs refers to the decisions to develop training. This is done through assessment to determine whether training is the right solution, as well as what kind of training is appropriate for the transfer of knowledge. The variable 'Guideline' in terms of TR for Training SMEs and Engineering SMEs refers to the standard processes in assessing, developing, delivery, implementing, and evaluating training. The variable 'Cost' in terms of TR for Training SMEs and Engineering SMEs refers to the cost and resources needed to assess, develop, deliver, implement, and evaluate training.

The most significant variables relating to TI for Training SMEs and Engineering SMEs cannot be determined due to the number of interviewees being too small. Statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between Training SMEs and Engineering SMEs with regards to variables relating to TI.

The most significant variables relating to OE for Training SMEs and Engineering SMEs are irrelevant to this set of interest as none of the interview questions were in the context of OE. Conceptually, the most significant variables for the three constructs of TR and TI are shown in Figure 4-9.

Figure 4-9. The most significant variables for the two constructs of TR and TI for the set of interest 'Training SME and Engineering SME'

Engineering SME involved in TR and Engineering SME not involved in TR

As shown in Table 4-3 and 4-4, the most significant variables in general for Engineering SMEs involved in TR and Engineering SMEs not involved in TR are Schedule, Training, Cost, Success, Guideline, Performance, Challenge, and Technology. It is expected that Training and Technology are found to be among the most significant variables for Engineering SMEs involved in TR and Engineering SMEs not involved in TR as the interviews were in context of the constructs of TR and TI. Hence, the main significant variables to consider from the analysis for Engineering SMEs involved in TR and Engineering SMEs not involved in TR are ***Schedule, Cost, Success, Guideline, Performance, and Challenge***. Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Engineering SMEs involved in TR and Engineering SMEs not involved in TR.

Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Engineering SMEs involved in TR and Engineering SMEs not involved in TR with regards to variables relating to TR. However, the most significant variables relating to TR for Engineering SMEs involved in TR and Engineering SMEs not involved in TR cannot be determined due to the number of interviewees being too small. In this case there were a total of seven interviewees out of 14 interviewees.

Statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between Engineering SMEs involved in TR and Engineering SMEs not involved in TR with regards to variables relating to TI. However, the most significant variables relating to TI for Engineering SMEs involved in TR and Engineering SMEs not involved in TR cannot be determined due to the number of interviewees being too small. In this case there were a total of seven interviewees out of 14 interviewees.

The most significant variables relating to OE for Engineering SMEs involved in TR and Engineering SMEs not involved in TR are irrelevant to this set of interest as none of the interview questions were in the context of OE. Conceptually, the most significant variables for the three constructs of TR and TI are shown in Figure 4-10.

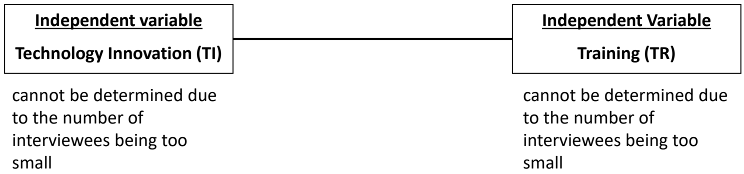


Figure 4-10. The most significant variables for the two constructs of TR and TI for the set of interest 'Engineering SME involved in TR and Engineering SME not involved in TR'

Training Manager and Engineering Manager

As shown in Table 4-3 and 4-4, the most significant variables in general for Training Managers and Engineering Managers are Measurement, Training, and Indicator. It is expected that Training, Organizational Effectiveness, and Technology are found to be among the most significant variables for Training Managers and Engineering Managers as the interviews were in context of the three constructs of TR, TI, and OE. Hence, the main significant variables to consider from the analysis for all five manager interviewees are ***Measurement and Indicator***. Statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between Training Managers and Engineering Managers.

The most significant variables relating to TR for Training Managers and Engineering Managers is Schedule. Statistically, the Spearman's rank-order correlation value indicates a moderate (+/- 0.50) positive relationship between Training Managers and Engineering Managers with regards to variables relating to TR. In this case there were a total of five interviewees out of 14 interviewees.

The variable 'Schedule' in terms of TR for Training Managers and Engineering Managers refers to the time it takes to train the workforce, as well as the time it takes to transfer the necessary knowledge from SMEs to novice engineers. As the workforce environment is constantly changing due to new hires, people retiring, new suppliers, and engineers transferring from one department to another, workforce assessment is a key driver for training. As a training manager comments, *"…you have the learning drivers, and by the way are never ending, learning drivers will never end because it's new tools, new technologies, new processes, staffing changes, demographics of your population (like our demographics were 40-50% of all workforce could retire in five years)…[I1, 9:3]."*

Statistically, the Spearman's rank-order correlation value indicates a strong (+/- 0.70) positive relationship between Training Managers and Engineering Managers with regards to variables relating to TI. However, the most significant variables relating to TI for Training Managers and Engineering Managers cannot be determined due to the number of interviewees being too small. In this case there were a total of five interviewees out of 14 interviewees.

Statistically, the Spearman's rank-order correlation value indicates a weak (+/- 0.30) positive relationship between Training Managers and Engineering Managers with regards to variables relating to OE. Moreover, the most significant variables relating to OE for Training Managers and Engineering Managers cannot be determined due to the number of interviewees being too small. In this case there were a total of five interviewees out of 14 interviewees. Conceptually, the most significant variables for the three constructs of TR, TI, and OE are shown in Figure 11.

Figure 4-11. The most significant variables for the two constructs of TR and TI for the set of interest 'Training Manager and Engineering Manager'

4.6 Addressing General Observations and Exploratory Questions

Based on the detailed analysis of the interviews, this section will describe how the information analyzed from the interview data addressed the general observations (GO TR-OE, GO TI-OE, and GO TI-TR-OE) through the EQs that were listed earlier in this chapter. Conclusions will be listed and described after each general observation.

Training and Organizational Effectiveness (GO TR-OE)

EQ1. For what aspects of organizational effectiveness does training play a role?

Training relates to organizational effectiveness in terms of Market Need, Decision Making, and Schedule. The variable 'Market Need' in terms of TR-OE refers to the need to fill the skill gaps within the workforce. The business side of the company, OE, needs the workforce to be skilled and updated on the latest technology innovation in order for the organization to be effective. Without a skilled workforce, the efficiency and accuracy of the work needing to be completed would be stalled. The variable 'Decision Making' in terms of TR-OE refers to the process and guidelines taken to decide on whether training is necessary or not for the workforce or engineering community. The variable 'Decision Making' and 'Guideline' are related to each other. The variable 'Schedule' in terms of TR-OE refers to the time it takes for the workforce or engineers to be skilled enough to efficiently and accurately do their job. It has to be determined what kind of training is most effective and efficient in transferring the knowledge necessary for the workforce. This is in terms of total training hours and the total number of engineers that are trained.

EQ2. How do you align training to organizational goals?

According to I14 from Narrative 7, training alignment to organizational goals involve direct involvement with the management. Management support is a driver for the success of training. Management support means gaining the funding and resources necessary to assess, develop, deliver, implement, and evaluate training. As I14 commented before, *"Without management support, you will fail."* Moreover, management support is only a driver for the success of training if it is full management support at all levels. All levels mean that management support comes from the localized level through the top high-level business. This requires that the management at the various levels communicate the training and business needs to each other and ensure that the two needs align. Business needs is often in terms of schedule, cost, and performance; while the training needs are often in terms of the funding and resources necessary to assess, develop, deliver, implement, and evaluate training. In addition, for the business needs and training needs to align, often times compromises need to be made and agreed upon prior to initiating a training program. For example, in cases where the business needs a skilled workforce, the business may need to adjust the schedule of delivering the product to the market and allow the workforce some time to take the training necessary to improve their skill set. Finding the right balance between the business and the various organizations is the key to success.

EQ3. How does the training leadership team participate in the strategic planning process for the enterprise?

The training leadership team at the local level meets with the engineering leadership team at the local level to align to the engineering needs to fill gaps in skill set. The leadership teams at the local levels then meet with the higher level management, who has control of the business aspect of the company. Because of this relationship, it is necessary to explicitly illustrate the local training organizational effectiveness separately from the overall business aspect of the company known as OE in the descriptive conceptual model.

Narrative 11. Case on TR and OE relationship

Another key factor for training to be successful is the direct involvement and support of the management at all levels – localized and business-level. It is crucial to the success of a training program for the localized leadership and the business leadership to align with regards to the business needs and training needs. This alignment can further be ensured by aligning the business goals and objectives directly within the performance measures, where the workforce is measured on annually. A training manager further elaborates:

And some of those things that make it very effective, as opposed to some external large organization managing all the training, is, one of the key principles of organizational effectiveness, in the relationship of training to organizational effectiveness, is that you understand both the organization very well and you need to understand the learning drivers that are impacting that organization. One of the key principles of this model is that this localized learning, one of the really effective principles of it is that the leadership is as much tied into the success of the university construct, as the university members themselves. And the reason it's tied in, is because they put it on their business goals and objectives as performance measures, and that rolls right on down onto mine, and the people on my team, and even to the instructors and developers.

- [I1, 9:74,84]

Technology Innovation and Organizational Effectiveness (GO TI-OE)

EQ4. For what aspects of organizational effectiveness does technology innovation play a role in?

Technology innovation relates to organizational effectiveness in terms of Schedule and Guideline. The variable 'Schedule' in terms of TI-OE refers to the time it takes for a technology innovation to mature and become application ready. It is when the technology innovation is in production when it affects the business or OE. For the business, TI can affect the OE by having the product ready for the market and ready to be sold to the customers. On time delivery translates to cost and profit for the company. The variable 'Guideline' in terms of TI-OE refers to the processes and guidelines necessary for a technology innovation to be certified for market use. Once the technology is ready for market use, the company can begin making profit, which translates to cost performance.

EQ5. How do you align technology innovation to organizational goals?

Aligning technology innovation to organizational goals means having managements support. With management support, organizational goals of meeting schedule and cost needs become apparent. Having management support can yield success when there is a balance between business needs and engineering needs. When the business provides a realistic timeframe for the engineers to design, develop, test, and deliver a product, the engineers can help with finding the right balance between cost and performance.

EQ6. How does the technology function leadership team participate in the strategic planning process for the enterprise?

The engineering leadership team at the local level meets with the training leadership team at the local level to discuss the engineering needs to fill gaps in skill set. The leadership teams at the local levels then meet with the higher level management, who has control of the business aspect of the company, which translates to control over funding and resources. An example of this was described in Narrative 11 from I1, where alignment between the business level managers and localized level managers is crucial to the success of any organization.

Training, Technology Innovation, and Organizational Effectiveness (GO TI-TR-OE)

EQ7. For what aspects of technology innovation planning process does training play a role in?

Training plays a role in the technology planning process in terms of Schedule, Cost, Audience, Market Need, Management, and Guideline. The variable 'Schedule' in terms of TI-TR refers to the development time, delivery time, the implementation time, and the recurring time it takes to keep the training material up-to-date. Moreover, as technology innovation continues to evolve constantly, it is necessary that the timing of the training for the engineers is aligned. In terms of keeping the material up-to-date, an engineering SME comments, *"…the third methodology on keeping this material up-to-date is that we use lots of subject matter experts for teaching itself [I10, 13:59]."* The variable 'Cost' in terms of TI-TR refers to the funding needed for training. Funding is in terms of resources needed for the development, delivery, implementation, and evaluation of training. The variable 'Audience' in terms of TI-TR refers to the engineering workforce and suppliers. The variable 'Market Need' in terms of TI-TR refers to engineering skill set that is needed within the company. This includes new employees, knowledge transfer from expert to novice engineers, and current engineers learning a new skill set. Market need is determined by performing a training needs analysis to help identify any gaps in skills within the workforce. The variable 'Management' in terms of TI-TR refers to management or leadership support within the engineering organization, training organization, and overall business OE. It is the overall high level business organization that provides the funding for overhead dollars to the engineering organization, which then provides funding to the training organization to develop the needed training for the engineering workforce. The variable 'Guideline' in terms of TI-TR refers to processes that an organization follows in order to provide training for their workforce. Whether training comes from an enterprise training organization, localized training group, or training centers, they all follow a common general guideline loosely based off of the ADDIE model.

EQ8. For what aspects of training planning process does technology innovation play a role in?

As the common variables for TI and TR are Schedule, Cost, Audience, Market Need, Management, and Guideline, which were described earlier, technology innovation plays a role in the training planning process by driving the schedule need, cost need, audience need, and market need. Technology innovation also plays a role in the training process by having the engineering managers communicate their needs to the training organization. The standard training guidelines allow for a needs analysis to be performed by the training organization to determine whether training is needed for the technology innovation.

EQ9. How does the relationship between TI and TR affect organizational effectiveness?

How the relationship between TI and TR affects the overall business OE is dependent on management support at the localized organization level. The managers at the localized organization level report to the higher level managers who have control of the business aspect of the company. It is the business aspect of the company which represents the Organizational Effectiveness (OE) construct within this research. *Hence, the relationship between TI and TR affects the overall OE through the localized organization level OE.* According to I10, the global training managers meet with global technology chiefs to ensure that their goals align with regards to a skilled workforce. Having a skilled workforce positively affects the overall OE.

CHAPTER 5
MODEL DEVELOPMENT:
DESCRIPTIVE CONCEPTUAL MODELS

This chapter is represented as Phase III, shown in Figure 5, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. The aim of this chapter is to find appropriate solutions for the challenges that are conceptualized and specified during Phase II. The goal of this chapter is to operationalize the variables for the three constructs of TI, TR, and OE. This characterization will then be represented in a revised descriptive general conceptual model and an operationalized conceptual model. A general conceptual model was developed from the findings in Chapter 4, confronted with the findings from literature. The general conceptual model highlighted the most significant variables for each of the three constructs and the relationships between the constructs. After studying and interpreting the interactions between training and technology innovation, training and organizational effectiveness, and technology innovation and organizational effectiveness, the operationalized conceptual model was developed. This transition sets the foundation in Chapter 6 to link practice with theory. Hence, the operationalized conceptual model will be further explored and implemented in Phase IV of the mixed methods research design through detailed case studies.

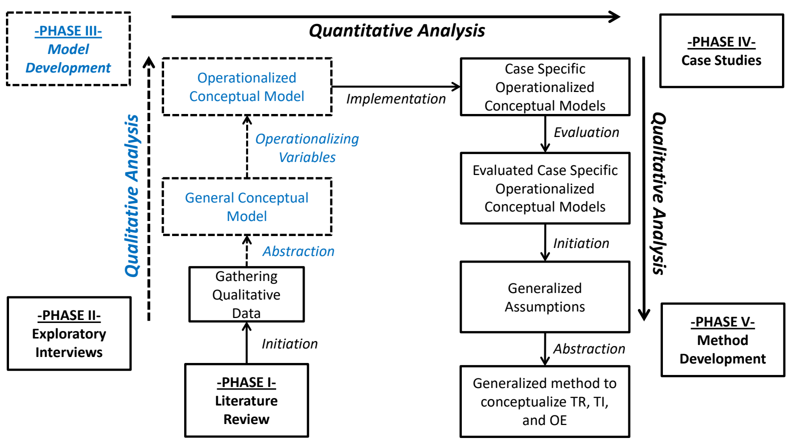


Figure 5. Phase III of the blended five-phased approach of the exploratory sequential mixed methods design based from Creswell (2009)

5.1 Motivation for Operationalizing Variables

The motivation for operationalizing the variables is to support the relationships between the constructs that have been observed through current literature and research. Specifically, the observations include the relationships between the main constructs that need to be further described in detail from a practical relevance as introduced in the blended research strategy from Chapter 1. The aim for this chapter is to bridge the approach taken with qualitative data analysis and confront with the quantitative data analysis. In order to do so, the latent variables resulting from the qualitative data analysis need to be operationalized, where the raw data from the operationalized variables will serve as input for the quantitative data analysis for the detailed case studies in Chapter 6. In addition, the aim for this chapter is to provide additional insight into the first research sub-question from Chapter 1: *What key variables are significant for training, technology innovation, and organizational effectiveness?*

Notable Statistical Correlations

Variables relating to TR for Boeing and non-Boeing have the strongest relationship with a correlation value of 0.924. For both Boeing and non-Boeing, training is a significant variable. Hence, it is expected that the variables relating to training for both Boeing and non-Boeing will also have strong relations. What stood out was that the variables relating to TR for both Boeing and non-Boeing have the strongest relationships as compared to variables relating to each of the three constructs for all other groups of interest. What can be inferred from this is that both Boeing and non-Boeing agree with regards to TR.

Variables relating to OE for Engineering and Training Managers have the weakest relationship with a correlation value of 0.468. For both Training Managers and Engineering Managers, organizational effectiveness was not a significant variable. Hence, it is expected that the variables relating to OE for both Training Managers and Engineering Managers will not have strong relations. What was unexpected was that OE was not a significant variable for both Training Managers and Engineering Managers because OE was determined to be a significant variable for all managers. When observing the individual group of interest 'Training Manager' and 'Engineering Manager,' OE was determined to be significant for Training Managers, but not for Engineering Managers. What can be inferred from this is that although OE is determined to be significant for all managers, this may be due to the number of references to OE that Training Managers had made in comparison to Engineering Managers. Therefore, because Training Managers referenced OE more than Engineering Managers, it is not surprising that variables relating to OE for Training and Engineering Managers have a weak relationship. Also, the number of interviewees for managers was low, so when further separating this group of interest into two additional groups of interest, the most significant variables cannot be determined due to the number of interviewees being too small.

The most significant variables for Boeing are similar to non-Boeing in general and across all three constructs. As discussed earlier in the 'Boeing and non-Boeing' sub-section, this result confirms that the conceptual model to be developed can be used by both Boeing and non-Boeing.

The most significant variables for Managers are similar to non-Managers in general and across all three constructs. As discussed earlier in the 'Managers and non-Managers' sub-section, this result confirms that the conceptual model to be developed can be used by both Managers and non-managers.

Expected Statistical Correlations

Training SMEs and Engineering SMEs have a weak rank-order relationship in relation to TI. This was expected. Training SMEs and Engineering SMEs are not expected to have similar variables in relation to TI. There are different goals for each group of interest that is common for large organizations. That is, training organizations and engineering organizations are separate entities with goals specific to their organizations.

Schedule is common across all sets of interest. This was expected. Regarding TR and Schedule alignment from a training manager, *"Certainly, when new initiatives come out, we get called upon to make sure that the training align with those new initiatives, and sometimes we have to quickly develop new training materials to - yes, to be available for the roll out of those new initiatives [I14, 14:42]."*

Guideline is common across all groups of interest. This was expected. In general, guideline is common across all groups of interest because within the business environment, guideline refers to standard processes, tools, and policies. These standardized guidelines are in place for the workforce to be both effective and efficient in the workplace. Moreover, the standardized guidelines are in place for certification purposes of the products that companies produce.

In relation to OE, Management and Training are common. Regarding TR and OE alignment from a training manager, *"Yes, to me, it's making sure that the course is what the business really wants and that you work with them through every stage of that development process to make it successful [I14, 14:41]."*

In relation to TI and Training, Schedule, and Audience are common. Regarding timing and TR, an engineering SME comments, *"yeah I think the timing could have been better for anything that we try to teach our partners as well [I6, 5:5]."* This leads to the variable 'Audience.' According to a training SME, *"I think it depends on skill set of the people being hired so it could be that there is a big technology investment as an example, composite as you mentioned, but before we determine how much training needs to be invested in that group we would take an assessment of the workforce to be able to understand are rehiring people coming out of college today have a general knowledge of composites are ready but do not have applied knowledge at a corporation or are we hiring people with corporate knowledge of composites from other companies and have already been doing this for 10 years [I3, 7:15]."* To help determine who the audience is, there is a workforce assessment that companies use. A training SME elaborates, *"It depends on the results of the workforce assessment. Depending on what knowledge is needed on that new technology that would affect the type of training that we would deliver and how much training would need to be delivered how soon an early that we would need to start that training [I3, 7:49]."* Another training SME adds, *"It is really about trying to understand what is the desired performance outcome, who is the audience that needs to know it and what is the content [I7, 12:9]."* This leads to following processes or having guidelines within the company to determine the audience. A training SME comments on the company using a competency matrix as a guideline for developing training, *"This competency matrix defines the must-haves of any engineers we employ in the company, and that is subdivided by different specialty areas. The core of the company, as we are an oil and gas industry, are our petroleum engineers [I10, 13:3]."* This same training SME further added, *"So, the training became an integral part of the Technology Center, and that had extremely positive results because your experienced engineers, subject matter experts and the young engineers are sitting next to each other [I10, 13:11]."*

In relation to TR, Guideline and Schedule are common. Regarding Guideline and TR, *"It is not that what they are doing is bad but I think that would free them up to do more of the engineering work that they are probably more passionate about and more valuable to the company for and it also allows us to get a more common approach to training. So rather than 12 different groups with each having a slightly different version of a specific training if we can get all 12 of those groups to get to a more common training to when something needs to be adjusted or it helps keep errors from happening in random groups, if we can get everything more common we can keep a more level status on what's going on in making sure everybody is doing things the right way across the board [I3, 7:25]."* A training manager further supports that the company has a standard process that everyone aims to follow, *"And the answer is, yes, absolutely we have an instructional design system process we follow [I1, 9:61]."* As introduced in Chapter 2 and further described in context of the Boeing Company in Chapter 3, the instructional design system is similar to those described in literature for companies in general. In terms of aligning the learning objectives to business needs, an engineering SME comments, *"So, learning objectives are set globally and tied to this competency matrix [I10, 13:39]."* This engineering SME further added, *"The competency framework is regularly refreshed and specified, and for each competency level: awareness, knowledge, skill and mastery - these four, different - you have a clearly defined sequence of requirements, and these requirements are tested. After every course, we have a quiz, and the quiz tests how much a student got out of his courses [I10, 13:236]."* With regards to following guidelines to align with the schedule, an engineering SME shares that, *"how we are keeping this material up-to-date is that we use lots of subject matter experts for teaching itself [I10, 13:59]."* Along the lines of the variables 'Guideline' and 'Schedule' being closely aligned, a training manager comments, *"We do tie our training very closely to our competence frameworks, and we do have a drive to reduce the time - what we call "the time to autonomy," which you may have heard that term, trying to get them up to competence more quickly, through both training and on-the-job learning [I14, 14:14]."*

Narrative 12. Case on Guideline and Training example of good alignment

Another key factor for the success of a training program is following standard guidelines set forth by the company. This ensures consistency between all of the training courses in terms of the design, material, delivery, and evaluation. Also, standard guidelines within companies are developed and approved by several organizations. Hence, there is concurrence and understanding between organizations, as well as the business with regards to the overall company goals. Guidelines ensure clear work statements so that both the business and the individual, localized organizations are aligned. An engineering SME provides an example of processes that has been successful for training and developing a skilled workforce:

The Training Center makes sure that all training courses go through the same design process. So, in the structure design process, making sure that the learning is fit for the human mind - meaning that there's blended learning, there is sufficient exercises, there are sufficient presentations, there are sufficient structure in the course. Then, of course, all of that goes through the same design process so all the courses has the [consistent] touch and feel. The content of these courses broadly follows the competency framework. And people who do the work, who design new products, are working then as lecturers themselves, making sure that the latest knowledge is implemented in the courses within a matrix followed with global standards.

- [I10, 13:60,65]

Unexpected Statistical Correlations

Managers and non-managers have a strong rank-order relationship in relation to OE. This was unexpected. This shows that although manager and non-managers have different set of deliverables, they both agree on the overall business goals of the company. The business side of the company refers to OE.

Training SMEs and Engineering SMEs have a strong rank-order relationship in relation to TR. This was unexpected. This shows that although engineering SMEs and training SMEs are from entirely different organizations with different deliverable, they both agree when speaking in terms of TR.

Training Managers and Engineering Managers have a weak rank-order relationship in relation to OE. This was unexpected. This may be due to the small number of interviewees in this set of interest being analyzed. There were only five interviewees within this set of interest.

Competency is not one of the most important variables for non-managers. This was unexpected. This may be due to the fact that when competency was discussed, it was discussed in terms of guidelines and processes within the company.

Cost is not common across all sets of interest. This was unexpected. Surprisingly, the variable cost only showed up once in the Most Significant Variables for the set of interest. Cost also did not show up once in terms of Most Significant Variables relating to OE. Because this was unexpected, this variable will be studied further and possible reasons behind why the variable 'Cost' was not common across all sets of interest will be explored. Any training at any company costs the company in terms of time and resources. A training manager comments, *"…and just like any kind of learning thing, you want to do it on the least amount of dime that you can, just because training is an overhead, for anything [I1, 9:28]."* A training SME further adds, *"the larger the investment in the technology, the larger the training [I3, 7:74]."* An engineering SME points out that although training is a cost to the company, it is also valuable, *"recognizing that training is a cost, training also provides value; and so it is ingrained in the company that whenever there is a change [in technology], we need training (I13, 15:42)."* Furthermore, an engineering SME comments that 'Cost' is controlled by the high-level executives responsible for the business decisions at a company, *"The HR VP will say, "Well, that's your budget, and that's it [I13, 15:44]."* An engineering SME remarks in terms of TI and OE, *"What kind of comes down to in the most simplest sense is cost schedule and weight. I mean in weight kind of in structure turns into performance is really what the weight is [I6, 5:33]."*

With respect to TI and OE, costs equally plays a role as an engineering SME points out, *"there are a number of business realities, including business decisions, contract decisions, political decisions related to the process and to the architecture that was selected for the program as well as the organizational structural responsibilities that affected the long-term recurring costs of the airplane in a negative way [I5, 6:9]."* Another engineering SME breaks down cost by finding solutions to reduce cost in the technology's lifecycle, a company *"can even price their vehicles more competitively because the profit margin goes up on every vehicle they sell [I8, 13:40 and 13:149]."* And with respect to TI and OE, investing in knowledge transfer within the company helps contribute to productivity by getting entry-level engineers up-to-speed quicker. This is done by *"performing external benchmarking on how we are doing on getting our graduates to autonomy faster [in the workplace], which includes external metrics on our cost for training [I14, 14:19]."* Additionally, an engineering SME commented that research and development (R&D) requires funding, *"And I think part of that [getting funded for R&D] is you almost need a program to put money behind it to make this kind of stuff happen. Because if we don't get funded, we won't have a program. Unless you put a bunch of money into R&D and say okay so here's $30 million go play with this and when it's ready to come out the other end and put it on the airplane. That doesn't happen [I6, 5:49]."* Another remark regarding funding for research was added by an engineering SME, *"Generally there's a fund of money that is derived almost like a tax from the operation unit. So whatever unit produces a lot of gas around the world will pay a certain amount of money into a pool which funds research. And money is collected some place and it could find its way back to a sister unit through the line management to different groups that do research [I11, 11:4]."* Finally, an engineering manager comments regarding what drives sales at engineering companies, *"Here we have a very simple metric which is the evolution of sales, because the engineers are driving customer satisfaction and customer satisfaction is a driver of sales [I2, 5:13]."*

'Cost' is also in terms of the workforce. An engineering SME comments, *"That's the amount of money that is sufficient to cover the staff involved in the organization [I11, 11:7]."* Furthermore, 'Cost' is also in terms of cost-savings. An engineering SME states, *"They my increase the sales, double the sales, and things like that, but when they pick on things like this where, "Oh, let's do things for the -." You know, without enough knowledge, and* *"let's just jump into it; one-fifth of the cost is the cost of engineers, so let's do our FEM overseas. You want better performance, which also means better reliability, and from the reliability comes the safety aspect of it, because you want it to work ten years, at least, in a very challenging environment [I8, 13:2,5]."* Moreover, another engineering SME comments, *"So the leads could make decisions about what to do and their managers and we didn't have program level people looking at every little thing we changed on [Program X]. At one point there was a chart where it was a cost and weight grid and what it said was if you're saving a certain amount of cost and a certain amount of weight, the first line manager can decide to implement. And then, as you move toward spending some money to save weight or adding some weight to save money, then you have to get the next level up to decide because now you are starting to affect both money or performance [I6, 5:34-35]."* An engineering SME also comments regarding 'Cost' and 'Schedule,' *"I think what happened was the schedule gets committed based on selling the airplane and regardless of whether you are ready or not you go for it [I6, 5:41]."* Also, an engineering SME remarks regarding the balance between cost and performance, *"The other piece to that was its heavier and it is more expensive but it gave you the big performance. Boeing is spending more money to put this on the airplane, but we are going to give it to the airlines and they are going to save [generic dollar amount] a year on performance or fuel [I6, 5:45-46]."*

Narrative 13. Case highlighting cost example

> At companies, the business is often concerned with the schedule, cost, and performance. Hence, for effectiveness and efficiency, organizations need to align with the overall business goals. This can mean reducing errors, reducing, rework, and finding ways to save cost to the business, while meeting all of the scheduled deliverables set forth by the business. A training SME explains in terms of the training organization aligning to the overall business goals:
>
> *The main goals for our training organization are to make sure that the work that we are doing is aligning with the strategies of the engineering group that we support. If we are building training that is not in agreement with the overall goals of the engineering organization, then we need to relook at why we are doing it. Another goal would always be to improve the knowledge transfer amongst the team, improve the productivity…a change in behavior that results in productivity gains, reduced errors, reduced rework, and cost savings. If the company is a for-profit company and not a non-profit company, you obviously want to make some money. So if training is not driving towards reducing costs in some way, whether that is through reducing the time it takes to do something or reducing errors or reducing the risks of failure down the road, then the training might not be necessary.*
>
> *- [I3, 7:89]*

As it has been demonstrated in this section that clearly, the variable 'Cost' plays a significant role within companies; it shows that it is unexpected that during the analysis that this variable did not show up as being one of the most significant variables across all sets of interest. There are a few possibilities as to why this is the case. The first one being that the criteria for choosing the most significant variables is too stringent. If the criteria for choosing the most significant variables was set a little bit looser, then the variable 'Cost' might have been common across all sets of interest. Another possibility is not enough higher level executives were interviewed. At companies, it is well known that overall business decisions, or the control of how funding is distributed across the company, are made at the executive level. The lower level managers are less involved in the overall business decisions, but play a closer role within the organization in which they manage. The last possibility is that because the variable 'Cost' is incredibly apparent to all the interviewees, the direct mention of this variable was not used. Instead, the variable 'Cost' may have been described in other terms or variables that are considered for this research. An example of this is that 'Cost' is commonly described in terms of time or 'Schedule' within companies. An expression "Time is money" is well known. This can be interpreted as time being a valuable resource; therefore it is better to do things as efficiently as possible. In terms of a company, the entire workforce is paid to produce a product; hence efficiency in doing so is significant to the success of a company. Efficiency is represented as the variable 'Schedule' in this research and it has been described throughout the earlier sections that 'Schedule' is among the most significant variable across all sets of interest. Therefore, if 'Schedule' and 'Cost' are directly related, then is can be substantiated that 'Cost' be included in the conceptual model in an indirect manner wherever 'Schedule' is used.

Narrative 14. Case highlighting the balance of schedule, cost, and performance

At engineering companies, aligning to business needs in terms of schedule, cost, and performance can be challenging for the workforce. In reality, there is some balance that needs to be considered between performance - which can be described in terms of reliability, safety, and productivity – and cost and meeting scheduled deliverables. An engineering SME further explains with an example:

What was done was basically they increased the performance. Also, at the same time, they decreased the cost. There were two huge hurdles to work on, which they successfully did in the mid-90s, and we're talking about computers for cars, and the production rate - like a big automaker, probably you are looking at 3 million vehicles, or maybe even more, per year. The daily production rates are in the thousands. You're looking at something like producing something like 12,000 computers, in just an 8-hour shift, across many factories, of course. This is a massive, massive project, because it involves production rates that are so high. If you just stick to the individual cost, this is a huge amount of revenue, and it had to be tested. It had to be reliable, and it had to basically satisfy all the requirements for being mounted under the hood of the vehicle. That's where the two issues come in. You want better performance, which also means better reliability, and from the reliability comes the safety aspect of it, because you want it to work in ten years, at least, in a very challenging environment. There's a huge safety component to that. Of course, at the same time, another huge objective was to bring down the cost.

This was a very large project, where the key decisions were made by executives at that time, a huge challenge for the whole organization. Usually, you have one of the two goals to bring down cost, or improve performance; so you're looking at a huge, maybe 5x drop in cost, and at the same time, maybe a 10x improvement in performance. Both requirements needed to be satisfied at exactly the same time. This was a massive project, lasting three years. It was executed very successfully.

What they did is, unlike other big projects, they were very knowledgeable about the difficulties of introducing new technology because it's all about new technology. That's the only way you can satisfy both the requirements of performance, as well as cost, at the same time. It's new technology. They were very realistic about their approach to this. They [the business] gave enough lead time. They gave about five years to bring this to reality. There were plenty of challenges, but it was on time. That was the most significant part. They went into high-volume production, in time, five years.

This is the level of reliability requirement. For any failure, they have to go back to finding root cause, whether it's a manufacturing issue or it's a design issue, because then the change is going to be significantly greater. That is what really determines whether it is fit for high-volume production. High-volume production means that's it, it's on the vehicle a few days after it's been produced. That was very successful because it was delivered on time, it met all the reliability requirements, and it was a huge drop in cost. Obviously, that increased the company's bottom line, because you can make it for less, and the way they could make it for less is that they simplified so many operations.

- [I8, 13:142-146]

Narrative 15. Case highlighting example of management driving TI with cost and funding

There are times when finding the balance between performance and cost leads to challenges for the engineering workforce. There are sometimes cases where the engineering workforce develops a product that meets or exceeds the performance needs that the business sets forth, but increases the cost, and it is not always clear to the engineering workforce why this balance is not acceptable to the business. An engineering SME provides an example and explains:

In about 2007 or so, the [program] was looking for weight reduction to get more range of the airplane and one of the technologies was [technology X] and there were some people working in the electrical standards group who developed composite spanner bars. It would seem that we completely blew it; it meaning the costs and it's not obvious to me why that is. I think there are a number of business realities and business decisions, meaning sourcing and contracting decisions, political decisions, and decisions related to the process and to the architecture that was selected for the program, as well as the organizational structural responsibilities that affected the long-term recurring costs of the [product] in a negative way. So it's challenging to separate and segregate the product design element of it from the other stuff [business aspects].

- [I5, 6:9-10]

5.1.1 General Conceptual Model

During the last phase of Miles and Huberman's QDA approach, a general descriptive conceptual model is presented based on the analysis performed in Section 4.5.2 and 4.5.3, in Chapter 4. Conceptually, the most significant variables that are *considered* for this research across all sets of can be seen in Figure 5-1 as they relate to the three main constructs of this research. Since it was statistically determined earlier that the most significant variables for Boeing are similar to non-Boeing in general and across all three constructs; and the most significant variables for Managers are similar to non-Managers in general and across all three constructs, one descriptive conceptual model can be used for all sets of interest. This conclusion was made based on the assumption that all of the groups of interest can either fall in the set of interest 'Boeing and non-Boeing' or 'Manager and non-Manager.' In other words, both of these sets of interest contain data from all 14 interviewees. Hence, one descriptive conceptual model can be used for all sets of interest.

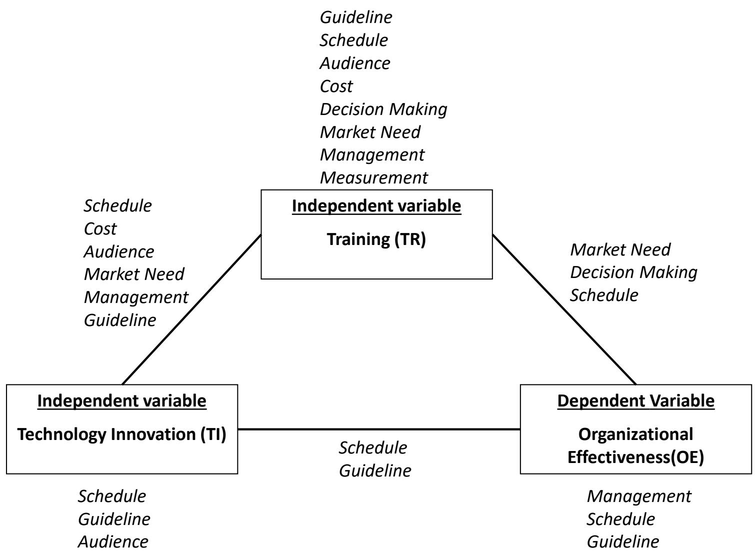


Figure 5-1. The general conceptual model showing the most significant variables that are considered for the three constructs of TR, TI, and OE, and the combined constructs of TI-TR, TI-OE, and TR-OE across all sets of interest

5.1.2 Conclusions from Empirical Data in Phase II

Conclusion 1. The interaction between TR and OE may have an additional construct to consider: TROE.

As addressed in EQ2 and EQ3 in Chapter 4, which was interpreted based on the qualitative data from the interviews, the interaction between TR and OE includes the OE at the localized level within the training organization. Hence, the training organizational effectiveness (TROE), is considered in the descriptive conceptual model as illustrated in Figure 5-1.

Conclusion 2. In large engineering companies, localized TROE may be present in order for TR to have a positive effect on OE.

Regarding how the business works, a training manager comments, *"We each have sort of that learning manager hat where we connect with that global [business] and make sure in the learning review process - every year, we do a learning review with them and their direct reports to make sure we understand the business imperatives and how - the fact development needs that come out of those, and then how can learning help - what sorts of priorities do we need to give ourselves? [I14, 14:25]."* If there were no localized TROE present, then the workforce within the training organization would not have the alignment with the higher level business OE needed for TR to have a positive effect on OE. As mentioned by various interviewees, a key factor for TR to be successful is management support.

Conclusion 3. The interaction between TI and OE may have an additional construct to consider: TIOE.

As addressed in EQ5 and EQ6, which was interpreted based on the qualitative data from the interviews, the interaction between TI and OE includes the OE at the localized level within the engineering organization. Hence, the technology innovation organizational effectiveness (TIOE), is considered in the descriptive conceptual model as illustrated in Figure 5-1.

Conclusion 4. In companies, localized TIOE may be present in order for TI to have a positive effect on OE.

Regarding how the business works, an engineering SME comments, *"Then they go, on the other hand, to meetings with technology chiefs. These technology chiefs are the highest technical authorities in every operating unit. The multinational companies have a technology chief: one for North America, one for Canada, one for Mexico and so forth. And these technology chiefs also meet, and they say what the demand is [I10, 13:95]."* Again, similar to TROE in the training organization, if there were no localized TIOE present, then the workforce within the engineering organization would not have the alignment with the higher level business OE needed for TI to have a positive effect on OE. As mentioned by various interviewees, a key factor for TI to be successful is management support.

Conclusion 5. TI and TR may be driven by the Cost and Schedule assigned by the business aspect of the company (OE), where Cost and Schedule are directly related.

As addressed in EQ7 and EQ8, the variable 'Cost' in terms of TI-TR refers to the funding needed for training. Funding is in terms of resources needed for the development, delivery, implementation, and evaluation of training. Moreover, as technology innovation continues to evolve constantly, it is necessary that the timing of the training for the engineers is aligned, so that the engineering workforce has the necessary skills to be effective within the organization. Hence, the 'Cost' and the 'Schedule' in terms of TI-TR are a direct function of each other.

Conclusion 6. TI and TR may be driven by the Audience and Market Need assigned by the business aspect of the company (OE), where Audience and Market Need are directly related.

As addressed in EQ7 and EQ8, the audience refers to the workforce where the skill set within the company constantly changes. This is due to new employees, knowledge transfer from expert to novice engineers, retaining knowledge from people leaving the company, and current engineers learning a new skill set. Market need is determined by performing a training needs analysis to help identify any gaps in skills within the workforce. Hence, since market need is dependent on the gaps in skills within the workforce, and the audience refers to the workforce, market need is dependent on the gaps in skills within the audience.

Conclusion 7. Guideline, Decision Making, Management, and Measurement may all be directly related in context of the three constructs.

As interpreted from the qualitative data from the interviews, Management refers to the management support needed in order for TI and TR to have a positive influence towards the overall business OE. For management support to be effective, standard guidelines and measurements within the company are used by managers to make decisions within the organization.

Conclusion 8. The relationship between TI and TR may affect the overall OE through the localized organization level OE (i.e. TIOE and TROE).

As addressed in EQ9, how the relationship between TI and TR affects the overall business OE is dependent on management support at the localized organization level. The managers at the localized organization level report to the higher level managers who have control of the business aspect of the company. Hence, as mentioned by several interviewees, it is critical to the success of TI and TR to have management support.

Conclusion 9. In large engineering companies, the qualitative data suggests that TIOE and TROE interact together to positively influence OE in terms of TI and TR.

Since the management within TIOE and TROE directly meet with the business OE, TIOE and TROE must interact together on behalf of the engineering organization and training organization in order for TI and TR to ultimately have a positive effect on the overall business OE. An engineering SME states, *"Yes, this was a very large project, so the key decisions were made by executives at that time, a huge challenge for the whole organization [I8, 13:6]."*

5.1.3 Revised General Conceptual Model

Because the relationship between TI and TR is dependent on management support at the localized organization level, the relationship between TI and TR affects the overall OE through the localized organization level OE. This aspect is added to the descriptive empirical model to form the descriptive conceptual model shown in Figure 5-2. Operationalization of variables in Chapter 5 will be performed to further investigate the descriptive conceptual model. It should be noted here that the dotted lines between TROE and OE, and TIOE and OE indicate that this relationship is *inferred* based on the interviews with the five managers. For the line to be solid would denote that a significant number of interviews was conducted with executive level managers, but due to the access and lack of support at that level of management, this was not possible for this research. By '*significant number of interviews*,' it is intended that more interviews be conducted for the data to have any statistical relevance. For this research, only two executive level managers were interviewed. It will be recommended for future research that additional interviews with executives be conducted to represent the high-level business aspect of OE.

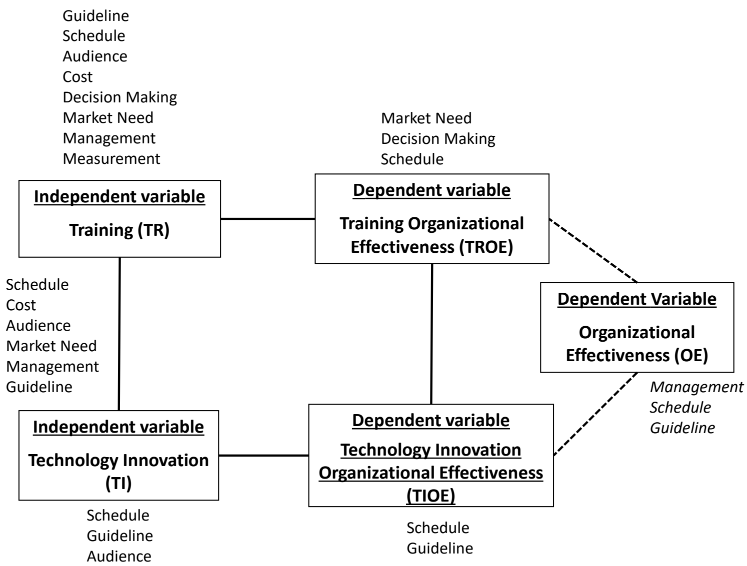


Figure 5-2. The revised general conceptual model showing the most significant variables that are considered for the three constructs of TR, TI, and OE, with two additional variables TROE and TIOE to further describe OE

5.1.4 Summary of Generalized Method for Qualitative Data Analysis

The generalized method for qualitative data analysis, shown in Figure 5-3, gives a summary of the recommended approach for qualitative data analysis. This approach was used during this research with five different companies to determine the latent variables that represented each of the three constructs. It was determined that between the five companies, the latent variables could be used interchangeably between the five companies. Figure 5-2 shows a generalized descriptive conceptual model that would apply for any of the five companies and furthermore, may possibly be used by any company having comparable characteristics as the companies selected in this research, as described in Chapter 4.

If it is determined that the company and organization using this method is comparable to the companies selected in this research, then the list of latent variables shown in Figure 5-2 may be used. If it is determined that the company and organization using this method is not comparable to the companies selected in this research, then it is advised that the method shown in Figure 5-3 is followed to determine the latent variables representative of the three constructs. The sub-sections following the general method for qualitative data analysis will give additional guidelines if the latter approach is taken to follow the method shown in Figure 5-3.

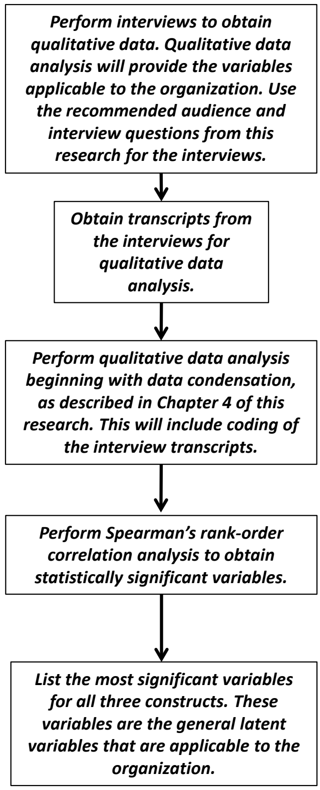


Figure 5-3. Generalized Method for Qualitative Data Analysis

Guidelines for Interviews

The audience being considered for interviews need to be evenly distributed from the following categories: engineering manager, training manager, training SME, and engineering SME. It is mandatory that the interviews be recorded for the purposes of data analysis. The transcripts from the interviews will serve as the raw data for the qualitative data analysis.

List of General Interview Questions

The interview questions are based upon the audience and function (e.g. training SME, manager, subject matter expert (SME), etc.) of the person being interviewed. This approach ensures that there will be an evenly distributed amount of data addressing each of the three constructs of Organizational Effectiveness, Technology Innovation, and Training. All of the interview questions are intended to be open questions in the context of the three main constructs.

IQ1. What do you perceive as the main organizational goals for training or technology innovation?

IQ2. How does the training or engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?

IQ3. How does the training or engineering organization know when a new technology is being considered by the other organizations?

IQ4. How does the company manage the adaptation of its training programs to new technological developments and innovations?

IQ5. What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?

IQ6. Think of a successful training or technology innovation program that you have worked on in the past. How would you define a program as being <u>successful</u>? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?

IQ7. Think of an unsuccessful training or technology innovation program that you have worked on in the past. How would you define a program as being <u>unsuccessful</u>? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?

5.2 Reflections on Qualitative Data Analysis

The descriptive conceptual model shown in Figure 5-2 illustrates what actually happens at companies, as opposed to Figure 5-1. As OE in this research refers to the business and where decisions are being made, at companies there are several levels that work together. The ultimate business decisions are at the top management level, which in Figure 5-1 and Figure 5-2 is shown as the construct OE. Localized business decisions are made at the intermediate management level, shown in Figure 5-2 as TROE and TIOE. The localized OE and the overall OE meet occasionally in order for the localized organizations to align to the overall business goals, which are in terms of schedule, management, and guideline. The variable 'Schedule' for TIOE, TROE, and OE all refer to the time it takes for the workforce to be skilled so that the workforce is efficient in developing and delivering the company's product to the market. As mentioned several times by the various managers and SMEs being interviewed, schedule is significant because schedule and costs are directly related within the company environment. It is the nature of the business to be profitable. But there is a balance that companies need to maintain between efficiency and effectiveness. It is possible for a company to be efficient in delivering their product to the market, but if the product is flawed and the market is unhappy with the product, and rework is needed to improve the product, then this would be costly and ineffective for the organization. In order for an organization to be effective, there are many factors that need to be considered as described in this chapter. Schedule and cost cannot compromise the standard guidelines set forth by the company to meet quality and certification standards. Hence, the variables 'Guideline' and 'Decision Making' are directly related.

When making observations regarding the descriptive conceptual models that were based on findings from literature in Chapter 2 and 3, and comparing to what was observed in the business environment based on the findings from the interviews performed in this chapter, it can be concluded that what actually happens in the business environment is much more complex than what is described in literature. The theories shown in literature illustrate a very high-level view of what the main constructs are in companies. But when observing and analyzing the qualitative data from the interviews, the business environment is much more complex and cannot be explained by simply relating the existing two independent variables TI and TR directly to OE. The interviewees clearly expressed that an additional element is involved between TI and OE, and TR and OE. Even what is shown in Figure 13 is a high-level view of the business environment, but with additional key factors that are explicitly illustrated based from the qualitative data gathered from the interviews. This high-level view can be viewed as the elements that all companies similar to Boeing comprise of. The number of specific levels that each construct is divided further is dependent on the nature of the company.

The conclusions made in this chapter set a foundation for the operationalization of variables in the next sub-sections of this chapter, which consists of operationalizing the latent variables resulting from the qualitative data analysis performed in Chapter 4 and in this chapter. The aim for the next sub-sections of this chapter will be to use the conclusions and general conceptual model earlier in this chapter to transition from a qualitative approach towards a quantitative approach. The operationalized variables developed in this chapter will be implemented in Chapter 6 using detailed case studies. The goal for Chapter 6 will be to perform quantitative data analysis on the operationalized variables developed in this chapter, in addition to developing a case specific operationalized conceptual model.

5.3 Approach towards Operationalized Conceptual Model

The approach towards operationalized conceptual model is to operationalize the latent variables resulting from the qualitative data analysis performed in Chapter 4 and earlier in this chapter. Operationalizing the variables will take the generalized conceptual model and move towards an operationalized conceptual model specific to the Boeing organization. Hence, the results from Section 5.3 through Section 5.5 will be specific to the Boeing organization. The approach taken to operationalize the latent variables representing each of the constructs is intended to be a generalized approach, where any organization comparable to Boeing, will be able to use. This chapter will conclude with this generalized approach to operationalizing the latent variables.

5.4 Operationalization of Variables

Observed variables for each of the constructs were operationalized and will be presented in the next two sub-sections. The detailed case studies in Chapter 6 will use the quantitative data for time series analysis to form case specific operationalized conceptual models. Moreover, the quantitative data aims to show how each of the variables influence each other, as well as how the variables interact in terms of each other (i.e. positive or negative influence and strength). The outcome of the case studies will be case specific operationalized conceptual models. The case specific operationalized conceptual models will then be evaluated with a small (< 5 panel evaluation) group of industry SMEs, where their feedback will be considered when discussing the evaluated case specific operationalized conceptual models that are specific to the Boeing Company.

The most significant variables for each of the five constructs of TI, TR, TIOE, TROE, and OE from Chapter 4 are operationalized in this section. There are some common factors when operationalizing the variables. All of the quantitative data for the operationalized variables were in terms time and were analyzed over time (e.g. 2000-2013). The quantitative data for the operationalized variables are all from the commercial airplanes organizations. TRL (technology maturity) and ADDIE (training maturity) are both discrete variables and were used to further describe the trends for each of the case studies.

TR construct

TR (Guideline – Decision Making – Management – Measurement)

Guideline, Decision Making, Management, and Measurement are variables not quantifiable, but is supported qualitatively within the scope of this research. Guideline refers to the guidelines that the training organization follows to assess, develop, deliver, implement, and evaluate training. Decision making and management refers to the process in which management follow to decide to invest in training. Measurement refers to the evaluation of training. These four variables in terms of TR are not intended to be operationalized quantitatively. Moreover, the variable Guideline is a discrete variable in terms of TR and is used qualitatively to describe the stage of training with respect to the ADDIE model at a certain timeframe in each of the case studies.

Limitations: The descriptions of the variables Decision Making, Management, and Measurement are limited to the qualitative data gathered from the 14 interviews, as described in Chapter 4, and was not used to operationalize TR for the case studies.

TR (Schedule): Number of courses delivered per year

To operationalize schedule in terms of TR, the number of courses delivered per year was used as a quantitative measure. Courses refer to workplace learning activities that require students to officially enroll using the company website. Courses include workshops, seminars, online courses, and formal instructor classes. As indicated from the interviews, workplace learning follows the 70-20-10 model, where 70% of the workplace learning is on-the-job, 20% informal through online learning and websites, and 10% is classroom instruction.

Limitations: The data for the number of courses delivered per year was gathered internally, only from the core engineering organization, enterprise training organization, and engineering union-represented training within The Boeing Company as this data was reliable and accessible. The ideal data set would be for all structural engineers across the commercial organizations, but this data and database was not accessible.

TR (Cost): Number of students completing courses per year

To operationalize cost in terms of TR, the number of students were used. From the interviews, the time the employees used towards training translates to the monetary cost. The number of students refers to the number of students completing a course. This includes students that complete several courses (i.e. Student A completing five courses would count as a total of five students (or heads) completing the courses). Hence, regardless of whether the same employees takes ten courses or ten different employees each taking the ten courses separately, the time the student spends at the training course all counts the equivalently.

Limitations: The data for the number of students completing courses per year was gathered internally, only from the core engineering organization, enterprise training organization, and engineering union-represented training within The Boeing Company as this data was reliable and accessible. The ideal data set would be for all structural engineers across the commercial organizations, but this data and database was not accessible.

TR (Audience-Market Need): BCA employment numbers per year

To operationalize employment in terms of TR refers to the number of employees hired into BCA per year. This number can further be broken down to the number of employees hired per airplane program per year. Ideally, having reliable data showing the number of structural engineers within the 777 and 787 airplane programs would be preferred, but this level of data is not readily available. Hence, the reliable data that can be publicly referenced to is BCA employment numbers per year.

Limitations: The quantitative data for the BCA employment numbers per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. Again, the ideal data set for the case studies would be specific employment numbers for the 777 and 787 program, and more specifically the number of structural engineers hired for each of these airplane programs. This level of detail for the preferred data set was not accessible.

TI Construct

TI (Schedule): Number of product Orders per year

To operationalize schedule in terms of TI, the number of product orders per year was used as a measure. Product orders include orders for all commercial airplane models. The ideal airplane model to study for this research was the 777 and 787 models as the technologies detailed in the case studies are considered for these airplane programs.

Limitations: The quantitative data for the number of orders of product per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. This data set was limited to the number of orders of 777 and 787 products per year as these are the two airplane programs where the technologies in the case studies were intended for.

TI (Guideline): Number of patents per year filed and issued

To operationalize guideline in terms of TI, the number of patents filed and issued per year was used. The number of patents filed per year refers to the number of patents that the employees in the commercial airplane programs files annually for a particular technology. The number of patents issued refers to the number of patents that were actually issued by the US government after reviewing the patents filed. It should be noted here that there was a delay between the time in which a patent is filed and the time the patent is issued. Also, it should be noted that not all patents filed are issued by the government. It is possible that some patents that were filed were rejected. But for the purposes of this research, the aim is to know when to offer training to positively influence organizational effectiveness; hence, it is the aim to study the uptake of technology innovation within the organization. Since this is the aim, the number of patents filed per year is within the scope of this research rather than the number of patents issued. An additional reason for not using the operationalized variable of number of patents issued is the number of unknown variables associated with the time lag between when a patent is filed and when it is issued. The number of patents issued is dependent on the person reviewing it, how long the patent is, how long the process is, etc. The one thing that is certain between the number of patents filed and the number of patents issued is that there is a lag time. Hence, it is expected that if there is a correlation with the number of patents issued, then that the operationalized variable may possibly also have a lag time relationship with the number of patents filed.

Additionally, the variable Guideline is also a discrete variable in terms of TI and is used qualitatively to describe the stage of maturity of a technology with respect to the TRL at a certain timeframe in each of the case studies.

Limitations: The quantitative data for the number of patents filed and issued per year was gathered internally from an enterprise database. This database was limited to internal Boeing only. There was a lag time between when the patents are filed and when they are issued. Not every patent filed was issued. There were also political reasons as to Boeing allowing their employees to file a patent, as this would make the invention protected, but publicly available. Hence, the number of patents filed and issued does not entirely represent the technology innovations studied in the case studies (i.e. if relying on the patent data for determining the peak of a technology innovation, that peak may be inaccurate), but rather give a trend showing the possible uptake of certain technology innovation. In addition, the keywords used to look up the patents were limited to the technologies of interest studied in the case studies within the scope of this research. The keywords used for the patents search will be outline directly in those chapters.

TI (Audience): BCA employment numbers per year

To operationalize employment in terms of TI refers to the number of employees hired into BCA per year. This number can further be broken down into the number of employees hired per airplane program per year. Ideally, having reliable data showing the number of structural engineers within the 777 and 787 airplane programs would be preferred, but this level of data was not readily available. Hence, the reliable data that can be publicly reference to was BCA employment numbers per year.

Limitations: The quantitative data for the BCA employment numbers per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. Again, the ideal data set for the case studies would be specific employment numbers for the 777 and 787 program, and more specifically the number of structural engineers hired for each of these airplane programs. This level of detail for the preferred data set was not accessible.

TROE Construct

TROE (Market Need): BCA employment numbers per year

To operationalize employment in terms of TROE refers to the number of employees hired into BCA per year. This number can further be broken down to number of employees hired per airplane program per year. Ideally, having reliable data showing the number of structural engineers within the 777 and 787 airplane programs would be preferred, but this level of data was not readily available. Hence, the reliable data that can be publicly reference to was BCA employment numbers per year.

Limitations: The quantitative data for the BCA employment numbers per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. Again, the ideal data set for the case studies would be specific employment numbers for the 777 and 787 program, and more specifically the number of structural engineers hired for each of these airplane programs. This level of detail for the preferred data set was not accessible.

TROE (Decision Making)

Decision Making was a variable not quantifiable, but supported qualitatively within the scope of this research. Decision making and management refers to the process in which management follow to decide to invest in training.

Limitations: The description of the variable Decision Making was limited to the qualitative data gathered from the 14 interviews, as described in Chapter 4, and was not used to operationalize TROE for the case studies.

TROE (Schedule): Number of course hours delivered per year

Operationalizing schedule in terms of TROE refers to the number of course hours delivered per year. Courses refer to learning activities that require students to officially enroll using the company website, where course hours include workshop hours, seminar hours, online course hours, and formal instructor class hours.

Limitations: The data for the number of course hours delivered per year was gathered internally, only from the core engineering organization, enterprise training organization, and engineering union-represented training within The Boeing Company as this data was reliable and accessible. The ideal data set would be for all structural engineers across the commercial organizations, but this data and database was not accessible.

TROE (Cost): Number of student hours per year

To operationalize cost in terms of TROE, number of student hours was used. Number of student hours refers to the number of student hours per course.

Limitations: The data for the number of student hours for completed courses per year was gathered internally, only from the core engineering organization, enterprise training organization, and engineering union-represented training within The Boeing Company as this data was reliable and accessible. The ideal data set would be for all structural engineers across the commercial organizations, but this data and database was not accessible.

TIOE Construct

TIOE (Cost): Investment in technology per year

To operationalize cost in terms of TIOE, investments in the product per year was used as a measure. Investment in the product refers to the technology in context of the research.

Limitations: The quantitative data for the investment dollars in technology per year was gathered internally at The Boeing Company. This data set was limited to internal Boeing only and cannot be accessed externally outside of Boeing. This data set was limited to the years between 2002 through

2010, as this was the only accessible data. This data set was also limited to the technologies of interest studied in the case studies.

<u>*TIOE (Schedule):*</u> *Delivery of product per year*

To operationalize schedule in terms of TIOE, the delivery of product per year was used as a measure. Delivery of product per year refers to the number of airplanes that were delivered to the customers (e.g. airlines) annually. Delivery of product per year can be further broken down to the number of airplane deliveries by airplane programs per year.

Limitations: The quantitative data for the number of deliveries of product per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. This data set was limited to the number of deliveries of 777 and 787 products per year as these are the two airplane programs where the technologies in the case studies were intended for.

<u>*TIOE (Guideline):*</u> *Number of Memo documents per year*

To operationalize guideline in terms of TIOE, the number of memo documents published internally per year was used as a measure. Memo documents are filtered to only include the technologies that are detailed in the case studies.

Limitations: The quantitative data for the number of memo document published per year was gathered internally from and core engineering structures database. This database was limited to internal Boeing, core engineering employees only. In addition, the memos were manually and individually looked at by the researcher to determine if the memo was within the scope of this research and within the scope of the technology being studied in the case studies chapters.

OE Construct

<u>*OE (Management-Guideline)*</u>

Guideline and Management are variables not quantifiable, but supported qualitatively within the scope of this research. Guideline refers to the guidelines that the training organization follows to assess, develop, deliver, implement, and evaluate training. Measurement refers to the evaluation of training.

Limitations: The descriptions of the variables Management and Guideline were limited to the qualitative data gathered from the 14 interviews, as described in Chapter 4, and were not used to operationalize TR for the case studies.

<u>*OE (Cost):*</u> *Revenue per year*

To operationalize cost in terms of OE, revenue per year was used as a measure. Revenue refers to the overall income of the money, which includes all of the sales and income derived from the company for a fiscal year. Cost in terms of OE can also be operationalized as Profit. Profit is revenue minus the debts. Debts in terms of a large airplane manufacturing company (150,000+ employees) may include operating costs, late penalties for not meeting scheduled deliveries or performance standards, payment of loans and interests, employee compensation (e.g. insurance, etc.), land and lease holding, and all evaluated operating costs of the company (e.g. computing, janitorial needs, etc.), building of facilities, etc.

Limitations: A large company like The Boeing Company produces many products, where the total revenue includes the income from all of the products. Hence, a limitation of this research was the access to the revenue data for each particular airplane products (e.g. 777, 787, 767, 747, 737, etc.). The revenue data that is available for this research is detailed to the organization level, meaning commercial or military. Again, this research was interested in observing the relationships within the commercial organization; therefore, to be consistent with the data gathered for the qualitative data analysis, quantitative data was gathered from the commercial organization.

OE (Schedule): Number of products ordered to the market per year (continuous variable); Number of products delivered to the market per year

To operationalize schedule in terms of OE, the number of product orders per year was used as a measure. Product orders include orders for all commercial airplane models. The ideal airplane model to study for this research was the 777 and 787 models as the technologies detailed in the case studies are considered for these airplane programs.

Another measure to operationalize schedule was delivery of product per year. Delivery of product per year refers to the number of airplanes that were delivered to the customers (e.g. airlines) annually. Delivery of product per year can be further broken down to the number of airplane deliveries by airplane programs per year.

Limitations: The quantitative data for the number of deliveries and orders of product per year was gathered from the public Boeing website, as this data was easily accessible, publicly available, and reliable. This data set was limited to the number of deliveries and orders of 777 and 787 products per year as these are the two airplane programs where the technologies in the case studies were intended for.

Simplifying the number of observed variables and constructs

Because the measured variables for TROE are the same as the measured variables for TR, the construct TROE can be eliminated from the prescriptive conceptual model and for the purposes of quantitative data analysis. In addition, the measured variables for OE were determined to be too high level for the purposes of this research. Hence, the measured variables used for OE were specified to be closer to technology innovation and training at a localized level.

Through the qualitative data analysis, the conclusion '*The relationship between TI and TR affects the overall OE through the localized organization level OE (i.e. TIOE and TROE)*' was made. Hence, TIOE can also represent OE at a more localized level.

Summary of constructs, observed variables, and operationalized variables

A summary of the constructs, observed variables, and operationalized variables are shown in Table 5-1. Notes were also included to indicate which observed variables were eliminated for quantitative studies. Some of the observed variables were eliminated from the quantitative studies because these variables were described using qualitative data. In addition, some of the observed variables cannot be operationalized and can only be described in a qualitative nature; hence, the elimination of these variables from the quantitative studies. The final operationalized variables simplified for the quantitative data analysis studies in Chapter 6 are shown in Table 5-2.

Table 5-1. Summary of constructs, observed variables, and operationalized variables

Construct (Latent Variable)	Observed Variable	Measured Variable (Operationalized Variable)	Notes
Training (TR)	Guideline	Described using qualitative data	Eliminating for quantitative studies
	Schedule	Number of courses delivered per year	Included for quantitative studies
	Audience	BCA employment numbers per year	Included for quantitative studies
	Cost	Number of students completing courses per year	Included for quantitative studies
	Decision Making	Described using qualitative data	Eliminating for quantitative studies
	Market Need	BCA employment numbers per year	Included for quantitative studies - combining observed variable with Audience as the measured variable is the same
	Management	Described using qualitative data	Eliminating for quantitative studies
	Measurement	Described using qualitative data	Eliminating for quantitative studies
Technology Innovation (TI)	Schedule	Number of orders per year	Included for quantitative studies
	Guideline	Number of patents filed and issued per year	Included for quantitative studies
	Audience	BCA employment numbers per year	Included for quantitative studies
Training Organizational Effectiveness (TROE)	Market Need	BCA employment numbers per year	Observed variable is the same as TR construct, but in terms of different measured variables. This observed variable can be captured in TR construct; therefore, eliminating this construct for quantitative studies.
	Decision Making	Described using qualitative data	Observed variable is the same as TR construct, but in terms of different measured variables. This observed variable can be captured in TR construct; therefore, eliminating this construct for quantitative studies.
	Schedule	Number of course hours delivered per year	Observed variable is the same as TR construct, but in terms of different measured variables. This observed variable can be captured in TR construct; therefore, eliminating this construct for quantitative studies.
	Cost	Number of student hours completing courses per year	Observed variable is the same as TR construct, but in terms of different measured variables. This observed variable can be captured in TR construct; therefore, eliminating this construct for quantitative studies.
Technology Innovation Organizational Effectiveness (TIOE)	Schedule	Number of deliveries per year	Included for quantitative studies
	Cost	Investment in product per year	Included for quantitative studies
	Guideline	Number of memo documents per year	Included for quantitative studies
Organizational Effectiveness (OE)	Management	Described using qualitative data	Too high level - describe through TIOE and TI constructs; therefore eliminating this construct for quantitative studies.
	Schedule	Number of orders per year; Number of deliveries per year	Too high level - describe through TIOE and TI constructs; therefore eliminating this construct for quantitative studies.
	Cost	Revenue per year	Too high level - describe through TIOE and TI constructs; therefore eliminating this construct for quantitative studies.
	Guideline	Described using qualitative data	Too high level - describe through TIOE and TI constructs; therefore eliminating this construct for quantitative studies.

**Revenue is total of all incoming money, meaning total money brought in where debts are not included*
**Profit is revenue minus debts and recurring costs*

Table 5-2. Summary of constructs, observed variables, and operationalized variables simplified for quantitative data analysis

Construct (Latent Variable)	Observed Variable	Measured Variable (Operationalized Variable)
Training (TR)	Schedule	Number of course hours delivered per technology innovation per year
	Audience/Market Need	BCA employment numbers per year
	Cost	Number of student hours completing courses per technology innovation per year
Technology Innovation (TI)	Schedule	Number of orders per technology innovation per airplane per year
	Guideline	Number of patents filed per technology innovation per year
	Audience	BCA employment numbers per year
Technology Innovation Organizational Effectiveness (TIOE)	Schedule	Number of deliveries per technology innovation per airplane per year
	Cost	Investment in product per technology innovation per year
	Guideline	Number of memo documents per technology innovation per year

Measurements

The data collected for the measured variables came from several resources, which includes external website, internal library, and internal databases. The approach for data collecting is based on the following criteria: reliability, repeatability, and access to available data. There were a few cases where certain data had restricted access between organizations. Cases where data was limited to a certain organization was described in Chapter 6 when reporting the results from the quantitative data analysis.

5.5 Operationalized Conceptual Model

The operationalized variables representing each of the three constructs are shown in Figure 5-4. The operationalized variables of TR[Audience], TR[Schedule], and TR[Cost] represent the construct of TR. The operationalized variables of TI[Audience], TI[Schedule]. And TI[Guideline] represent the construct of TI. The operationalized variables of TIOE[Cost], TIOE[Guideline], and TIOE[Schedule] represent the construct of OE. Data from each of these operationalized variables will be collected and will serve as raw data for the quantitative data analysis performed in Chapter 6.

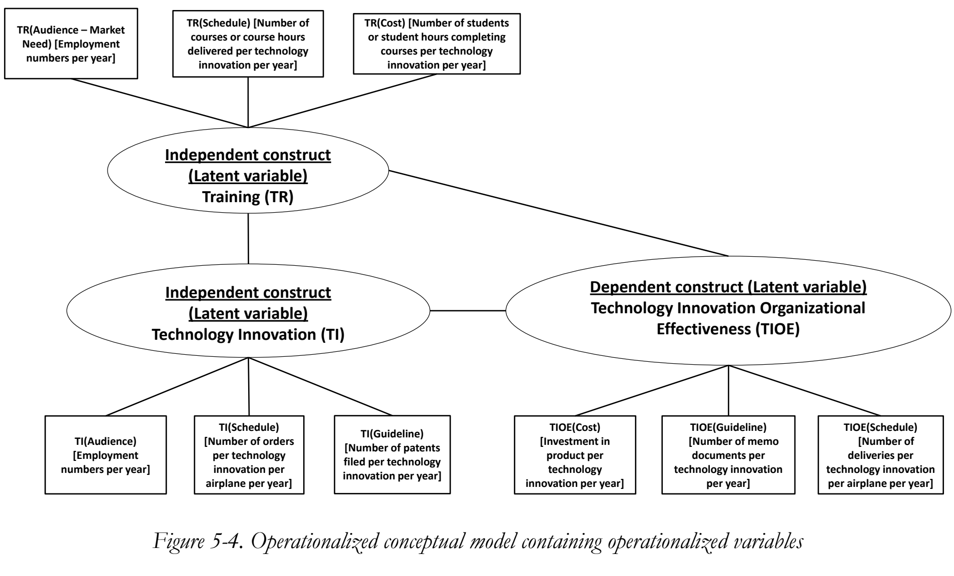


Figure 5-4. Operationalized conceptual model containing operationalized variables

5.6 Summary of Generalized Method for Operationalizing Variables

A summary of the generalized method for operationalizing variables is shown in Figure 5-5. All of the quantitative data for the operationalized variables are in terms time and analyzed over time (e.g. 2000-2013). The majority of the quantitative data for the operationalized variables are at a localized level for more accuracy. The higher level the data is collected, the higher the possibility of more unknown variables is creating noise in the data. SMEs and managers were involved in suggesting what to use as a proxy for representing the latent variable. In addition, literature was reviewed for examples of what others have used in operationalizing similar latent variables.

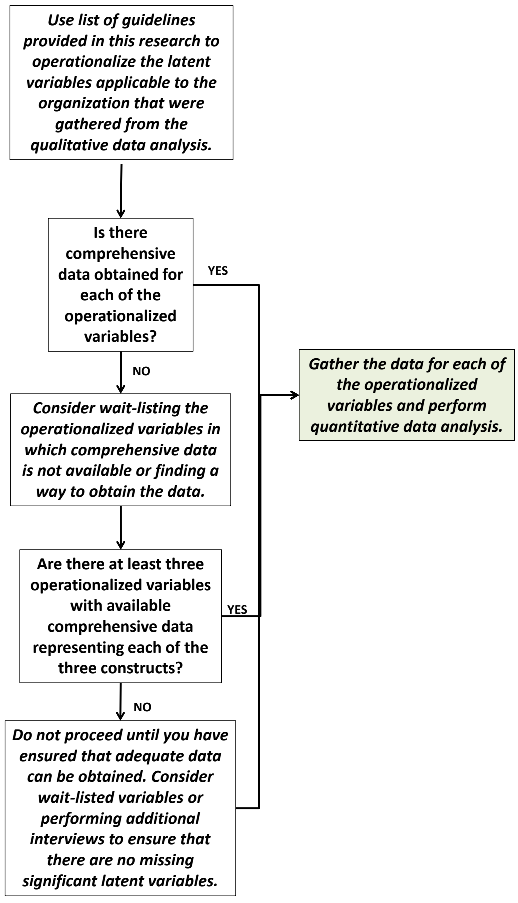


Figure 5-5. Generalized method for operationalizing variables

The combination of generalized method for qualitative data analysis and the generalized method for operationalizing variables results in a combined generalized method referred to as Gate 1 in this research, shown in Figure 5-6. The intended outputs for Gate 1 are operationalized variables containing data that is applicable and specific to the organization using this method.

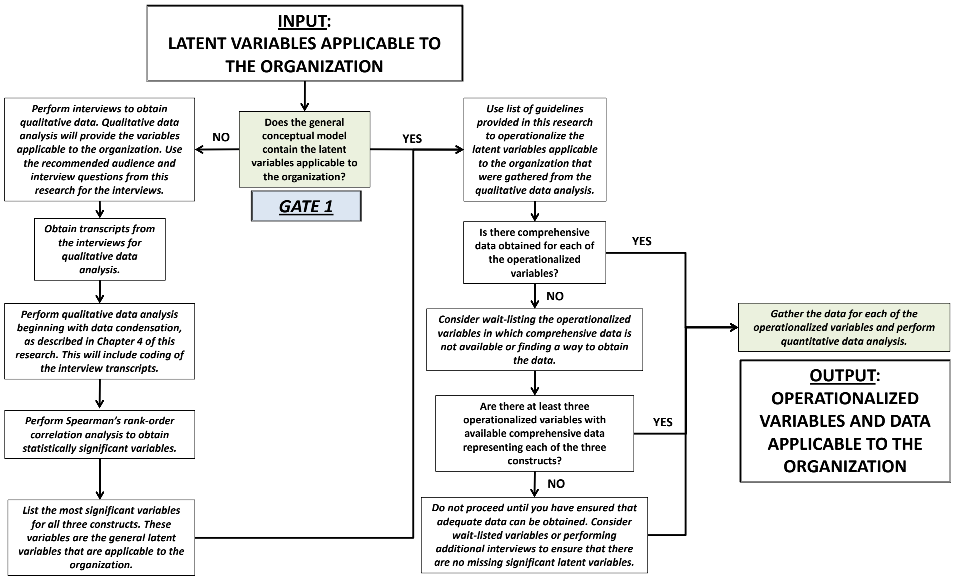


Figure 5-6. Generalized method for qualitative data analysis

Chapter 6
Quantitative Data Analysis: Case Studies

This chapter is represented as Phase IV, shown in Figure 6, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. The aim of this chapter is to characterize solutions for the challenges that are conceptualized and specified during Phase II and Phase III. During Phase III, the general conceptual model formulated during Phase II was revised to represent the operationalized variables, and thus, formulating an operationalized conceptual model. These descriptive conceptual models will be further explored in this Phase IV of the mixed methods research design through detailed case studies.

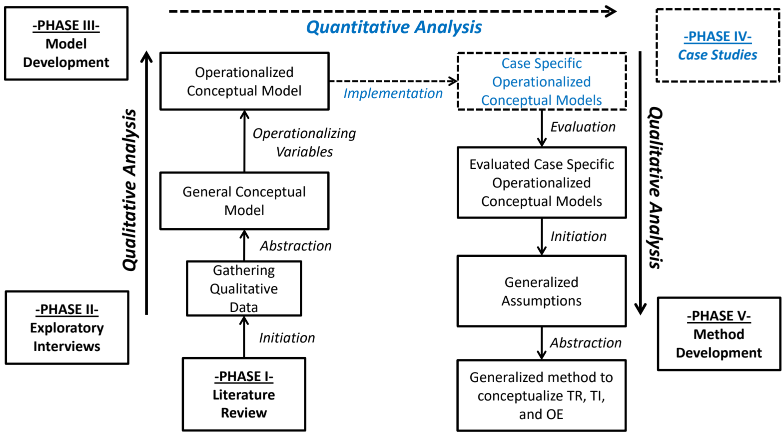


Figure 6. Phase IV of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

6.1 Motivation for Case Studies

The motivation for the case studies is to further research the relationships between the constructs that have been observed through the correlation analysis performed in Chapter 5. Specifically, the observations include the relationships between the main constructs that need to be further investigated in detail in terms of time. The aim for this chapter is to provide insight into the second research sub-question from Chapter 1: *What are the relationships between the key variables?*

6.2 Approach towards Case Specific Operationalized Conceptual Model

In the five-phased approach of the blended research strategy as adopted from Creswell, this chapter depicts Phase 4 and begins with *Implementation* of the operationalized conceptual model initiated in Chapter 5. By implementing the conceptualized conceptual model from Chapter 5, this research uses a cross correlation approach to represent the current state (lag = 0) of the relationships between TR, TI, and TIOE. In addition, a cross correlation approach to represent a lagged state was also performed, which is analyzed by lagging the data sets over time.

The approach towards formulating the case specific operationalized conceptual model begins with a time series analysis, specifically a cross correlation analysis. Afterwards, a lagged cross correlation analysis was performed since there was a possibility that there was a lagged time effect with the variables being considered for the quantitative data analysis. Lagged cross correlation refers to the correlation between two time series shifted in time relative to one another. The purpose of the lagged cross correlation analysis was to show the lag time between the constructs. Addressing this lag time through quantitative analysis will answer research sub-question three by firstly, addressing why there may be some discrepancies in the correlation findings between the observed variables, and secondly, addressing when to offer training. This thereby, will lead to Chapter 7 where a small evaluation study to determine how subject matter experts and decision makers may use this model and if this model may help with their decision making regarding training and technology innovation. It is not the intent of this research to show if an observed variable causes another, as this type of causality research will require a much larger sample size. In addition, the aim of the lagged cross correlation analysis is to also address the hypotheses for the constructs, which will be introduced and described in the next section.

6.2.1 Approach for Quantitative Data Analysis

Cross Correlation Analysis (Lag = 0)

The approach towards formulating the descriptive conceptual model begins with a correlation analysis. The goal is to further investigate the inter-relationships between the observed variables that were found significant for each of the constructs from Chapter 4. The Pearson's correlation coefficient was used to show which observed variables correlate with each other. The purpose of performing this correlation analysis is to confirm the conclusions from the qualitative data analysis from Chapter 4, as well as ensure the validity of exploratory hypotheses, which will be described later in this chapter. It is not the intention to show causality at this time. The aim is to determine if additional correlation analyses should be considered. Again, this correlation analysis aimed to show correlation between the observed variables only.

The approach towards formulating the descriptive conceptual model begins with a time series analysis. Several methods were considered (e.g. granger causality, VAR, etc.), but because of the small sample size, a simple time series cross correlation analysis is appropriate. The purpose of the time series analysis was to show the lag time between the constructs. Addressing this lag time through quantitative analysis will partially answer research sub-question three by firstly, addressing why there may be some discrepancies in the correlation findings between the observed variables, and secondly, addressing when to offer training. This thereby, will lead to a small evaluation study to determine how subject matter experts and decision makers may use this model and if this model may help with their decision making regarding training and technology innovation. It is not the intent of this research to show if an observed variable causes another, as this type of causality research will require a much larger sample size. The time series analysis was performed for Chapter 6. In addition, the aim of the time series analysis is to also address the hypotheses for the constructs, which will be introduced and described later in this chapter.

Normalizing Data

For correlation analysis, it is not necessary to normalize the data as the correlation coefficient is a form of normalizing the data between -1 and 1. Because of the nature of the data being collected, it is expected that the data would fall in a non-normal curve. When analyzing the shapes of the curves and comparing all of the data in one plot, the data was normalized. Because correlation is dependent on co-variances, and can simply be understood as a normalized version of co-variance, the magnitude is influenced by the variances. Hence, it should be noted that when comparing a variable with a large magnitude data set versus a variable with a small magnitude data set, the differences in magnitude and variances may influence the correlation results. As such, this influence on the correlation does not negate the existence of the correlation between the two variables of interest. Therefore, for the aim of this research, correlation analysis performed on the data gathered for the operationalized variables is sufficient.

Missing Data and Zeroes

Missing data in the scope of this research refers to the data that was not available or made available to the researcher. The missing data was indicated by blank spaces in the Excel spreadsheet. When using SPSS to analyze the data within the Excel spreadsheet, the user-defined missing values were treated as missing. The statistics for each pair of variables were based on all cases with valid data for that pair. Valid data refers to data that is not missing. Hence, a value of zero "0" is considered valid data for the pair of variables.

In the un-conservative case, leading zeroes were considered for each pair of variables for case-by-case bases. As annual data was collected for each operationalized variable, there were some variables that had values greater than zero for different time periods. Zeroes were considered when the pair of variables differs in time periods. This was done to include all of the data that had values greater than zero, as the aim was to observe correlations using as complete data set as possible and avoiding elimination of data. It should also be noted that zeroes were considered for each pair of variables for case-by-case bases to ensure that false correlations does not occur with the value of "zeroes" being correlated with other "zeroes" between a set of variables. Note that the zeroes used for the lag correlation analysis for this chapter was the same and consistent with the data that was used for the correlation analysis in Chapter 5. That is, no zeroes were added to the existing data set.

In the conservative case, correlation analysis was performed with the leading zeroes removed from the data set. The detailed comparisons between using leading zeroes and removing the leading zeroes will be described in Section 6.5 in this chapter. The purpose of performing correlation analyses for both data sets with and without leading zeroes is to aid in the decision process of what would make the most logical sense when analyzing a bivariate set, especially when taking into consideration lag and lead times. For the scope of this research, after analyzing both the un-conservative and conservative cases, the data for the conservative case will be considered for the conclusions and recommendations of this research. This is due to the unrealistic strong correlations shown in the un-conservative case, especially at lag time = 0. However, for reference, the data from the un-conservative case will be made available in Appendix 6A and Appendix 6B, for case study 1 and case study 2, respectively.

Case Study Approach for Data Collection

Data was collected for two technology maturity cases for this research. The first case study represented a technology that was fully matured (Composites), whereas the second case study represented a technology that was early in the maturity cycle (Nanotechnology). The purpose for selecting the extreme ends of the maturity was to observe the timing of training, which addresses the third research sub-question. That is, observing whether the timing of training differs between the two technologies, and whether the timing of training was too late or too early.

Limitations

Only two technology maturity cases were considered for this research, representing the extreme cases. Extreme cases in the context of the research means one case where the technology was fully matured (i.e. TRL 9) and another case where the technology was in the early stages of maturity (i.e. TRL 1-3). Ideally, collecting and analyzing data for all stages of technology maturity would be preferred, but because of time constraints, the extreme approach was taken.

Correlation Analysis

A correlation analysis was performed for the current time period. The results for this correlation analysis will hereby be referred to as the current state. The correlation analysis aims to determine if any of the observed variables correlate within each of the constructs, thereby validating that any of the observed variables can represent the construct. During the analysis, if there is a difference in correlation, then this analysis may suggest that a time series analysis is necessary in determining the lag time between the variables. This type of analysis is also known as a lagged cross correlation time series analysis.

Approach for Quantitative Data Collection and Lagged Cross Correlation Analysis

The approach in analyzing several bivariate for each case study originated from analyzing the correlation coefficient matrix at lag = 0. Because there were some bivariate that did not show significant correlation when there was an expected correlation, a theory was hypothesized that it may possible that there was a lagged correlation affecting the results. Hence, this Chapter 6 also aims to thoroughly analyze each bivariate for each of the two case studies to determine if there is a lagged correlation. Moreover, every bivariate from the correlation coefficient matrix at lag = 0 will be analyzed in detail to determine if there was a lagged correlation. Leaving out a bivariate would be an incomplete analysis for the scope of this research. Therefore, there will be a total of 28 bivariate for case study 1 and 18 bivariate for case study 2 that will be analyzed.

Elimination of Operationalized Variables

For both case studies, the operationalized variable of 'TI[Guideline]: Number of patents issued per technology innovation per year' will be eliminated because of unforeseen variables that affect this variable that cannot be controlled. That is, before patents are issued, there are many variables that can prevent this from happening. These may include management support, company support, delays from the patent office, etc. Hence, the more appropriate operationalized variable to use that would be in the scope of this research is 'Number of patents filed per technology innovation per year.' This operationalized variable gives a more accurate depiction of when the uptake of a technology innovation begins, which is in the scope and interest of this research.

For case study 2, the operationalized variables TIOE[Schedule] and TIOE[Guideline] are eliminated due to being out of scope for this case study. That is, TIOE[Schedule] represents the number of airplanes delivered per technology innovation per year and TIOE[Guideline] represents the number of memos per technology innovation per year, and this is not possible for nanotechnology because the technology is too early in the maturity cycle to be integrated onto the airplane nor to have guidelines developed. Memos are only developed for mature technologies. Hence, these operationalized variables of TIOE[Schedule] and TIOE[Guideline] are eliminated from case study 2.

Normalizing Data

For lagged correlation analysis, the same criteria was used for the approach for cross correlation analysis at lag = 0.

Missing Data and Zeroes

For lagged correlation analysis, the same criteria was used for the approach for cross correlation analysis at lag = 0.

Limitations regarding Data Collection

It should be noted that the number of samples for each bivariate is not the same across all the bivariate sets. Hence, as the lag and lead times were being considered for each bivariate data set, depending on the bivariate being analyzed, there were limitations with how much lead or lag time can be applied. For those data sets that have small sizes, as good statistical practice, when shifting the data set to simulate the lag and lead times, a minimum sample size was ≥ 5 data points.

6.2.2 Approach for Reducing Variables

The purpose of the following approach to reduce variables is to determine if one descriptive conceptual model for each of the case studies will result from the quantitative data analysis, or if more than one descriptive conceptual model is necessary.

Through qualitative analysis and interpretation of qualitative data, TR is observed by the variables *TR[Audience], TR[Schedule], and TR[Cost]*. The variables Audience, Schedule, and Cost in terms of TR can be measured by employment numbers per year, courses delivered annually, and students completing courses annually, respectively. If there is strong correlation between any or all three observed variables, then the TR construct may be represented by *any* of the three observed variables when determining the relationships between the constructs. If there is not a strong relationship or no relationship between the observed variables, then all of the observed variables represent the TR construct separately. If the latter case holds true, then there will be several descriptive conceptual models in terms of the measured variables individually.

Through qualitative analysis and interpretation of qualitative data, TI is observed by the variables *TI[Audience], TI[Schedule], and TI[Guideline]*. The variables Audience, Schedule, and Guideline in terms of TI can be measured by employment numbers per year, courses delivered annually, and number of patents filed and issued per year, respectively. If there is strong correlation between any or all three observed variables, then the TI construct may be represented by any of the three observed variables when determining the relationships between the constructs. If there is not a strong relationship or no relationship between the observed variables, then all of the observed variables represent the TI construct separately. If the latter case holds true, then there will be several descriptive conceptual models in terms of the measured variables individually.

Through qualitative analysis and interpretation of qualitative data, TIOE is observed by the variables *TIOE[Cost], TIOE[Guideline], and TIOE[Schedule]*. The variables Cost, Guideline, and Schedule in terms of TIOE can be measured by the investment dollars per technology innovation per year, number of memos per technology innovation per year, and number of deliveries per technology innovation per airplane per year, respectively. If there is strong correlation between any or all three observed variables, then the TIOE construct can be represented by any of the three observed variables when determining the relationships between the constructs. If there is not a strong relationship or no relationship between the observed variables, then all of the observed variables represent the TIOE construct separately. If the latter case holds true, then there will be several descriptive conceptual models in terms of the measured variables individually.

6.3 Case 1. Composites Technology *(Representing mature technology)*

6.3.1 Cross Correlation Time Series Data Analysis for Lag = 0

Exploratory analysis is performed with correlation analysis to gain additional insights towards revising the operationalized conceptual model and formulating a descriptive conceptual model. A simple cross correlation time series analysis was performed over one time period for each bivariate being analyzed. The data used for the simple cross correlation began with the operationalized dataset used from chapter 5. For bivariate set, Pearson's correlation coefficient was determined using SPSS. Pearson's correlation coefficient was then plotted for each bivariate set for the current time period lag = 0. The same criteria in terms of strength between the variables that was described and used in Chapter 4, was also used for this analysis:

- ***Exactly –1.*** *A perfect downhill (negative) relationship, representing a perfect correlation*
- ***–0.70.*** *A strong downhill (negative) relationship, representing a large correlation effect*
- ***–0.50.*** *A moderate downhill (negative) relationship, representing a medium correlation effect*
- ***–0.30.*** *A weak downhill (negative) relationship, representing a small correlation effect*
- ***0.00*** *No relationship*
- ***+0.30.*** *A weak uphill (positive) relationship, representing a small correlation effect*
- ***+0.50.*** *A moderate uphill (positive) relationship, representing a medium correlation effect*
- ***+0.70.*** *A strong uphill (positive) relationship, representing a large correlation effect*
- ***Exactly +1.*** *A perfect uphill (positive) relationship, representing a perfect correlation*

Both conservative and un-conservative cross correlations for lag time = 0 are shown in Table 6-1, Table 6-2, and Table 6-3. It is expected that there be some lag time between courses ready to be delivered and TI and TIOE variables. The fact that the un-conservative cases show several significant correlations for TR variables at lag time = 0 seem unrealistic. Hence, for this research, the conservative cross correlation matrix is taken into consideration more strongly than the un-conservative cases.

Table 6-1. Conservative at Lag = 0 [With no leading zeroes for any bivariate data sets for lag = 0]

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.041 (p = 0.862)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.827**	0.829**	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.505*	-0.240 (p = 0.249)	0.173 (p = 0.657)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.303 (p = 0.194)	0.353 (p = 0.056)	0.902**	0.090 (p = 0.669)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.250 (p = 0.318)	0.354 (p = 0.149)	0.670*	-0.238 (p = 0.883)	-0.130 (p = 0.608)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.492 (p = 0.322)	-0.388 (p = 0.448)	0.998*	-0.309 (p = 0.552)	-0.409 (p = 0.421)	0.158 (p = 0.765)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.269 (p = 0.607)	-0.388 (p = 0.448)	0.379 (p = 0.752)	0.173 (p = 0.743)	-0.226 (p = 0.667)	0.666 (p = 0.149)	0.361 (p = 0.482)	1.000

*p < 0.05 is denoted as **
*p < 0.01 is denoted as ***
Means significant values between lag time = 10 and lead time = 10

Table 6-2. Un-conservative at Lag = 0 [With leading zeroes for case by case basis for lag = 0]

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.366*	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.291	-0.360	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.614**	-0.221	0.507*	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.223	0.598**	0.513**	0.309*	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.250	0.354	-0.825**	-0.238	0.073	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.691**	-0.075	0.711*	0.211	0.403**	0.077	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.644**	0.090	0.677*	0.269	0.403**	0.014	0.361	1.000

*p < 0.05 is denoted as **
*p < 0.01 is denoted as ***
Means significant values between lag time = 10 and lead time = 10

Table 6-3. Extreme un-conservative case at Lag = 0 [With leading zeroes for all bivariate cases for lag = 0]

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.234	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.705**	0.141	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.772**	0.273*	0.666**	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.334**	0.676**	0.554**	0.396**	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.250	0.352	-0.825**	-0.238	-0.130	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.718**	0.205	0.660**	0.393**	0.434**	-0.077	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.688**	0.190	0.609**	0.430**	0.433**	-0.014	0.936**	1.000

*p < 0.05 is denoted as **
*p < 0.01 is denoted as ***
Means significant values between lag time = 10 and lead time = 10

Observations for the Conservative Case

TIOE Construct

There is a strong, direct correlation between TIOE(Schedule) and TIOE(Cost) with 0.827 ($p < 0.01$), as well as TIOE(Guideline) and TIOE(Cost) with 0.829 ($p < 0.01$). Moreover, TIOE(Schedule) and TIOE(Guideline) have a common observed variable of TIOE(Cost)[Total Composite Investment]. The term 'common' observed variable used in this context refers to direct correlation to each of the two observed variables being analyzed.

Interrelationships between the three constructs

TI(Schedule)[Total Commercial 777 and 787 Airplanes Ordered] and TIOE(Schedule) [Total Commercial 777 and 787 Airplanes Delivered] are directly correlated with 0.505 ($p < 0.05$). TI(Guideline)[Total Commercial Composite TI Patents Filed] and TIOE(Cost) [Total Commercial Composite Investment] are directly correlated with 0.902 ($p < 0.01$). TIOE(Cost) [Total Commercial Composite Investment] and TI/TR(Audience)[BCA Employment Numbers] are directly correlated with 0.670 ($p < 0.05$). TIOE(Cost) [Total Commercial Composite Investment] and TR(Schedule)[Total Number of Course Hours Delivered] are directly correlated with 0.998 ($p < 0.01$).

Conclusion

The model cannot be simplified possibly because of time lag. Recommendation is to further analyze the time lag for each observed variable using time series analysis for two case studies.

Observations for the Un-Conservative Case

TIOE Construct

None of the three observed variables have a strong positive correlation with each other. There is a direct correlation between TIOE(Guideline) and TIOE(Schedule), but it is a negative correlation. Moreover, TIOE(Guideline) and TIOE(Schedule) have a common observed variable of TI(Guideline)[Number of patents issued]. The term 'common' observed variable used in this context refers to direct correlation to each of the two observed variables being analyzed.

TIOE(Schedule) and TIOE(Cost) are not directly related, but can be inferred as indirectly related through another observed variable TI(Schedule) from the TI construct. TI(Schedule) and TIOE(Schedule) have a direct correlation of 0.614 ($p < 0.01$). TI(Schedule) and TIOE(Cost) have a direct correlation with 0.507 ($p < 0.05$). Therefore, since TI(Schedule) has a positive correlation with both TIOE(Cost) and TIOE(Schedule), it may be inferred that TIOE(Schedule) and TIOE(Cost) indirectly correlate through TI(Schedule). Additional common observed variables for TIOE(Schedule) and TIOE(Cost) are TR(Cost) and TR(Schedule).

There is also not a direct relationship between TIOE(Cost) and TIOE(Guideline). However, there is a direct positive correlation between TI(Guideline)[Number of patents filed] and TIOE(Guideline), as well as TI(Guideline)[Number of patents filed] and TIOE(Cost). Therefore, it may be inferred that TIOE(Guideline) and TIOE(Cost) indirectly correlate through TI(Guideline)[Number of patens filed].

TI Construct

TI(Guideline)[Number of patents issued] and TI(Guideline)[Number of patents filed] are not directly correlated. However, these two observed variables share three common observed variables TI(Schedule), TR(Schedule), and TR(Cost). TI(Guideline)[Number of patents issued] and TI(Schedule) are directly correlated with 0.433 ($p < 0.01$) and do not share any common observed variables. TI(Guideline)[Number of patents issued] and TI(Audience) are not directly correlated. TI(Guideline)[Number of patents filed] and TI(Schedule) are directly correlated 0.309 ($p < 0.05$) and share a common variable of TIOE(Cost). TI(Schedule) and TI(Audience) are not directly correlated.

TR Construct

TR(Audience) is not directly correlated to either TR(Schedule) or TR(Cost) and do not share any common variables. TR(Schedule) is not directly correlated to TR(Cost). However, these variables share common observed variables of TIOE(Schedule), TI(Guideline)[Number of patents filed], TI(Guideline)[Number of patents issued], and TIOE(Cost).

Interrelationships between the three constructs

TI(Audience)/TR(Audience) are directly correlated to TIOE(Cost) with -0.825 ($p < 0.01$) and do not share any common variables. TI(Guideline)[Number of patents filed] and TIOE(Cost) share common observed variables of TR(Schedule) and TR(Cost). TI(Schedule) and TIOE(Cost) are directly correlated with 0.507 ($p < 0.05$) and share a common variable of TI(Guideline)[Number of patents filed]. TI(Schedule) and TIOE(Schedule) are directly correlate with 0.614 ($p < 0.01$) and do not share any common variables. TI(Guideline)[Number of patents filed] and TIOE(Guideline) are directly correlated with 0.598 ($p < 0.01$) and do not share any common variables. TI(Guideline)[Number of patents issued] and TIOE(Guideline) are directly correlated with 0.314 ($p < 0.05$) and share a common observed variable TIOE(Schedule). TIOE(Cost) and TR(Cost) are directly correlated with 0.677 ($p < 0.05$) and have a common observed variable of TI(Guideline)[Number of patents filed]. TIOE(Cost) and TR(Schedule) are directly correlated with 0.711 ($p < 0.05$) and have a common observed variable of TI(Guideline)[Number of patents filed]. TIOE(Schedule) and TR(Schedule) are directly correlated with 0.691 ($p < 0.01$) and have a common observed variable of TI(Guideline)[Number of patents issued]. TIOE(Schedule) and TR(Cost) are directly correlated with 0.644 ($p < 0.01$) and have a common observed variable of TI(Guideline)[Number of patents issued].

Conclusion

The model cannot be simplified possibly because of time lag. Recommendation is to further analyze the time lag for each observed variable using time series analysis for two case studies.

6.3.2 Lagged Cross Correlation Time Series Data Analysis

The detailed data analysis is needed as some of the expected correlations was not shown by performing quantitative data analysis at lag = 0. In addition, the quantitative data analysis at lag = 0 for the conservative, and un-conservative cases suggests that in the un-conservative cases, the results showed unrealistic correlations between the bivariate. Using conservative data eliminates unrealistic correlations resulting from data that is comparing small values with the zero values. When small values are being correlated with the zero values, the resulting analysis of the bivariate may appear that there is strong correlation, when in actuality, the correlation between the bivariate were misrepresented. Moreover, the data from the exploratory data analysis suggests that there may be some time lag between the bivariate sets. Hence, this section aims to perform lagged cross correlation time series analysis on the conservative operationalized data that resulted from Chapter 5.

A simple lagged cross correlation time series analysis was performed over several time periods specific to each bivariate being analyzed. Lagged correlation may be lagging ahead or behind, where a variable may be referred to as lagging or leading. The data used for the simple lagged cross correlation began with the dataset used from chapter 5 as a baseline. From that dataset, each bivariate set of data was shifted to lead and to lag. For each lead or lag set, Pearson's correlation coefficient was determined using SPSS. Pearson's correlation coefficient was then plotted for each lead and each lag time, where negative value between -1 to -10 represents "lead" time in years, and positive value between 1 to 10 represents "lagged" time in years. The same criteria in terms of strength between the variables that was described and used in Chapter 4, was also used for this analysis.

The aim of performing the lagged cross correlation is to determine at what lag or lead time is the strongest correlation for each bivariate. Once this is determined, comparisons between the current situation and the lag or lead time, if that exists, will be analyzed. Finally, case specific operationalized conceptual models will be proposed using the observations made with the lagged cross correlation results.

Summary of Variables for Simplified Model for Case 1

The results for the conservative case for lagged cross correlation between all of the bivariate sets for case study 1 are shown in Table 6-4. There are several bivariate sets that show no significant correlations. Those bivariate sets are listed with a brief description of the results in Appendix 6A. The rest of the bivariate sets, 14 total, show significant correlation and will be further described below in terms of unexpected and expected results.

Table 6-4. Conservative Lagged Cross Correlation Coefficient Matrix

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.668* (TIOE[Guideline], x-10)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.978** (TIOE[Schedule], x+10)	-0.904** (TIOE[Guideline], x+8)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.806** (TI[Schedule], x+7)	-0.420* (TIOE[Guideline], x+1)	0.870* (TI[Schedule], x-6)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.852** (TIOE[Schedule], x+9)	-0.433* (TI[Guideline], x-8)	0.902** (TI[Guideline), x=0)	*no significant correlation*	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.908** (TIOE[Schedule], x-10)	-0.906** (TIOE[Guideline], x-5)	-0.892** (TI/TR[Audience], x+5)	*no significant correlation*	-0.706** (TI[Guideline], x-3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	*no significant correlation*	*no significant correlation*	0.998* (TIOE[Cost], x=0)	*no significant correlation*	*no significant correlation*	*no significant correlation*	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation - too little data points*	1.000

*$p < 0.05$ is denoted as **
*$p < 0.01$ is denoted as ***
'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

The values in Table 6-4 were derived from Table 6C-2 through Table 6C-22 in Appendix 6C. The coefficient correlation values referred to in this paragraph will all be from Table 6C-2 through Table 6C-22 in Appendix 6C. All significant correlation coefficient values that are highlighted in green are summarized in Table 6.3-4. Where there are no significant correlation coefficients found, the term "no significant correlation" was listed in Table 6.3-4 for those bivariate. Those significant correlation coefficient values that are highlighted in green are the highest values in comparison to the other significant correlation coefficient values from Table 6C-2 through Table 6C-22. Those significant values that are highlighted in yellow indicate the other possible correlation coefficients that are significant, but not the most significant.

Unexpected Cross Correlation Results

The term "unexpected" used in this chapter is in the context of correlation results that were not in line with the relationships that were observed in literature or during the qualitative data analysis. These unexpected results will be evaluated by the SMEs in Chapter 7.

TIOE[Guideline] and TIOE[Cost]

The results for TIOE[Guideline] and TIOE[Cost] are shown in Figure 6A-8a and Figure 6A-8b in Appendix 6A. The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

It is common sense and expected that the uptake of TIOE[Guideline] and TIOE[Cost] do not have a lag. As a technology innovation is being heavily invested in, the organizations have funds to direct towards the resources necessary to develop the memo documents per technology innovation per year. As the funding becomes less, the number of resources to develop memos should decline as well. This can be seen in Figure 6A-8b when observing the trends for the normalized data values between the bivariate.

TIOE[Guideline] and TI[Schedule]

The results for TIOE[Guideline] and TI[Schedule] are shown in Figure 6A-9a and Figure 6A-9b in Appendix 6A. TIOE[Guideline] lags TI[Schedule] between 1-5 years inversely. As there is an uptake in the number of orders, the number of memos being developed for the technology innovation decreases. This is unexpected because as the orders are being made for an airplane program containing the new technology innovation, the memos should be developed shortly thereafter. It would be expected that as another airplane program begins again, especially investing in a new technology innovation, the number of memos would be expected to rise. The discrepancy may be due to the data used for TI[Schedule] and TIOE[Guideline] contains both airplane programs.

Expected Cross Correlation Results

The term "expected" used in this chapter is in the context of correlation results that were in line with the relationships that were observed in literature or during the qualitative data analysis.

TIOE[Schedule] and TIOE[Guideline]

The results for TIOE[Schedule] and TIOE[Guideline] are shown in Figure 6A-1a and Figure 6A-1b in Appendix 6A. TIOE[Guideline] leads TIOE[Schedule] by about 10 years in the conservative case. The guidelines for composites that are being developed takes some time as trade studies, testing, analysis, and approval process is involved for the composite materials planning to be used on the airplane.

TIOE[Guideline] inversely leads TIOE[Schedule] by about 3 years in the unconservative case, as shown in Figure 6A-1a in Appendix 6A. Although there may be some statistical significance shown in this case, it is unrealistic for guidelines at a large company to be fully developed in 3 years. Hence, using the statistical significance from the conservative case is recommended. If the result in the unconservative case is considered, then the explanation may be that as the deliveries are being made for an airplane program containing the new technology innovation, the memos should already be in place. It would be expected that as another airplane program begins again, especially investing in a new technology innovation, the number of memos would be expected to rise.

However, the operationalized variable of TIOE[Schedule] contains data for two airplane models that had orders at different timeframes. This may be one of the possible reasons why there is statistical significance showing TIOE[Guideline] possibly leading by 10 years or possibly lagging by 10 years. Moreover, the initial deliveries between the two airplane models were approximately 10 years apart.

TIOE[Schedule] and TIOE[Cost]

The results for this bivariate, as shown in Figure 6A-2a and Figure 6A-2b in Appendix 6A, are inconclusive as the investment in product per technology innovation per year may not be a complete data set. Therefore, the results shown in both the conservative and un-conservative cases using TIOE[Cost] will not be heavily considered in the final conclusions of this research. As shown in both cases, TIOE[Cost] is statistically significant and may be useful for companies to use as an indicator if a complete data set was available.

However, the operationalized variable of TIOE[Schedule] contains data for two airplane models that had orders at different timeframes. This may be one of the possible reasons why there is statistical significance showing TIOE[Schedule] possibly lagging TIOE[Cost] by 10 years, inversely lagging TIOE[Cost] by 5 years, and leading TIOE[Cost] by 5 years.

In addition, the data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

TIOE[Schedule] and TI[Schedule]

The results for TIOE[Schedule] and TI[Schedule] are shown in Figure 6A-3a and Figure 6A-3b in Appendix 6A. The most realistic is TI[Schedule] occurs about 7 years before TIOE[Schedule]. The plot shows a cyclic nature to this bivariate because of the nature of the airplane programs being considered in this data set. There are several different airplane derivatives of the same airplane model that are being ordered and delivered over a period of the observed ten years. Hence, as orders are being made with respect to a new airplane program containing new technology innovations such as composites, it is expected that about 7 years later, the airplane will be delivered.

TIOE[Schedule] and TI[Guideline]

The results for TIOE[Schedule] and TI[Guideline] are shown in Figure 6A-4a and Figure 6A-4b in Appendix 6A. TIOE[Schedule] lags TI[Guideline] by 9 years. The variable TIOE[Schedule] contains data from two different airplane models. Hence, the uptake of deliveries for each airplane model may increase at different periods of time depending on the market need.

TIOE[Schedule] and TI/TR[Audience]

The results for TIOE[Schedule] and TI/TR[Audience] are shown in Figure 6A-5a and Figure 6A-5b in Appendix 6A. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all of the audience included in this data set needed to take the training that is described in this research. In addition, the variable TIOE[Schedule] contains data from two different airplane models. Hence, the uptake of orders for each airplane model may increase at different periods of time depending on the market need.

TIOE[Guideline] and TI[Guideline]

The results for TIOE[Guideline] and TI[Guideline] are shown in Figure 6A-10a and Figure 6A-10b in Appendix 6A. TI[Guideline] leads TIOE[Guideline] inversely by about 8 years in the conservative case, as shown in Figure 6A-10b. It is expected that as the SMEs supporting the development of patents increases, the number of memo documents decreases because the resource is not available to develop the memos. It is also expected that the development of patents occurs prior to memos being developed, as patents can be developed while the technology innovation is still not mature. Memos are only developed when the technology innovation is fully mature.

TIOE[Guideline] and TI/TR[Audience]

The results for TIOE[Guideline] and TI/TR[Audience] are shown in Figure 6A-11a and Figure 6A-11b in Appendix 6A. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. However, if the data set were complete, it would be expected that as the number of memos are completed, that the number of engineers would decrease as resources are reassigned to other projects. It is also expected that the employment numbers increase before the number of memos are published as the development of memos need resources to be developed.

TIOE[Cost] and TI[Schedule]

The results for TIOE[Cost] and TI[Schedule] are shown in Figure 6A-14a and Figure 6A-14b in Appendix A. TIOE[Cost] leads TI[Schedule] by about 2 years. It is expected that investments in the product occurs before the number of orders are made, as the technology innovation often times are used as a selling point for the airplane. In reality, a company tends to invest in the next new technology innovation to be competitive with competing companies. Once there is some promise shown in a technology innovation, the company will then begin selling the possibilities and competitive advantage that the new technology innovation brings to the customers. The company will then aim to gain orders from customers.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

TI[Guideline] and TIOE[Cost]

The results for TI[Guideline] and TIOE[Cost] are shown in Figure 6A-15a and Figure 6A-15b in Appendix 6A. It is expected that there be no lag between these two variables. As there is an uptake in investment in a technology innovation, the funding would be available for resources to research, develop and file for patents for a technology innovation. Hence, an uptake in TI[Guideline] would be expected at the same time as during an uptake for TIOE[Cost].

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

TIOE[Cost] and TI/TR[Audience]

The results for TIOE[Cost] and TI/TR[Audience] are shown in Figure 6A-16a and Figure 6A-16b in Appendix 6A. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. If the exact data needed for TI/TR[Audience] was available, the expected result would be for the number of employees to uptake around the same time as the investment in product per technology innovation. Once there is funding for the technology innovation, the funding is allocated to however many resources as needed to work with the technology innovation. In the conservative case, there is a significant correlation that supports this expectation.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

TIOE[Cost] and TR[Schedule]

The results for TIOE[Cost] and TR[Schedule] are shown in Figure 6A-17a and Figure 6A-17b in Appendix 6A. There is almost a perfect correlation between these two variables.

As the data set for TR[Schedule] was limited between each organization, the interpretation of these results may not provide an accurate account for the rest of the company. It was expected that as investment in the technology innovation has an uptake, there should be a positive uptake in the number of course hours corresponding to the technology innovation shortly thereafter. Therefore, a positive correlation was expected in this case.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

TI[Guideline] and TI/TR[Audience]

The results for TI[Guideline] and TI/TR[Audience] are shown in Figure 6A-23a and Figure 6A-23b in Appendix 6A. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. The results suggest that as TI[Schedule] leads TI/TR[Audience] 2-3 years, there is a negative correlation between these two variables. The results also suggest that as TI[Schedule] lags TI/TR[Audience] by 3-4 years, there is a strong positive correlation.

6.4 Case 2. Nanotechnology *(Representing technology early in the maturity cycle)*

6.4.1 Cross Correlation Time Series Data Analysis for Lag = 0

Both conservative and un-conservative cross correlations for lag time = 0 are shown in Table 6-5, Table 6-6, and Table 6-7. It is expected that there be some lag time between courses ready to be delivered and TI and TIOE variables. The fact that the un-conservative cases show several significant correlations for TR variables at lag time = 0 seem unrealistic. Hence, for this research, the conservative cross correlation matrix is taken into consideration more strongly than the un-conservative cases. TIOE[Schedule] not considered for Case 2 as nanotechnology has not been implemented onto the airplane. The technology is still under development. TIOE[Guideline] is not considered for Case 2 as nanotechnology is not a mature technology where memos can be written.

Table 6-5. Conservative at Lag = 0 [With no leading zeroes for any bivariate data sets for lag = 0]

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.203 (p = 0.600)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.019 (p = 0.961)	0.238 (p = 0.252)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.550 (p = 0.125)	-0.238 (p = 0.037)	-0.302 (p = 0.224)	1.000		
Total Number of Courses Delivered [TR(Schedule)]	-0.006 (p = 0.989)	0.337 (p = 0.415)	-0.341 (p = 0.408)	-0.496 (p = 0.212)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.148 (p = 0.751)	0.458 (p = 0.253)	-0.466 (p = 0.245)	-0.553 (p = 0.155)	0.939**	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant values between lag time = 10 and lead time = 10

Table 6-6. Un-conservative at Lag = 0 [With leading zeroes for case by case basis for lag = 0]

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.511*	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.619**	0.406**	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.925**	-0.238	-0.302	1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.226	0.618**	0.375**	-0.520*	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.341	0.683**	0.324*	-0.536*	0.939**	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant values between lag time = 10 and lead time = 10

Table 6-7. Extreme un-conservative case at Lag = 0 [With leading zeroes for all bivariate cases for lag = 0]

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.670**	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.632**	0.432**	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market	-0.925**	-.238	-.302	1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.676**	0.677**	0.388**	-0.520*	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.695**	0.726**	0.388*	-0.536*	0.981**	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant values between lag time = 10 and lead time = 10

Observations for Conservative Case

There was only one direct correlation for Case 2 for the conservative case. TR(Schedule)[Total Number of Courses Delivered] and TR(Cost)[Total Number of Students Completing Course] had direct correlation with 0.939 ($p < 0.01$).

Conclusions

The model cannot be simplified possibly because of time lag. Recommendation is to further analyze the time lag for each observed variable using time series analysis for two case studies.

Observations for Un-Conservative Case

TIOE Construct

None of the observed variables for the TIOE construct are directly correlated. Possibly when a technology is early in the maturity cycle, the high level business is not deeply involved and integrated with the training for this technology yet. When a technology is early in its maturity stages, the training is integrated at a localized level directly with the technology innovation, and indirectly with the business at the localized level through the TI construct. When comparing to a more mature technology innovation like composites in Case 1, the mature technology generally has direct correlation between all three constructs, specifically direct correlation between the business and the training.

TI Construct

TI(Guideline)[Number of patents issued] and TI(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.557 ($p < 0.01$). Both of the variables share a common observed variable of TIOE(Schedule). TI(Guideline)[Number of patents filed] and TI(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.406 ($p < 0.05$). Both of the variables share common observed variables of TIOE(Schedule), TIOE(Cost), TR(Schedule), and TR(Cost). TI(Audience) does not directly correlate with any of the other observed variables within the TI construct.

TR Construct

All three of the observed variables for the TR construct directly correlate with each other. TR(Audience) and TR(Schedule) are directly correlated with a Pearson's correlation coefficient of -0.520 ($p < 0.05$). They have a common observed variable of TR(Cost). TR(Audience) and TR(Cost) are directly correlated with a Pearson's correlation coefficient of -0536 ($p < 0.05$). They have a common observed variable of TR(Schedule). TR(Schedule) and TR(Cost) are directly correlated with a Pearson's correlation coefficient of 0.939 ($p < 0.01$). They have common observed variables of TR(Audience), TI(Guideline), and TI(Schedule).

Interrelationships between the three constructs

TIOE(Schedule) and TI(Guideline)[Number of patents issued] are directly correlated with a Pearson's correlation coefficient of 0.782 ($p < 0.01$). They both share a common observed variable of TI(Schedule). TIOE(Schedule) and TI(Guideline)[Number of patents filed] are directly correlated with a Pearson's correlation coefficient of 0.396 ($p < 0.01$). They share a common observed variable of TI(Schedule). TIOE(Schedule) and TI(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.614 ($p < 0.01$). They share common observed variables of TI(Guideline)[Number of patents filed] and TI(Guideline)[Number of patents issued]. TIOE(Cost) and TI(Audience) are directly correlated with a Pearson's correlation coefficient of -0.925 ($p < 0.01$). They do not share any common observed variables. TIOE(Cost) and TI(Guideline)[Number of patents filed] are directly correlated with a Pearson's correlation coefficient of 0.619 ($p < 0.01$). They share a common observed variable of TI(Schedule). TIOE(Cost) and TI(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.511 ($p < 0.05$). They share a common observed variable of TI(Guideline)[Number of patents filed]. TI(Guideline)[Number of patents filed] and TR(Cost) are directly correlated with a Pearson's correlation coefficient of 0.324 ($p < 0.05$). They share a common observed variable of TR(Schedule). TI(Guideline)[Number of patents filed] and TR(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.375 ($p < 0.01$). They share a common observed variable of TR(Cost). TI(Schedule) and TR(Cost) are directly correlated with a Pearson's correlation coefficient of 0.683 ($p < 0.01$). They share a common observed variable of TR(Schedule). TI(Schedule) and TR(Schedule) are directly correlated with a Pearson's correlation coefficient of 0.618 ($p < 0.01$). They share a common observed variable of TR(Cost).

Conclusions

The model cannot be simplified possibly because of time lag. Recommendation is to further analyze the time lag for each observed variable using time series analysis for two case studies.

6.4.2 Lagged Cross Correlation Time Series Data Analysis

Summary of Variables for Simplified Model for Case 2

The results for the conservative case for lagged cross correlation between all of the bivariate sets for case study 2 are shown in Table 6-8. There are several bivariate sets that show no significant correlations. Those bivariate sets are listed with a brief description of the results in Appendix 6B. The rest of the bivariate sets, seven total, show significant correlation and will be further described below in terms of unexpected and expected results.

Table 6-8. Conservative Lagged Correlation Coefficient Matrix

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	no significant correlation	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	no significant correlation	0.703** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	no significant correlation	no significant correlation	no significant correlation	1.000		
Total Number of Courses Delivered [TR(Schedule)]	no significant correlation	-0.774* (TI[Schedule], x-3)	0.787* (TI[Guideline], x-3)	0.901** (TI/TR[Audience), x+8)	1.000	
Total Number of Students Completing Course [TR(Cost)]	no significant correlation	-0.792* (TI[Schedule], x+4)	-0.814* (TI[Guideline], x+2)	-0.878** (TI/TR[Audience], x-3)	no significant correlation - too little data points	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

The values in Table 6-8 were derived from Table 6D-2 through Table 6D-22 in Appendix 6D, similarly to the approach taken during the development of conservative lagged correlation coefficient matrix for Case 1.

Unexpected Cross Correlation Results

The term "unexpected" used in this chapter is in the context of correlation results that were not in line with the relationships that were observed in literature or during the qualitative data analysis. These unexepected results will be evaluated by the SMEs in Chapter 7.

TI[Guideline] and TR[Schedule]

The results for TI[Guideline] and TR[Schedule] are shown in Figure 6B-11a and Figure 6B-11b in Appendix 6B. In the conservative case, TI[Guideline] inversely lags TR[Schedule] by about 2-5 years, as well as positively leads by 2-3 years. In the un-conservative case, the most significant positive correlation occurs when TI[Guideline] leads TR[Schedule] by about 2-3 years. As this is a technology that is early in the maturity cycle, it is not expected that training occurs later when the technology shows more promise.

TI[Guideline] and TR[Cost]

The results for TI[Guideline] and TR[Cost] are shown in Figure 6B-12a and Figure 6B-12b in Appendix 6B. In the conservative case, TI[Guideline] inversely lags TR[Cost] by about 1-5 years, as well as positively leads by 2-3 years. In the un-conservative case, the most significant positive correlation occurs when TI[Guideline] leads TR[Cost] by about 2-3 years. As this is a technology that is early in the maturity cycle, it is not expected that training occurs later when the technology shows more promise.

Expected Cross Correlation Results

The term "expected" used in this chapter is in the context of correlation results that were in line with the relationships that were observed in literature or during the qualitative data analysis.

TI[Schedule] and TI[Guideline]

The results for TI[Schedule] and TI[Guideline] are shown in Figure 6B-6a and Figure 6B-6b in Appendix 6B. In the conservative case, the results show that the strongest correlation occurs when TI[Guideline] leads 2-4 years before TI[Schedule]. It is expected that TI[Guideline] leads TI[Schedule]. It is also expected that the trends observed for this bivariate be cyclic in nature. That is, TI[Guideline] will always continue even after an airplane product is delivered as the technology innovation still exists. It is common that a technology innovation may be applied to other parts of the airplane in later models. Hence, there are significant correlations at different periods of time between this bivariate.

TI[Schedule] and TR[Schedule]

The results for TI[Schedule] and TR[Schedule] are shown in Figure 6B-8a and Figure 6B-8b in Appendix 6B. In the conservative case, TI[Schedule] leads TR[Schedule] by 3 years. This is depicting what is currently happening right now at the company. This does not suggest that this is the ideal way. It is in the scope of this research to recommend ideal situations for the companies to consider based on what was observed in this chapter, as well as the Chapter 2, 3, and 4.

TI[Schedule] and TR[Cost]

The results for TI[Schedule] and TR[Cost] are shown in Figure 6B-9a and Figure 6B-9b in Appendix 6B. In the conservative case, TI[Schedule] lags TR[Cost] by 4 years. The variable TI[Schedule] should be omitted from the data set as the technology innovation is too early in the maturity cycle to be placed on the airplane. That is, for this case study, the technology innovation is not production ready. Hence, any results seen here should not be taken into consideration when drawing conclusions for this chapter.

TR[Schedule] and TI/TR[Audience]

The results for TR[Schedule] and TI/TR[Audience] are shown in Figure 6B-13a and Figure 6B-13b in Appendix 6B. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. That is, it may be possible that not all the audience included in this data set will need to take the training that is described in this research. In both the conservative and un-conservative cases, the most significant positive correlation occurs when TI/TR[Audience] lags TR[Schedule] by about 8 years. In this case, where the technology is early in the maturity cycle, it is expected that the training was offered too early, where the targeted audience was not available and/or not ready to take the courses.

TR[Cost] and TI/TR[Audience]

The results for TR[Cost] and TI/TR[Audience] are shown in Figure 6B-14a and Figure 6B-14b in Appendix 6B. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. That is, it may be possible that not all the audience included in this data set will need to take the training that is described in this research. Similar to TR[Schedule], in both the conservative and un-conservative cases, the most significant positive correlation occurs when TI/TR[Audience] lags TR[Cost] by about 8 years. In this case, where the technology is early in the maturity cycle, it is expected that the training was offered too early, where the targeted audience was not available and/or not ready to take the courses.

6.5 Case Specific Operationalized Conceptual Models

Three case specific operationalized conceptual models resulted from the quantitative data analysis. These are shown in Figure 6-1 through Figure 6-3. The corresponding normalized plots, and lead and lag time series correlation analysis plots for each bivariate showing significant correlation are shown in Figure 6-4 through Figure 6-9. Moreover, the corresponding significant correlation coefficient values shown in Figure 6-1 through Figure 6-3 were obtained from the SPSS outputs shown in Table 6-9 through Table 6-14.

The significant correlation coefficient values shown in Figure 6-1 through Figure 6-3 were based on the significant values highlighted in green in Appendix 6C and Appendix 6D, for Case 1 and Case 2, respectively. The significant correlation coefficient values that are highlighted in yellow are represented in Figure 6-1 through Figure 6-3 in parentheses. There are values that were highlighted in green or yellow that was not represented in these figures as it was decided by the research, based on what was observed in literature and the qualitative data analysis, that the values shown in Figure 6-1 through Figure 6-3 best represent the relationship between the constructs. As this was a decision made by the researcher, these conceptual models will be evaluated further with SMEs in Chapter 7. The SMEs will help provide context behind these significant correlation coefficient values, as well as help explain whether or not the values in parentheses should also be considered.

The relationships between the operationalized variables are indicated with double headed arrows or single headed arrows in the context of this research. In this research, variables are determined to have a relationship if there is a significant correlation between the bivariate. The correlation values for each bivariate were determined and discussed in the previous Section 6.3 and Section 6.4 of this chapter.

A doubled headed arrow refers to a significant correlation between the bivariate at lag = 0. A single headed arrow refers to a significant correlation between the bivariate at a specific lag or lead time. The direction of the single headed arrow is determined by which variable "leads," thereby indicating that one variable is driving the other variable within a bivariate set by a certain number of years.

The relationships between the operationalized variables representing each construct infer the relationship between the constructs in terms of the operationalized variables. The *inferred* relationships between the constructs are shown as dotted double headed arrows or single headed arrows. A dotted double headed arrow between two constructs indicate that the operationalized variables for each of the two constructs had a significant correlation at lag = 0. A dotted single headed arrow between two constructs indicates that the operationalized variables for each of the two constructs had a significant correlation at a lag or lead time. The direction of a dotted single headed arrow between two constructs *infers* that the operationalized variable for one construct "leads" the operationalized variable for the other construct. If construct A is said to "lead" construct B, then all of the significant operationalized variables representing construct A leads all of the significant operationalized variables representing construct B. The term "significant" is used here to differentiate between the operationalized variables that were all used during the quantitative data analysis and the operationalized variables that were deemed significant after the quantitative analysis. Moreover, the number of years that a variable is leading another variable between the constructs may be summed up. For example, if for construct B, there are two operationalized variables representing construct B (variable 1 and variable 2), and variable 1 leads variable 2 by five years; and if for construct A, there is one variable representing construct A (variable 3), and variable 3 leads variable 1 by 15 years; then it can be concluded that variable 3 leads variable 2 by 20 years.

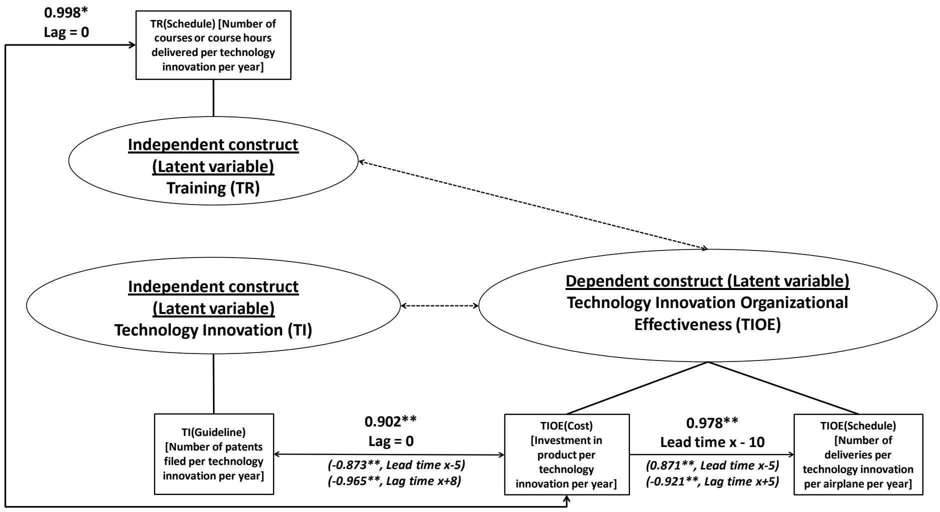


Figure 6-1. Case 1, model 1 – possible model based on quantitative data analysis

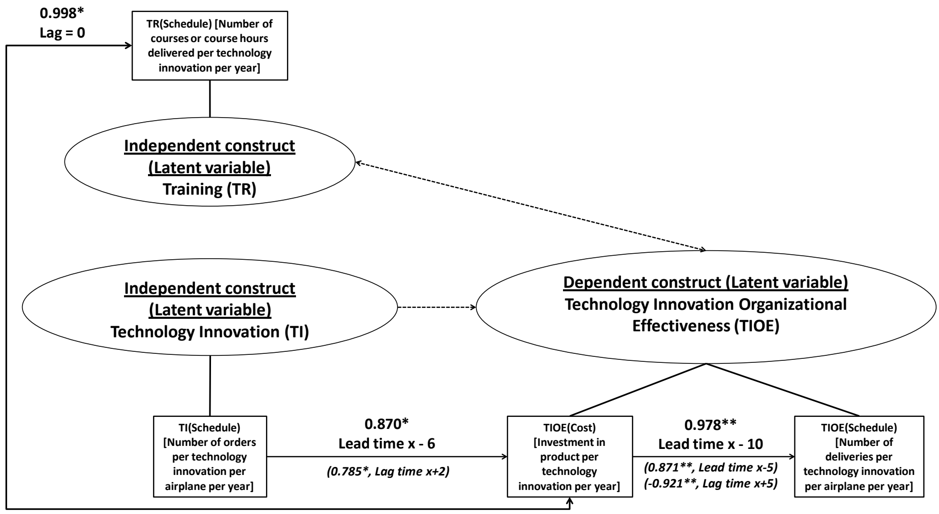


Figure 6-2. Case 1, model 2 – possible model based on quantitative data analysis

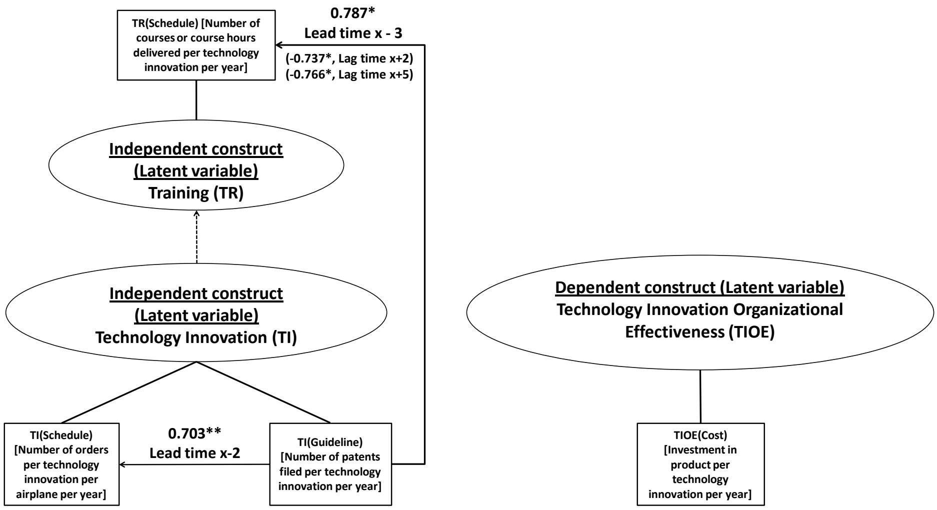


Figure 6-3. Case 2 – possible model based on quantitative data analysis

Table 6-9. Case 1 Composites - SPSS output of Pearson correlation coefficient for bivariate TIOE[Cost] and TR[Schedule]

Correlations

				TIOEc(0)	TRs
TIOEc(0)	Pearson Correlation			1	.998[*]
	Sig. (2-tailed)				.037
	N			3	3
	Bootstrap[d]	Bias		0[e]	.492[e]
		Std. Error		0[e]	.862[e]
		95% Confidence Interval	Lower	1[e]	-1.000[e]
			Upper	1[e]	1.000[e]
TRs	Pearson Correlation			.998[*]	1
	Sig. (2-tailed)			.037	
	N			3	3
	Bootstrap[d]	Bias		.492[e]	0[e]
		Std. Error		.862[e]	0[e]
		95% Confidence Interval	Lower	-1.000[e]	1[e]
			Upper	1.000[e]	1[e]

*. Correlation is significant at the 0.05 level (2-tailed).

d. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

e. Based on 888 samples

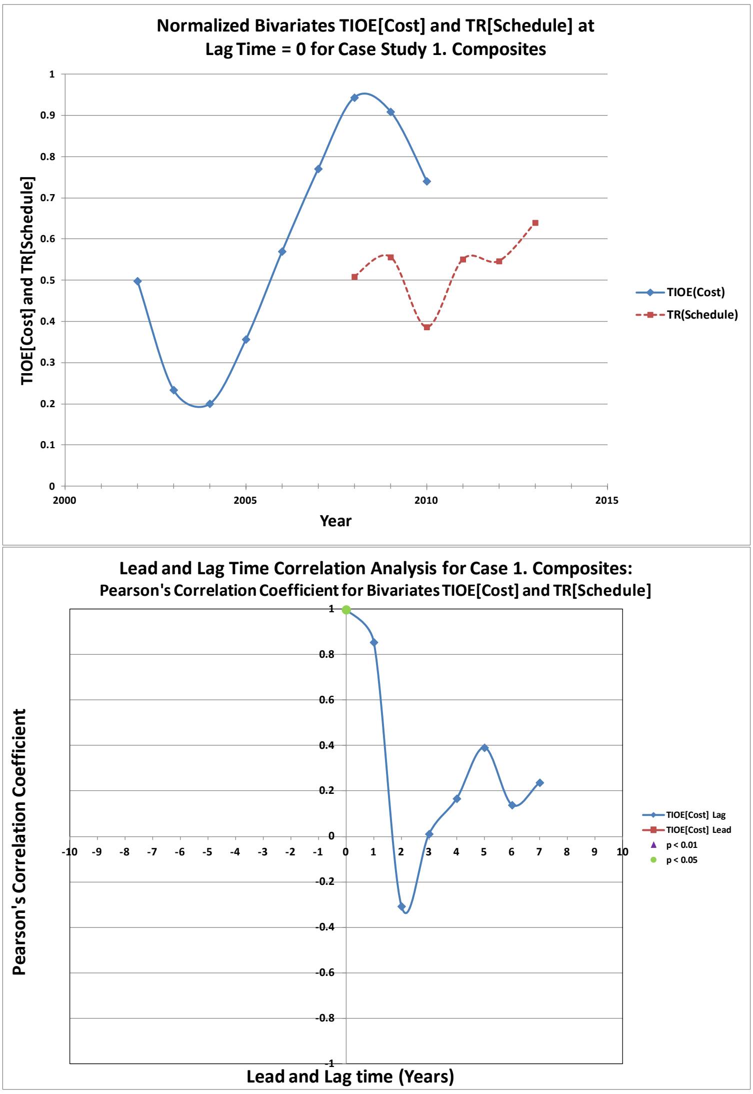


Figure 6-4. Case 1 Composites - Normalized bivariates TIOE[Cost] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Schedule]

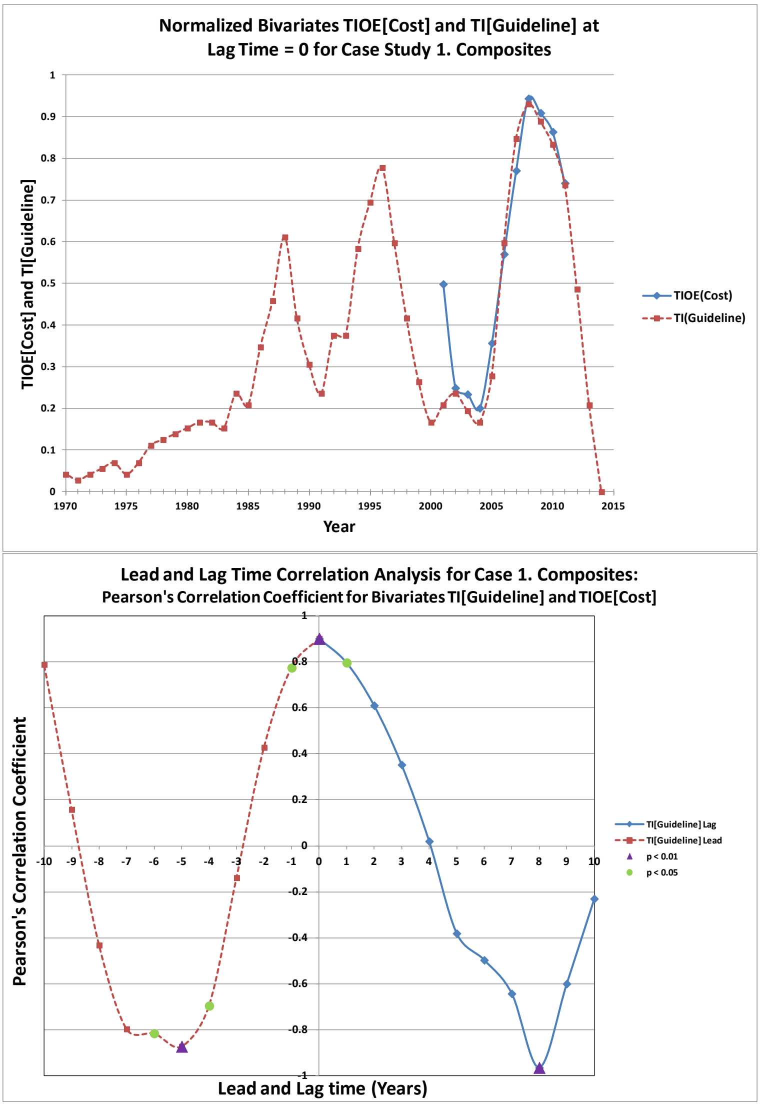


Figure 6-5. Case 1 Composites - Normalized bivariates TIOE[Cost] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Guideline]

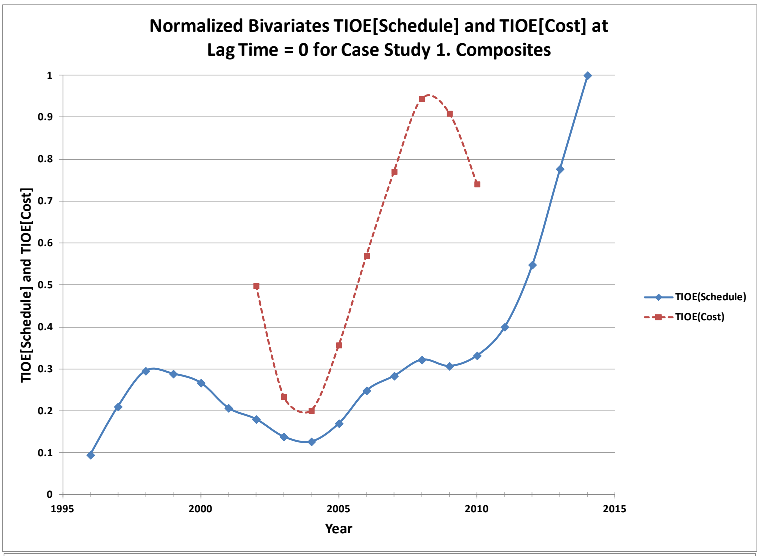
Table 6-10. Case 1 Composites - SPSS output of Pearson correlation coefficient for bivariate TIOE[Cost] and TI[Guideline]

Correlations

				TIOEc	Tig(0)
TIOEc	Pearson Correlation			1	.902**
	Sig. (2-tailed)				.001
	N			9	9
	Bootstrap[c]	Bias		0	.005
		Std. Error		0	.055
		95% Confidence Interval	Lower	1	.807
			Upper	1	.980
Tig(0)	Pearson Correlation			.902**	1
	Sig. (2-tailed)			.001	
	N			9	9
	Bootstrap[c]	Bias		.005	0
		Std. Error		.055	0
		95% Confidence Interval	Lower	.807	1
			Upper	.980	1

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples



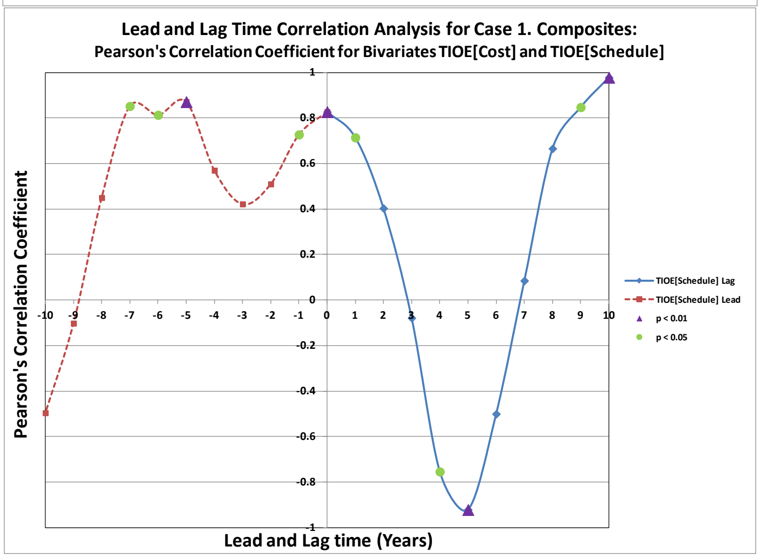


Figure 6-6. Case 1 Composites - Normalized bivariates TIOE[Schedule] and TIOE[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TIOE[Cost]

Table 6-11. Case 1 Composites - SPSS output of Pearson correlation coefficient for bivariate TIOE[Schedule] and TIOE[Cost]

Correlations

				TIOEs(10)	TIOEc
TIOEs(10)	Pearson Correlation			1	.978**
	Sig. (2-tailed)				.001
	N			6	6
	Bootstrap[d]	Bias		0[e]	.000[e]
		Std. Error		0[e]	.065[e]
		95% Confidence Interval	Lower	1[e]	.921[e]
			Upper	1[e]	1.000[e]
TIOEc	Pearson Correlation			.978**	1
	Sig. (2-tailed)			.001	
	N			6	6
	Bootstrap[d]	Bias		.000[e]	0[e]
		Std. Error		.065[e]	0[e]
		95% Confidence Interval	Lower	.921[e]	1[e]
			Upper	1.000[e]	1[e]

**. Correlation is significant at the 0.01 level (2-tailed).

d. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

e. Based on 999 samples

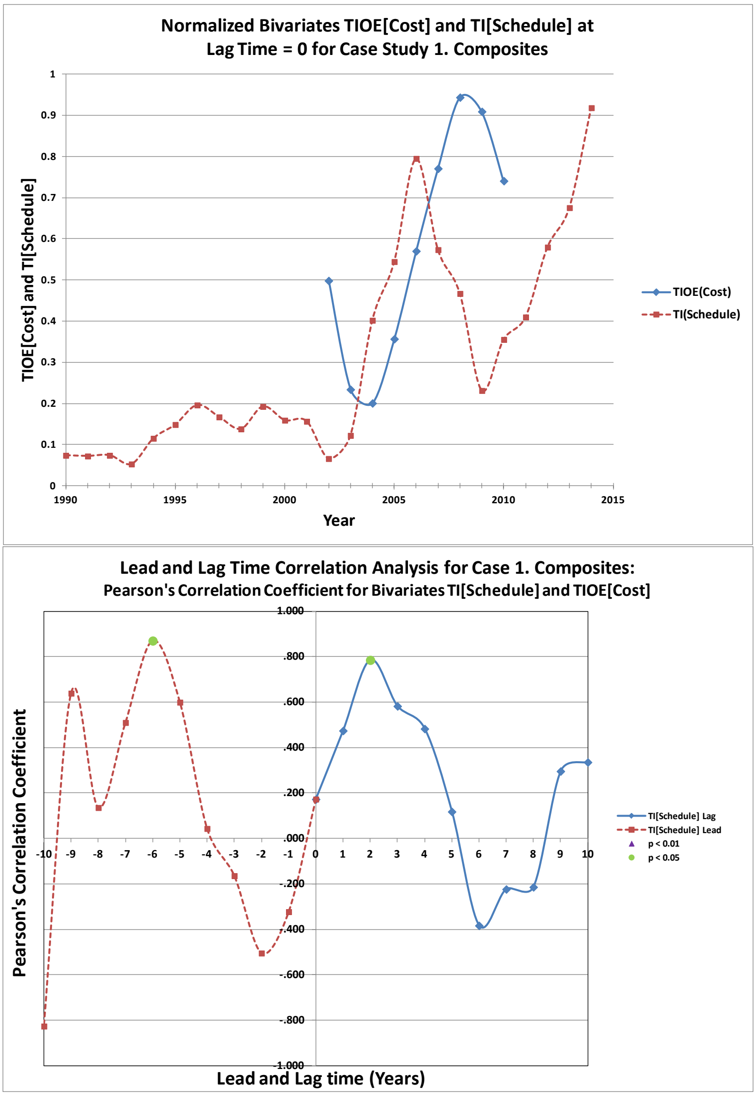


Figure 6-7. Case 1 Composites - Normalized bivariates TIOE[Cost] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Schedule]

Table 6-12. Case 1 Composites - SPSS output of Pearson correlation coefficient for bivariate TIOE[Cost] and TI[Schedule]

Correlations

				TIOEc	Tis(-6)
TIOEc	Pearson Correlation			1	.870*
	Sig. (2-tailed)				.011
	N			7	7
	Bootstrap[c]	Bias		0	-.043
		Std. Error		0	.202
		95% Confidence Interval	Lower	1	.350
			Upper	1	.996
Tis(-6)	Pearson Correlation			.870*	1
	Sig. (2-tailed)			.011	
	N			7	7
	Bootstrap[c]	Bias		-.043	0
		Std. Error		.202	0
		95% Confidence Interval	Lower	.350	1
			Upper	.996	1

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

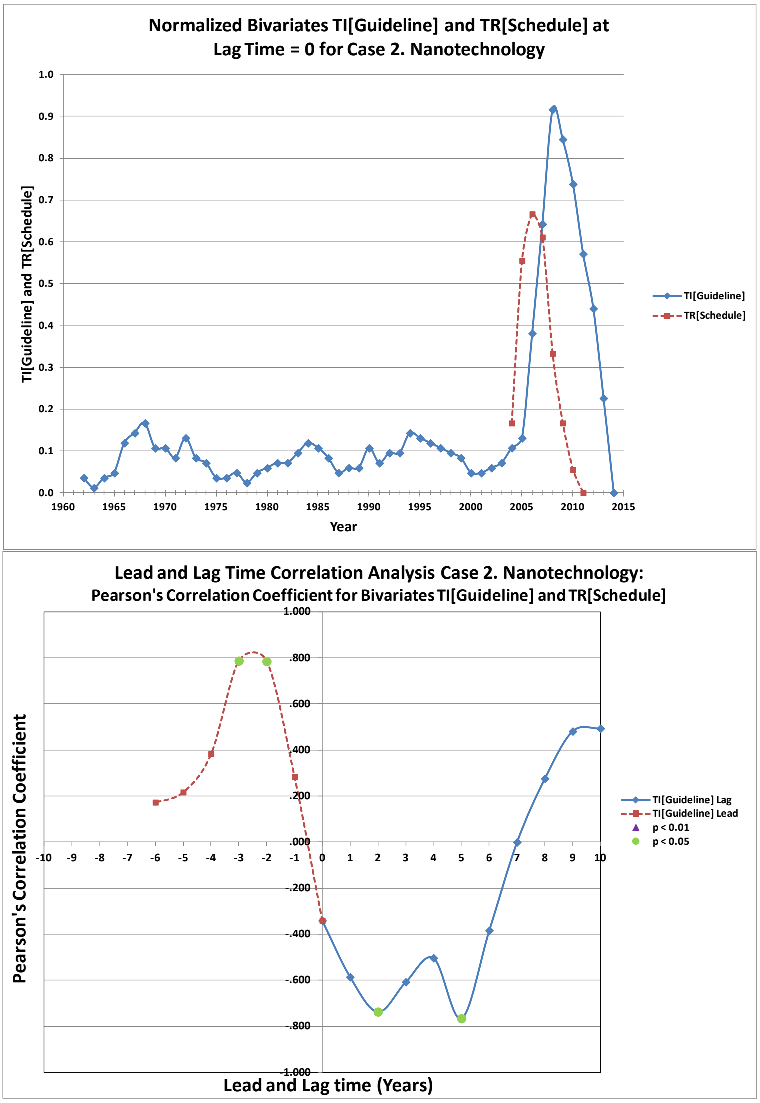


Figure 6-8. Case 2 Nanotechnology - Normalized bivariates TI[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Schedule]

Table 6-13. Case 2 Nanotechnology - SPSS output of Pearson correlation coefficient for bivariate TI[Guideline] and TR[Schedule]

Correlations

				Tig(-3)	TRs
Tig(-3)	Pearson Correlation			1	.787*
	Sig. (2-tailed)				.021
	N			8	8
	Bootstrap[c]	Bias		0	.004
		Std. Error		0	.142
		95% Confidence Interval	Lower	1	.479
			Upper	1	.975
TRs	Pearson Correlation			.787*	1
	Sig. (2-tailed)			.021	
	N			8	8
	Bootstrap[c]	Bias		.004	0
		Std. Error		.142	0
		95% Confidence Interval	Lower	.479	1
			Upper	.975	1

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

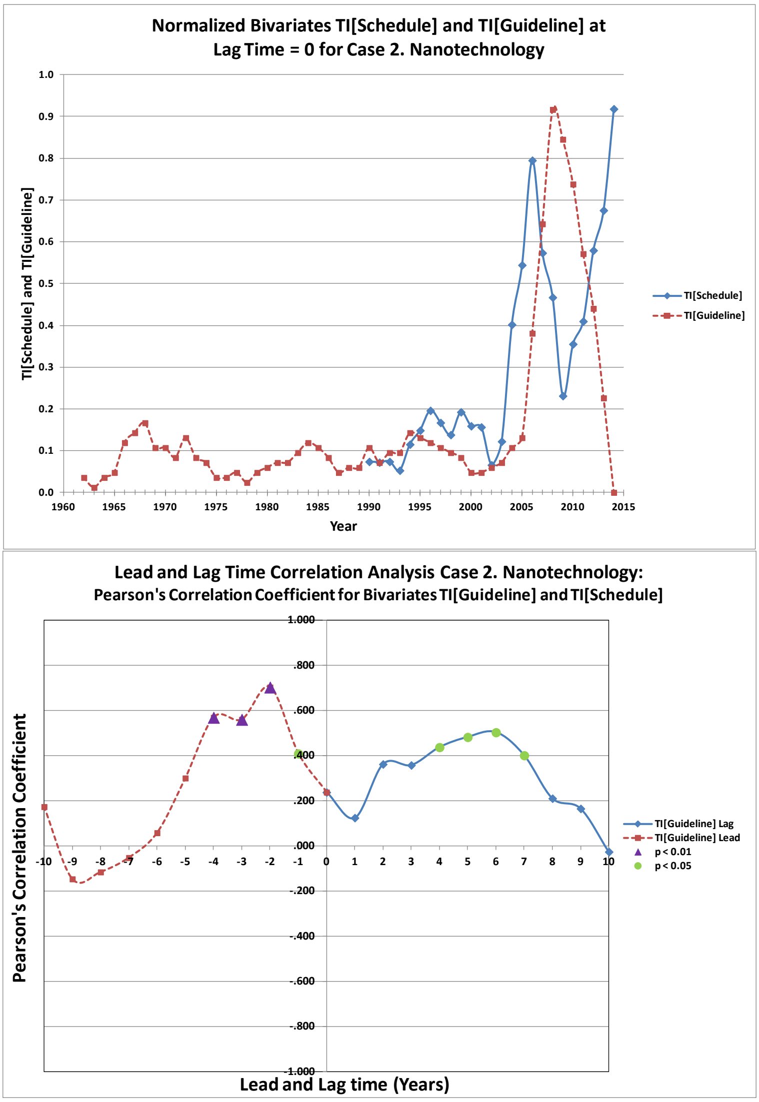


Figure 6-9. Case 2 Nanotechnology - Normalized bivariates TI[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI[Guideline]

Table 6-14. Case 2 Nanotechnology - SPSS output of Pearson correlation coefficient for bivariate TI[Schedule] and TI[Guideline]

Correlations

				Tis	Tig(-2)
Tis	Pearson Correlation			1	.703**
	Sig. (2-tailed)				.000
	N			23	23
	Bootstrap[c]	Bias		0	-.031
		Std. Error		0	.158
		95% Confidence Interval	Lower	1	.254
			Upper	1	.890
Tig(-2)	Pearson Correlation			.703**	1
	Sig. (2-tailed)			.000	
	N			23	23
	Bootstrap[c]	Bias		-.031	0
		Std. Error		.158	0
		95% Confidence Interval	Lower	.254	1
			Upper	.890	1

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Chapter 7

Evaluation Study: Evaluated Case Specific Operationalized Conceptual Models

This chapter is represented as Phase IV, shown in Figure 7, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. The aim of this chapter is to characterize solutions for the challenges that are conceptualized and specified during Phase II and Phase III. During Phase IV, quantitative data analysis was performed, where case specific operationalized conceptual models were developed. These case specific operationalized conceptual models will be further evaluated during the qualitative approach of Phase IV of the mixed methods research design through interviews with SMEs.

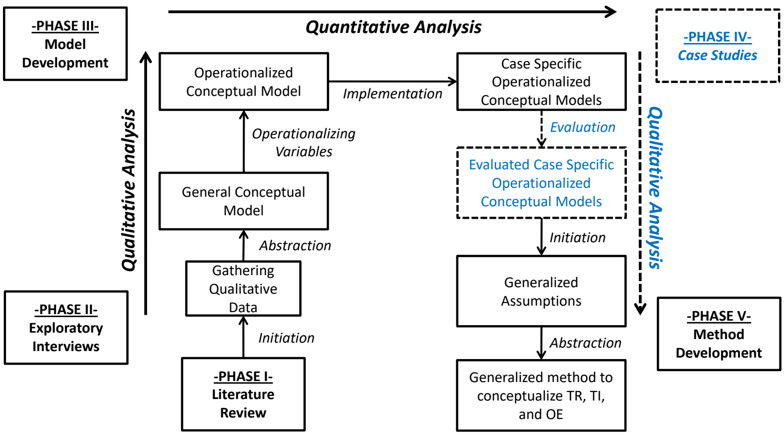


Figure 7. Phase IV of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

7.1 Motivation for Evaluating Case Specific Operationalized Conceptual Models

The motivation for evaluating the case specific operationalized conceptual models is to evaluate the results from the quantitative data analysis performed in Chapter 6. Specifically, the case specific operationalized conceptual models will be evaluated by engineering SMEs, where their input will be used to provide context to the conceptual models. Moreover, the SMEs input will provide consensus regarding which conceptual model most accurately depicts reality. The aim for this chapter is to further provide insight into the third research sub-question from Chapter 1: *How does the developed conceptual model show when to offer training when technology changes to positively influence organizational effectiveness?*

7.2 Discussion of Results from Quantitative Data Analysis

The discussion of results will be organized into three sub-sections. The first sub-section will compare Case 1 with Case 2. The second sub-section will compare the results from the quantitative data analysis results with the qualitative data analysis results. The third sub-section will compare the quantitative data analysis results with literature. The combination of the three comparison discussions will lead to general conclusions for this chapter. In addition, the comparisons listed in this section will form a baseline for the evaluation interview questions, where the results were presented to the SMEs and decision makers for their review and comments.

7.2.1 General Observations of the Quantitative Data

There were cases where there were a few distinct peaks in the data. This may indicate that the relationship between the two variables is cyclic in nature. There were cases where there were high significant values that occurred near the same timeframe. This may indicate that the most significant correlation coefficient is an approximation of the timeframe in which the bivariate have the strongest correlation. There were also cases where there were multiple peaks, which may indicate that the bivariate correlation is cyclic in nature. These are all assumptions that have been made based on what was observed in literature and in the qualitative data analysis. Moreover, these assumptions and observations will be further addressed during the evaluation interviews.

7.2.2 Comparison between Case 1 and Case 2

The purpose of comparing between Case 1 and Case 2 is to observe the differences, if any, between a technology that is fully matured versus a technology that is early in the maturity cycle. It is expected from observing literature and the findings from the qualitative data analysis that the maturity of the technology affects the relationships between the constructs of this research. By comparing Case 1 and Case 2 and showing that there are differences between the two in the way the constructs are affected, there will be strong suggestion that observing the maturity of a technology is critical during any decision making process that involves training and technology innovation.

Comparison 1

The relationships between the three constructs are dependent on the maturity level of the technology innovation. This can be clearly seen by observing the correlation coefficient matrices between Case 1 and Case 2. There are no common bivariate sets sharing strong significant correlations between Case 1 and Case 2. Case 1 represents a technology innovation that is mature, whereas Case 2 represents a technology innovation early in the maturity cycle. In Case 1, there are significant correlations between TR and OE, as well as between TI and OE. In Case 2, there are no significant correlations between TR and OE, and TI and OE. This suggests that when a technology innovation is early in the maturity cycle, the business (OE) is not investing heavily in the technology innovation yet. Moreover, it is expected that as the technology innovation matures, the business (OE) becomes more involved and invests more heavily in developing the technology innovation and formally training the engineers who will be using the technology innovation.

Comparison 2

The technology innovation in terms of number of patents [TI(Guideline)] tends to drive training in terms of the number of student hours [TR(Schedule)] in Case 2 and not in Case 1. In Case 2, [TI(Guideline)] leads [TR(Schedule)] by three years (0.787, $p < 0.01$). In Case 1, there are no significant correlations between the two variables. One possible reason for this difference is that for mature technologies, TI must be involved with TIOE in terms of the number of investment per technology innovation per year, [TIOE(Cost)], prior to engaging with TR. As TR is considered an overhead cost, it is necessary for TI to have engagement with TIOE to support TR. In Case 2, the technology innovation is too early in the maturity cycle for TIOE to be involved. Hence, the investment in the technology innovation is limited. Moreover, this may infer that the training that is delivered to the engineers at this stage of technology innovation maturity is not as extensive as the training that is delivered to the engineers for a technology innovation that is fully mature.

Comparison 3

The technology innovation in terms of the number of patents [TI(Guideline)] tends to drive TI in terms of the number of orders [TI(Schedule)] in Case 2 and not in Case 1. In Case 2, [TI(Guideline)] leads [TI(Schedule)] by two years (0.703, $p < 0.01$). In Case 1, there are no significant correlations between the two variables. One possible reason for this difference is that for mature technologies, TI[Guideline] and TI[Schedule] correlate through TIOE[Cost]. TI[Guideline] significantly correlates with TIOE[Cost] at lag = 0 (0.902, $p < 0.01$). TI[Schedule] leads TIOE[Cost] by six years (0.870, $p < 0.05$). Hence, it can be inferred that TI[Schedule] also leads TI[Guideline] by six years for a mature technology innovation. In Case 2, the technology innovation is too early in the maturity cycle for TIOE to be involved.

Comparison 4

The technology innovation in terms of the number of orders [TI(Schedule)] occur about 16 years before the number of deliveries [TIOE(Schedule)] for Case 1 and not in Case 2. Moreover, there is an inferred correlation between TI(Schedule) and TIOE(Schedule) through TIOE(Cost) in terms of the number of investment per technology innovation per year. In Case 2, there are no significant correlations between the two variables because the relationship with TIOE does not exist due to the technology innovation being too early in the technology maturity cycle.

Comparison 5

It is inferred that the training in terms of the number of courses delivered per technology innovation per year [TR(Schedule)] increases 10 years before the number of deliveries per year [TIOE(Schedule)] for Case 1 and not in Case 2. Moreover, this inferred correlation between TR(Schedule) and TIOE(Schedule) exists through TIOE(Cost). There is a direct significant correlation between TR(Schedule) and TIOE(Cost) at lag = 0, and TIOE(Cost) is significant correlated with TIOE(Schedule) at a lead time on 10 years. In Case 2, there are no significant correlations between the two variables because the relationship with TIOE does not exist due to the technology innovation being too early in the technology maturity cycle.

Comparison 6

In Case 1, the TI in terms of the number of patents per technology innovation per year [TI(Guideline)] and TIOE in terms of the number of investment per technology innovation per year [TIOE(Cost)] is significantly correlated at lag = 0 (0.902, $p < 0.01$). This is not the case in Case 2. In Case 2, there are no significant correlations between the two variables because the relationship with TIOE does not exist due to the technology innovation being too early in the technology maturity cycle.

Comparison 7

In Case 1, the TR in terms of the number of courses delivered per technology innovation per year [TR(Schedule)] and TIOE in terms of the number of investment per technology innovation per year [TIOE(Cost)] is significant at lag = 0 (0.998, $p < 0.01$). This is not the case in Case 2. In Case 2, there are no significant correlations between the two variables because the relationship with TIOE does not exist due to the technology innovation being too early in the technology maturity cycle.

7.2.3 Comparison between Quantitative and Qualitative Data

The purpose of comparing between the quantitative data analysis results and the qualitative data analysis results is to reflect between the case specific operationalized conceptual models and the general conceptual models. The general conceptual models that resulted from the qualitative data analysis gave a high level depiction of how the three constructs relate to each other. The qualitative data analysis did not provide the strength between the two constructs or bivariate within the constructs, nor provide the direction of correlation between the two bivariate. The case specific operationalized conceptual models resulting from the quantitative data analysis implemented the findings from the qualitative data analysis. This thereby shows the importance of a mixed methods approach for this research. It is the combination of both qualitative and quantitative data analysis that the goals of this research can be accomplished. Simply using one method would give a partial view and not the entire view of how these constructs interact within an engineering company.

The results from the qualitative data analysis may be viewed as subjective while the results from the quantitative data analysis are intended to be objective. There are a few observations made between the results from the qualitative data and quantitative data analyses. These observations are discussed in this sub-section.

Qualitative data suggests that the organization would have benefitted more if training was offered earlier for composites. The quantitative data suggests that the relationship between TR in terms of number of course hours delivered per technology innovation per year and TIOE in terms of investment in technology innovation per year are inversely significant at lag = 0. In addition, it can be inferred that since TIOE in terms of investment in technology innovation per year leads TIOE in terms of number of deliveries per year by 10 years, TR in terms of number of course hours delivered per technology innovation per year also leads TIOE in terms of number of deliveries per year by 10 years. This confirms the findings from the qualitative data that training should lead the organization, and that the current state (lag = 0) is not the optimum timing for training with respect to composites. The qualitative data suggests that the organization would have benefitted more if training was offered earlier for composites, but no specific timeframe was suggested. The quantitative data suggests that the most significant correlation between TR and TIOE occurs about 10 years lead time for TR.

Qualitative data suggests that the organization would benefit when management (OE) is directly involved in and supporting training. The quantitative data suggests that OE is necessary in the relationship between TI and TR for a mature technology innovation. The relationship between all three constructs is most significant when OE is involved for a mature technology innovation. In a technology innovation that is early in the maturity cycle, quantitative data suggests that it is not necessary that OE is involved between the relationship of TI and TR.

Qualitative data suggests that the organization would benefit when SMEs (TI) are directly involved in and supporting training. The quantitative data does not address this observation as there was not enough available data to operationalize the variable "SME."

7.2.4 Comparison between Quantitative Data and Literature

The purpose of comparing between quantitative data analysis results and what was observed in literature is to reflect on the major findings that supported literature, as well as further explained what was described in general in literature. This comparison helps "bridge" what was missing in literature. Most of what was in literature was purely theoretical and not applicable within the context of an engineering company. This section aims to provide the practical aspect that aligns with the theory found in literature.

In literature, these three constructs were not studied together as a system. Rather, there is literature discussing the constructs individually or as bivariates. There is extensive literature about OE, TI, and TR. There is also extensive literature about OE and TI and OE and TR. There are some indirect literature regarding the relationship between TI and TR. There is no existing literature studying the effect that these three constructs have on each other. With this said, there are some similar things found in the quantitative data analysis as in literature.

Literature suggests that management involvement (OE) is influential to training (TR) success.

Quantitative case studies suggest that for mature technology innovations, management involvement in training is more apparent than for technology innovations early in the maturity cycle. Management involvement is influential to training success as the technology innovations become more mature. Moreover, management involvement is less influential to training success as the technology innovations are less mature.

Literature suggests that aligning training to users of new technology is a challenge in terms of identifying specific training needs.

Quantitative case studies showed inconclusive results regarding the audience in terms of training and technology innovation. This may possibly be due to the raw data containing both users and non-users of the technology innovation. Although the results remain inconclusive in terms of audience, the possibility of many different types of users and non-users of the technology innovation illustrates the complexity of an organization within Boeing. This in turn suggests that aligning training to users of new technology is a challenge in terms of identifying specific training needs because of the complexity of the organization and the numerous types of users and non-users of the new technology. The term complexity used in this respect refers to having the ability to segregate all of the users of the specific technology innovation for the specific training needs for that technology innovation.

Literature suggests that the underlying drivers of OE are finance in terms of costs and economic cycles, products or markets in terms of product innovation and product development cycle, and human capital in terms of trained workforce.

Quantitative case studies suggest that the underlying drivers of OE are in terms of cost and schedule, which tends to agree with literature. In addition, TI is represented in terms of schedule and guidelines, which tends to agree with literature in terms of product development cycle and product innovation. In literature, the underlying driver of human capital is in terms of a trained workforce, which is fairly vague. In this research, it is the assumption that a trained workforce is necessary for organizational effectiveness, and that the underlying drivers of training are in terms of schedule and cost directed from OE.

Literature suggests that TRL process is performed to know the maturity of the technology innovation, which provides a timeline for the lifecycle of the technology innovation.

Boeing requires a method to ensure that technologies have reached Technology Readiness and Application Readiness when they are adopted into a business unit or product platform. From conception to application, the developmental path of a technology follows general stages of maturity in a method referred to as the TRL process.

Quantitative case studies suggest that how TR, TI, and OE interact is dependent on the maturity of the technology innovation. For each level of technology innovation maturity, the lag or lead time in terms of years will vary between the operationalized variables representing the three constructs of TR, TI, and OE. Hence, understanding the maturity of the technology innovation will give the organization some insight as to what to expect for training at the various stages of maturity.

7.3 Evaluation Study

The case specific operationalized conceptual models were evaluated by possible end users at the Boeing Company. This includes SMEs representing the engineering (TI) and training (TR) point of view, as well as the leadership team, which includes managers and senior managers, representing the business (OE) point of view. The evaluation of the conceptual models will be performed using closed interviews with a small group of SMEs and managers. The aim of the evaluation is to validate the results of the two case studies for validity and practicality. Suggestions for improvements were discussed during the interviews and were taken into consideration when evaluating the conceptual models. The following sub-sections describe the interview design, audience selection, interview protocol, and list of mainly closed interview questions.

7.3.1 Interview Design

The interview design aims to gather input from three decision makers and five SMEs at Boeing through informal interviews. The term informal used here is in the context of not needing transcripts, as the purpose of these interviews is to evaluate the case specific operationalized conceptual models in Chapter 6 and the general method developed in Chapter 8. Therefore, the main result of this interview approach is a two-fold: (1) to evaluate the conceptual models resulting from the quantitative data analysis in Chapter 6, and (2) to confirm the practicality of the general method developed in Chapter 8. The information resulting from this interview will be used to give context to the case specific operationalized conceptual models in Chapter 6.

The interviewees were all asked to review the information quoted or paraphrased from them to ensure accuracy. All of the interview questions were intended to be closed questions to evaluate the case specific operationalized conceptual models and the general method proposed in this research. Hence, the interview questions were in the context of the three main constructs of this research.

7.3.2 Interviewee Selection

The interviewees were chosen based upon the end users of the method. The categories are of people who are SMEs or managers (decision makers) in the area of technology innovation, training, or organizational effectiveness. Table 7-1 shows the list of interviewees as they correspond to the functions and the three constructs. There were a total of eight interviewees within Boeing, as the initial end user of this method will be within Boeing.

Table 7-1. List of interviewees and their functions as they relate to the three constructs of this research

Interviewee [I]	Function	Training	Technology Innovation	Organizational Effectiveness
I15	Engineering SME		x	x
I16	Engineering SME		x	x
I17	Training SME	x		x
I18	Training SME	x		
I19	Engineering SME		x	
I20	Manager		x	x
I21	Manager	x	x	x
I22	Manager	x	x	x

As shown in Table 7-1, most of the interviewees are decision makers or end users and fall into at least two construct categories and play two different roles within the organization. The SMEs are intended to evaluate the case specific operationalized conceptual models to comment on whether the results are valid. Revisions were made to the conceptual models based on the SME's evaluations. The decision makers are intended to comment on the effectiveness of the general method proposed in Chapter 7. In addition, the end users, or SMEs, are intended to comment on the practicality for analysts to use the general method proposed in Chapter 7 within the organization.

7.3.3 Interview Protocol

The interview protocol was followed during every interview. The interview protocol included an introduction to the research, purposes of the interview, description of the confidentiality, and the list of interview questions based upon the function (e.g. training SME, manager, subject matter expert, etc.) of the person being interviewed. The interview questions will be described in further detail in the next section.

Every person being interviewed was given a brief introduction of the research, which included the main goals of the research study. The purpose of the interview was described for each person being interviewed and the goals of the interview were based upon the function of the person being interviewed.

When possible, every interview was recorded with the permission of the person being interviewed. The purpose of having the interviews recorded was to have an accurate account of the interview and to be used for referencing purposes within the research. All of the data collected during the interview that was presented in the thesis was reviewed and approved by the person being interviewed. The intent of the recorded interview was to report accurate information with the given permission of the person being interviewed.

Each person being interviewed had the opportunity to choose to be anonymous or to be referenced to by name and/or title in this research. All direct quotes and references to the person being interviewed were approved by the person being interviewed.

7.3.4 Interview Questions

The purpose of the interviews is to evaluate the case specific operationalized conceptual models in this research. Below is the general list of closed interview questions (IQs). Again, each interview was tailored to the interviewee's function at the company. Engineering SMEs were asked questions with TI variables, whereas training SMEs were asked questions with TR variables. The complete set of general interview questions that were used for each interview based on the function of the interviewee can be found below.

Questions for Chapter 7 evaluation of case study results:

IQ1. Does it makes sense that the number of orders [TI(Schedule)] occur about 16 years before the number of deliveries [TIOE(Schedule)] for mature technologies (Case 1)? This question aims to address Comparison 4 in Section 7.2.2.

IQ2. Does it makes sense that the number of courses delivered [TR(Schedule)] occurs 10 years before the number of deliveries [TIOE(Schedule)] are made for mature technologies (Case 1)? Can you help explain this phenomena? This question aims to address Comparison 5 in Section 7.2.2.

IQ3. Does it make sense that in the early maturity case (Case 2), that there is not a significant direct relationship between OE, and TR and TI? This question aims to address Comparison 1 in Section 7.2.2.

IQ4. Does it make sense that the number of patents filed [TI(Guideline)] drives the number of courses delivered [TR(Schedule)] in a technology innovation early in the maturity stage (Case 2)? Can you explain why the number of patents [TI(Guideline)] tends to drive training [TR(Schedule)] in Case 2 and not in Case 1? This question aims to address Comparison 2 in Section 7.2.2.

IQ5. Does it make sense that the number of patents filed [TI(Guideline)] drives the number of orders [TI(Schedule)] for a technology innovation early in the maturity stage (Case 2)? Can you explain why the number of patents [TI(Guideline)] tends to drive the number of orders [TI(Schedule)] in Case 2 and not in Case 1? This question aims to address Comparison 3 in Section 7.2.2.

IQ6. Can you explain why in Case 1 (mature technology), TI and OE in terms of number of patents [TI(Guideline)] and investment in product per year [TIOE(Cost)] occur is most significant at the lag = 0? Is this expected or should one lead or drive the other? This question aims to address Comparison 6 in Section 7.2.2.

IQ7. Can you explain why in Case 1 (mature technology), TR in terms of number of courses or course hours delivered [TR(Schedule)], is significant to OE in terms of investment in product per year [TIOE(Cost)] at lag = 0? Is this expected or should one lead or drive the other? This question aims to address Comparison 7 in Section 7.2.2.

IQ8. Can you help explain the multiple peaks seen for the following cases: C1. TIOE[Cost] and TI[Guideline]; C1. TIOE[Schedule] and TIOE[Cost]; C1. TIOE[Cost] and TI[Schedule]; C2. TI[Guideline] and TR[Schedule]?

IQ9. Do the results presented from these two case studies help illustrate the relationship between TR, TI, and OE at Boeing? Why or why not? This question aims to evaluate whether the case specific operationalized conceptual models provide useful information in the Boeing environment.

7.3.5 Interview Discussion

This section aims to address IQ1 through IQ9 from Section 7.3.4. In addressing these questions through interviews, the comparisons from Section 7.2.2 will be confronted with the responses from the interviewees. In addition to directly answering the interview questions, the interviewees also gave some background around the complexities of training and technology innovation at a large engineering company. It is through these responses and guidance that the case specific conceptual models will be revised.

IQ1. Does it makes sense that the number of orders [TI(Schedule)] occur about 16 years before the number of deliveries [TIOE(Schedule)] for mature technologies (Case 1)?

According to I15 and I16, it is likely that the number of orders [TI(Schedule)] occurs about 16 years before the number of deliveries [TIOE(Schedule)] for mature technologies. The 777 began in 1995 and the 787 was delivered in 2011. Because the data contained both 777 and 787 data, this would make sense. Hence, this infers that whatever the combination of significant correlations that were added together to result in this conclusion would be the most accurate assumption.

IQ2. Does it makes sense that the number of courses delivered [TR(Schedule)] occurs 10 years before the number of deliveries [TIOE(Schedule)] are made for mature technologies (Case 1)? Can you help explain this phenomena?

The training SMEs I17 and I18 mention that it makes sense that the number of courses delivered [TR(Schedule)] occurs 10 years before the number of deliveries [TIOE(Schedule)] for mature technologies. In addition, the training SMEs also did discuss that although the data shows that the timing for [TR(Schedule)] with respect to [TIOE[Schedule)] makes sense, the number of training was still not enough to train all of the engineers. The training SMEs discussed the needs from the engineers were still great. As found during the qualitative data analysis, some engineers felt that the composite training came too late or that there was not enough training available to the engineers. Because of the mixed responses and thoughts between the training SMEs and engineering SMEs, the correlation between [TR(Schedule)] and [TIOE[Schedule)] is inconclusive.

IQ3. Does it make sense that in the early maturity case (Case 2), that there is not a significant direct relationship between OE, and TR and TI?

According to the training SMEs, when a technology is early in the maturity level, it is not expected that the business is involved in training. That is, it is not expected that the business requests extensive training courses to be developed for technologies that are early in the maturity level. According to the engineering SMEs, the business drives the technology innovation, but only when the technology innovation is mature. It is not common for the business to invest in a technology innovation that is not mature.

IQ4. Does it make sense that the number of patents filed [TI(Guideline)] drives the number of courses delivered [TR(Schedule)] in a technology innovation early in the maturity stage (Case 2)? Can you explain why the number of patents [TI(Guideline)] tends to drive training [TR(Schedule)] in Case 2 and not in Case 1?

According to the engineering SMEs, it is expected that [TI(Guideline)] drives [TR(Schedule)] for both cases. A possible reason for the data not showing this between Case 2 and Case 1 is that for Case 2, when a technology is early in the maturity cycle, there is not many patents filed; hence, there are less outside variables in the data. For a matured technology as depicted in Case 1, there are much more patents filed, which introduces more outside variables into the data set. When querying the data for [TI(Guideline)], the term “composites” is too general and would introduce many outside variables to the data set. But training is offered in a general sense in terms of composites and not at a detailed, micro level as mentioned by the training SMEs. Hence, there is a disconnect between [TI(Guideline)] and [TR(Schedule)]. Therefore, the quantitative findings between [TI(Guideline)] and [TR(Schedule)] are inconclusive.

IQ5. Does it make sense that the number of patents filed [TI(Guideline)] drives the number of orders [TI(Schedule)] for a technology innovation early in the maturity stage (Case 2)? Can you explain why the number of patents [TI(Guideline)] tends to drive the number of orders [TI(Schedule)] in Case 2 and not in Case 1?

Similar to the responses for IQ4, it is possible and expected that the number of patents filed [TI(Guideline)] tends to drive the number of orders [TI(Schedule)] for a technology innovation. The differences between Case 1 and Case 2 may be due to the query for [TI(Guideline)] being too general.

IQ6. Can you explain why in Case 1 (mature technology), TI and OE in terms of number of patents [TI(Guideline)] and investment in product per year [TIOE(Cost)] occur is most significant at the lag = 0? Is this expected or should one lead or drive the other?

According to the engineering SMEs, the query for [TI(Guideline)] was too general so this may have affected the results during the quantitative data analysis. In terms of expectations, the number of patents can coincide with the investment in product per year. The number of patents can also drive the investment or the investment can drive the number of patents, depending on a number of variables including the type of program, type of application, and timing of investments. Hence, any correlation using [TI(Guideline)] should be considered carefully.

IQ7. Can you explain why in Case 1 (mature technology), TR *in terms of number of courses or course hours delivered [TR(Schedule)], is significant to OE in terms of investment in product per year [TIOE(Cost)] at lag = 0? Is this expected or should one lead or drive the other?*

According to the training SMEs, it is expected for matured technologies that the number of courses delivered coincides with the investment in the technology innovation per year. Once a technology innovation is matured, it is expected that the business invests in the technology. The engineering SMEs tend to agree with the correlation at lag = 0 for TR(Schedule)] and [TIOE(Cost)].

IQ8. Can you help explain the multiple peaks seen for the following cases: C1. TIOE[Cost] and TI[Guideline]; C1. TIOE[Schedule] and TIOE[Cost]; C1. TIOE[Cost] and TI[Schedule]; C2. TI[Guideline] and TR[Schedule]?

According to the SMEs, for the cases using [TI(Guideline)], the results may be inconclusive due to the query being too general. With that said, it is expected that [TI(Guideline)] be cyclic in nature with respect to [TIOE(Cost)] because of the nature of investments in technology innovations that are being directly applied onto airplanes. For Case 1, composites were being used on both the 777 and the 787; hence, as the business began heavily investing into these airplanes, the technology innovations that go onto these airplanes tend to follow the same trend, as does the number of patents filed. The training SMEs also tend to agree with the cyclic nature of courses being delivered. The more the business is investing in a technology innovation, the more engineers need to be trained. In addition, it is expected that in most cases, when the variable [TIOE(Cost)], referring to the investment in the product per year, is being analyzed with another variable, the results tend to be cyclic in nature. Again, this is due to the business making investments where needed for new airplane programs. Hence, to have more precise results and not as general as what was found in this research, an organization would need to have access to query specific technology investments for the specific product that the organization is interested in. The more end products that are factors, the higher possibility for multiple peaks in the data results.

IQ9. Do the results presented from these two case studies help illustrate the relationship between TR, TI, and OE at Boeing? Why or why not?

In general, both the training and engineering groups of SMEs concur that the conceptual models help illustrate the relationship between the constructs of this research. The exact correlations and numbers associated with each bivariate may be inconclusive in some cases, but the SMEs tend to agree that if specific guidelines were written on how these variables were quarried, then the results would be more accurate.

Complexities with Training and Organizational Effectiveness

According to a training SME I17, the timing of training greatly depends on what type of training is needed (e.g. web based, certificate programs, etc.). In addition, the scheduling within training also varies the timing of training. Programs sometimes do not want training to be offered at a certain time due to the engineers needing to support a deliverable. Hence, at this particular company, with these particular variables, the airplane programs should be driving the training. That is what is expected and what actually is happening in the practical environment. Regardless of what type of training, all training development goes through the ADDIE process, which was first introduced in Chapter 2.

I18 agrees with I17, describing that the stakeholders from the programs drive the training and that affects the timing of the training. Moreover, if resources for the development and implementation of training include SMEs, then this can greatly affect the timing of training. SMEs may be pulled into supporting the technology being developed, which then delays the training. According to training SME I18, the current training is for composites in general and not at the level in which the standards are written. The content of the training is not at the microscopic, detailed level in which the programs (or engineering) organizations define the technology. Instead, the content of the training is more at the macroscopic, general level. This disconnect may contribute to the unexpected results observed in the case specific operationalized conceptual models.

Complexities with Technology Innovation and Organizational Effectiveness

According to an engineering SME I15, the executives ultimately make the decisions to drive the technology, whereas the engineers have minimal say in the initial decisions. Hence, it is up to the engineers to find a way to make the technology work in the initial stages. As the technology is tested, the engineers help make the later decisions of whether or not the technology will be able to be certified and integrated within the company. In the case of material technology (e.g. composites, nanotechnology, etc.), engineers need to ensure that processes exist for the material. Material and processes go hand in hand when considering materials in terms of technology innovation.

According to an engineering SME I16, the term "composites" is too high level. Hence, some of the results presented may be skewed. It is recommended that detailed guidelines are developed to guide future researchers or organizations in using the method to perform case studies with more specific conditions.

In addition, the timing of the technology innovation greatly depends on the type of technology, management push, and regulatory demands. All standards and processes are written to support the certification of the airplane. Hence, meeting regulatory standards is important to the development of technology innovation. I16 agrees with I15 that the material definition and the process definition go hand in hand. The development of a material technology cannot be successful without the development of the material process. Moreover, the manufacturing capability is also a significant factor in the development of a material technology.

In summary, according to I16, the process for material development begins with research and development. The capability of manufacturing is then analyzed. The regulatory process with applications is then defined, along with the material processes. Finally, an organization does the testing and writes the standards with a defined application. In general, for an aerospace company, the test plan needs to support a certification plan. In addition, there are many complexities around material development, some of which are summarized based on interviewees I15 and I16 in the following sub-sections.

Technology Maturity

Technology ready is defined as:

> *The relevant technology is available in all affected disciplines so technology users can, with reasonable confidence, perform the following tasks:*
>
> *a. Evaluate the benefits, costs, and risks of incorporating the relevant technology in a product or process.*
>
> *b. Successfully incorporate the technology in a product or process if the decision is made to do so.*

Application ready is defined as:

> *The relevant technology is not only technology ready, but has been assessed for a specific production application by the technology user and verified as adequate for a production commitment. Such application readiness assessment ensures that:*
>
> *a. The benefits, costs, and risks have been assessed by the technology user and support incorporation for that specific production application.*
>
> *b. The plans are complete for the specific production application and are compatible with program schedules.*
>
> *c. The scale-up requirements (including human, facility, and financial resources) for the specific application are known and acceptable to the technology user.*

Production Ready is declared when the technology has passed through all pre-production manufacturing trials and pre-production verification trials necessary to successfully support the production system. An internal document details the complete process necessary to evaluate new technology for a specific program.

Integration of new technology

Integrating new composites technology into a design can be especially difficult due to the nature of composite tooling and the long lead-time necessary to produce those tools. The integration process follows several key steps. Skipping any of these steps can be detrimental in achieving production readiness.

- Establish engineering requirements
- Describe the corners of design space
- Define the technology or process capability
- Characterize test program
- Gated reviews
- Refine, document and execute project

These steps are not always linear. Decisions and discoveries along the way can have the effect of taking steps backward. Developing the process capability is the most difficult step and therefore the most time consuming. Many factors impact a process: *material selection, capital equipment or the decision to not have any capital equipment, process specification to be used (new or revised), tooling concepts, and equipment needs.*

Establish Engineering Requirements

The clearer engineering defines their requirements the more likely the project will be successful. The understanding of a new technology also requires the evaluation of validation and certification testing. Knowing the pass/fail criteria for each test also sets requirements that must be achieved.

Describe the Corners of Design Space

Technology development usually begins with simple shapes and contours. It is imperative that designs are provided to those developing the technology that adequately reflects all design features that might be seen during a true production run. The idea is to develop the technology up front to meet the requirements and be capable of manufacturing the design features anticipated. Complex features not anticipated, but discovered during first part qualification can be detrimental to a program.

A close working relationship between design and the technology development team is essential. The designers must understand the process capability in detail in order to keep an eye out for potential features not seen before or more extreme than anticipated. These must be brought to the attention of the development team immediately for disposition and resolve.

Define the Technology or Process Capability

The technology or process meeting the requirements for the entire design space is considered. Agreements are made between engineering design and tooling, design and manufacturing, tooling and manufacturing, tooling and equipment, and equipment and manufacturing. Cost controls might dictate a non-preferred step in the process. Once the requirements are known, features established and the constraints identified, the technology development team must perform. The requirement is challenged. Is it a must have or a nice to have? Testing the deficiency is one method to determine if it is unacceptable. The requirements are honed to be more specific and altered if found to be too restrictive or over stated. This is a back and forth negotiation. At last the requirements are redefined and the process capability is established and agreed upon by all parties. This is a journey that takes the majority of the time in a development program.

Characterize Test Program

Test programs validate analysis methods or provide design values. A review of testing completed to prove existing design/process/technology will serve as a starting place to establish new test needs: allowables testing (coupon level), part testing (element level), assembly testing (sub-component level), or barrel testing (component level). If the technology or process does not meet the requirements and it is agreed upon, then it is imperative that the test program is conducted with the process capability in mind. An allowables program may be required to understand if a knockdown is necessary to capture the effects of fiber angularity, ply splices, or fiber thinning. Process deficiencies must be accounted for in the design allowables and element testing. They must become part of the analysis methods and design values in order to be acceptable.

Gated Reviews

Non-Advocate Reviews

The benefit of company experts reviewing findings, decisions, or proposed direction cannot be overstated. Yes, they take time to prepare for and can be tedious and exhausting, but when we work together to ensure important aspects of a schedule, resources, methods or test program have not been overlooked there is only improved odds of success and decreased potential for late findings or worse yet production failures.

Non-Advocate Reviews can have the following objectives: 1) Evaluate completeness of test program required to validate project, 2) evaluate compliance with regulatory requirements. 3) evaluate analytical methods and method basis, 4) evaluate technology, application, or production readiness, 5) preliminary design and critical design reviews.

Business Case Reviews

A cost benefit analysis is conducted prior to the approval of each trade study. Periodic updates are necessary as decisions are made or altered and discoveries found. The weight estimate can change with allowables and methods changes. Early equipment costs go from estimates to firm as design features and process steps are negotiated and refined throughout the project lifecycle. These updates allow the project leaders to decide if a project is on target or off. This in turn supports decisions to continue to fund new technologies. As business cases deteriorate, there is consideration to shut them down and transfer the funds to more promising endeavors.

Refine, Document and Execute Project

Cycle time is important in keeping fabrication costs under control. With the hard work done, refinement is needed to smooth the process steps and manage costs. A key ingredient to bringing everything to fruition is the creation of an integrated schedule to ensure alignment between teams involved. Accountability is established between each team as well as a change process for managing schedule revisions. Changes happen, but a change in milestones by one team may have effects on others. A rigorous approach for managing and accepting schedule revisions is mandatory because schedule changes increase overall costs. It is important to understand why a schedule is sliding as the Boeing philosophy has been to never compromise quality with schedule demands. Impacts must be understood and considered prior to any adjustment made.

Design Guides

The commercial airplanes design guides contain knowledge accumulated and lessons learned from design experience. They are intended as guidelines primarily for engineers with limited experience in the field. Design guides contain basic design requirements, objectives, approaches, considerations, historical information, and recommendations. Design guides are mainly intended to assist engineers in producing designs that meet company objectives and customer needs in terms of performance, reliability, producibility, and cost.

Many requirements and objectives govern the structural design of aerospace vehicles to ensure safe, reliable, and cost-effective operator performance. These requirements and objectives stem from generic regulatory requirements as well as product-specific requirements that are defined by Boeing and the customers, such as the airlines, NASA, and military agencies. A successful design meets all requirements while achieving the most effective balances between economic and performance objectives.

The Boeing structural design philosophy is to deliver a safe airframe that offers long-term reliable use, with minimum weight, cost, and maintenance [I15].

According to [I15] and [I16], there are several major factors that must be considered during the material selection process as follows:

Performance Issues. These include consideration of **static strength, damage tolerance, durability, impact resistance, and damage detection**. The material selection may also be driven by density, modulus, or application-specific service temperature requirements. The ability of a material to perform in any of these subcategories plays a significant role in determining structural efficiency.

Environmental Exposure Issues. These include consideration of corrosion resistance, flammability, moisture, thermal exposure effects, galvanic effects, ultraviolet radiation effects, fluid resistance (i.e., hydraulic fluids, fuel, maintenance chemicals), and lightning strike.

Service Issues. These include considerations of service-related items such as structural weight restrictions, reliability, maintainability and repairability, wear and rework, impact damage, lubrication requirements, inspection requirements, and inspectability.

Producibility Issues. These include considerations of material size restrictions, ease of producing the parts (i.e., for metals: ease of machining, forming, heat treating or other forms of thermal treatments, shot peening, chemical processing and finishing. For Composites: layup method, curing, drapability, ability to obtain wrinkle-free parts, etc.), tooling, and other requirements for successfully fabricating the part in a cost-effective manner. For composites, there are more producibility issues (operator dependent and process sensitive) than metals.

Business Issues. These include considerations of cost, benefits relative to competing alternatives, manufacturing facility requirements, compatibility with existing manufacturing capabilities (i.e., need for tooling and capital equipment such as autoclaves, etc.), supply chain consistency and integration, time constraints (i.e., maturity of the technology), and availability.

Regulatory Issues. These relate to certification requirements imposed by the aircraft regulatory agencies, and health, safety and environmental requirements.

Other Issues. These include standardization and maintaining commonality, the subcontractor (supplier) capabilities, and customer airline inputs/feedback.

When structural composites are considered as an alternative to metallic structure, their potential application must consider all relevant factors. Potential benefits of composites include weight reduction, improved fatigue performance, reduced corrosion, reduced part count, ability to tailor strength and stiffness, and lower buy-to-fly ratios. All have been realized in varying degrees as experience accumulates. However, two issues remain somewhat open; the overall cost trends, and the long-term maintainability and repairability of composites.

Structural design and analysis engineers develop and complete a finished design within a specific time period while providing the most cost-effective, weight-efficient, producible, functionally reliable, and safe structure possible [I16].

7.4 Evaluated Case Specific Operationalized Conceptual Models

Figure 7-1 through Figure 7-3 shows the evaluated case specific operationalized conceptual models. With all of the challenges presented in discussions with the interviewees, it is clear that some of the noise in the quantitative data may be affected by these challenges that a large company like Boeing faces. Hence, reviewing the case specific operationalized conceptual models with a panel of SMEs is critical to the interpretation of the data. It is recommended that only after thorough review with the SMEs and understanding all of the variables that may affect the results, that decision makers would then use the evaluated case specific operationalized conceptual models during their decision making process. This leads to the next sections where a general method for performing quantitative data analysis will be discussed.

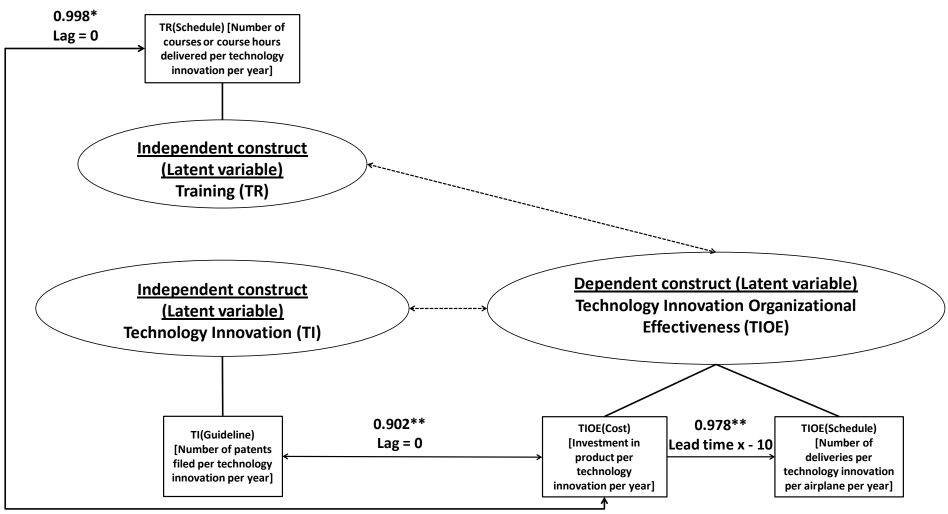


Figure 7-1. Evaluated case specific operationalized conceptual model for Case 1

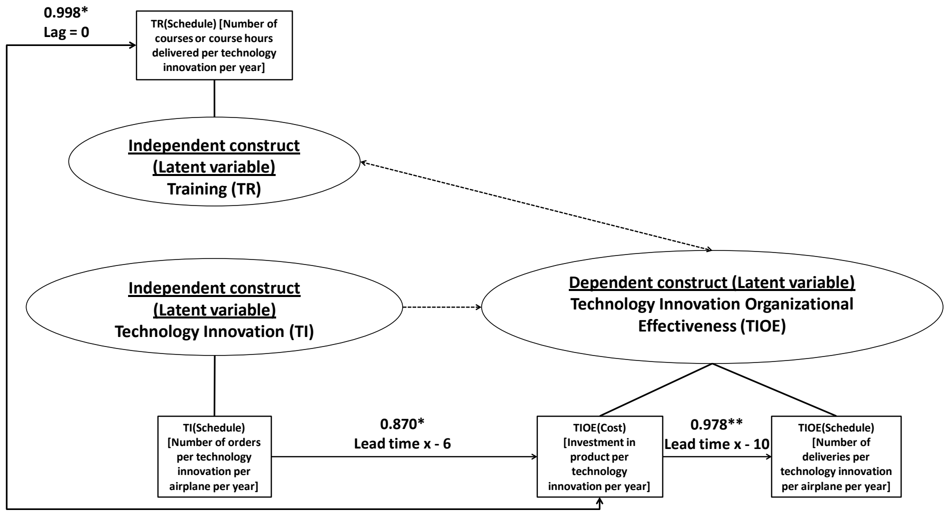


Figure 7-2. Evaluated case specific operationalized conceptual model for Case 1

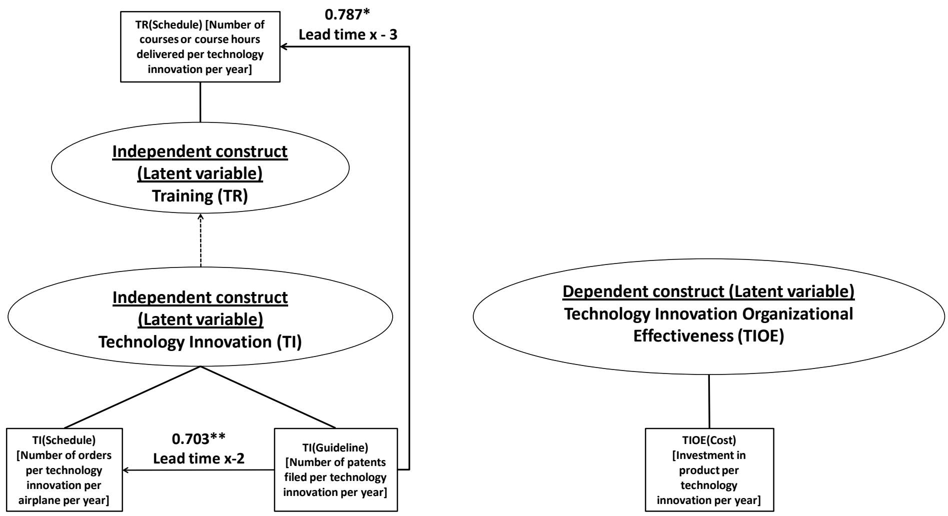


Figure 7-3. Evaluated case specific operationalized conceptual model for Case 2

7.5 Key Variables for Case Specific Operationalized Conceptual Models

The SMEs tend to agree that the key variables that were listed in the operationalized conceptual models are accurate variables to describe each of the constructs. However, the SMEs emphasized the importance of how critical it is to have access to the accurate quarries for each variable, as well as to be specific regarding the query. As has been described by the SMEs, there are many complexities in a large engineering company. As such, many variables are involved when quarries are too general.

7.6 Summary of General Method for Quantitative Data Analysis

Figure 7-4 shows a generalized method for quantitative data analysis depicting the result from Chapter 5 as input data to begin the quantitative data analysis. The generalized method for quantitative data analysis is referred to as Gate 2 in this research. The output for this method are case specific operationalized conceptual models specific to the organization using this method.

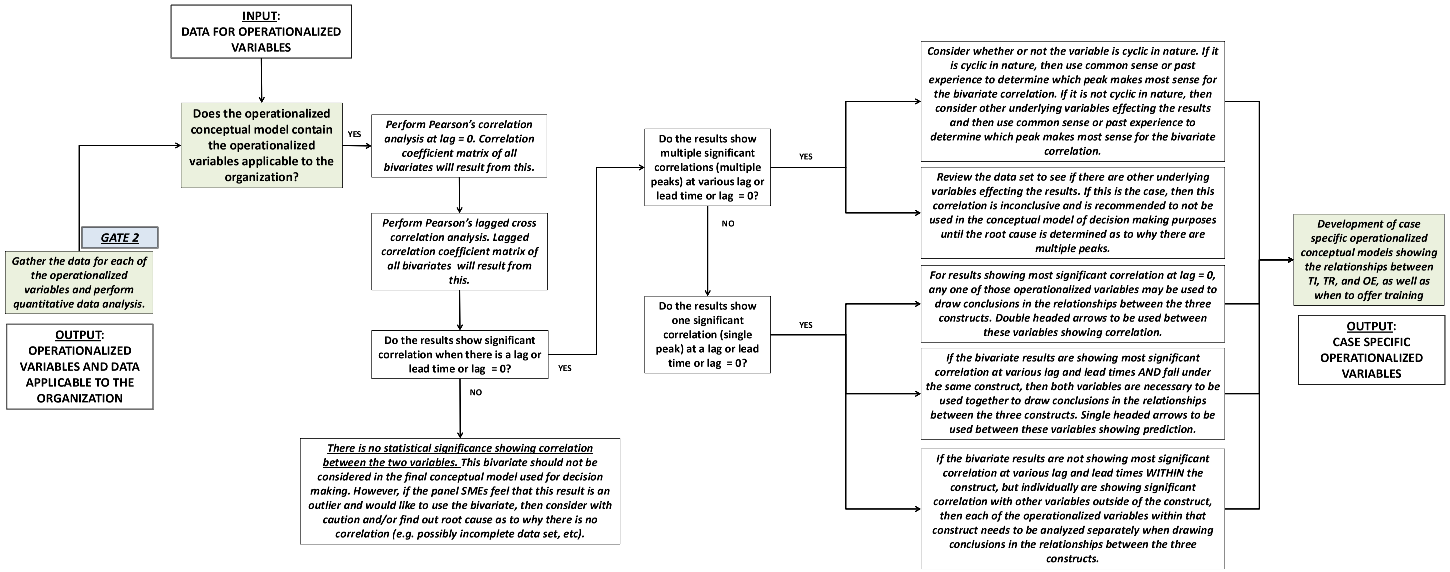


Figure 7-4. Gate 2 depicting process for quantitative data analysis

7.7 Summary of General Method for Evaluation of Results

Figure 7-5 shows a generalized method for evaluating the quantitative data analysis results. The generalized method for evaluation of the quantitative data analysis results is referred to as Gate 3 in this research. The output for this method is a non-general descriptive conceptual model specific to the organization using this method.

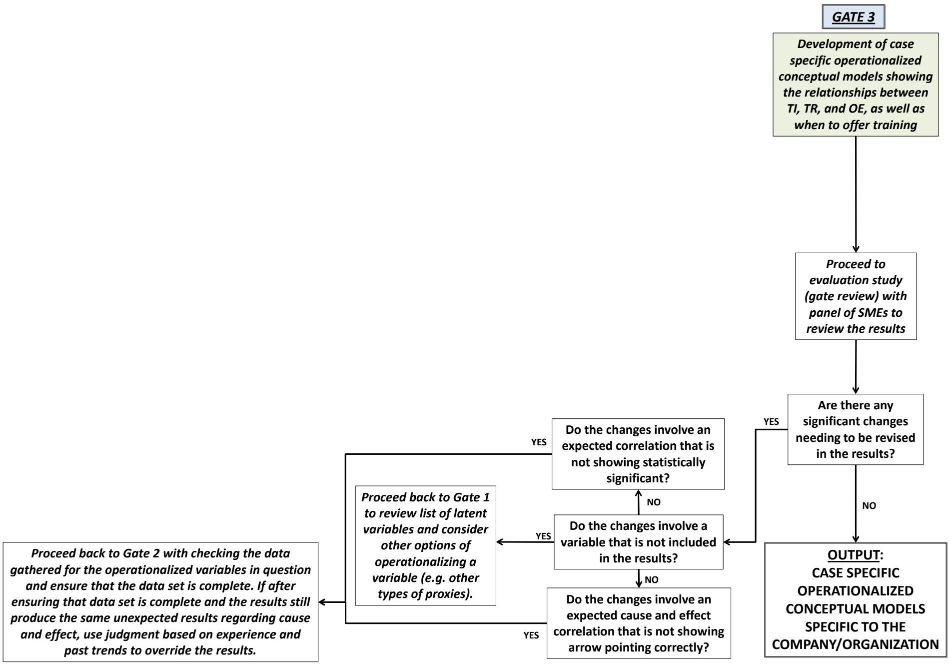


Figure 7-5. Gate 3 depicting process for validation of results

7.8 Conclusions

The main limitations of this chapter also provide opportunities for future research. First, the primary objective of the case studies was to come up with a baseline conceptual model common to the interaction between the measured variables and the three constructs of this research. A lagged time-series correlation study was thus used.

Altogether, this study was an attempt to interpret the relationship between TI, TR, and TIOE and understand the possible recursive and mutual relationships they share. In general, the study found significant evidence of relationships between the three constructs, depending on the maturity of the technology innovation. Moreover, the type of training provided for the technology innovation differed depending on the maturity level of the technology innovation. It therefore adds to the existing body of knowledge by incorporating the construct TR to gain insight into why, how, and when TI is implemented to impact OE in a positive manner. The results pertaining to the behavior between the three constructs TR, TI, and OE also provide direction and coherence to organizations by considering inherent time lags and differences, if any, between the measured variables for each of the three main constructs.

The model provides descriptive evidence for placing a greater emphasis on the importance of analyzing and developing prior to expending and implementing in terms of TI and TR. As the model presents, understanding the lag times between the constructs is significant in optimizing the relationships between the three constructs. Hence, once the correlation between the three constructs is optimized, it can be inferred that in order for OE to have a positive effect, TI and TR must have a strong correlation with OE.

In addition to the generalized conclusions described above, and in the context from section 7.2 in the case to case comparisons being discussed, the below conclusions were also made. The conclusions in this section are in the context of the selection of the case studies in terms of technology innovation maturity level.

Conclusion 1. The relationship between training, technology innovation, and organizational effectiveness may be dependent on the maturity level of the technology innovation.

Conclusion 2. In technology innovations that are early in the maturity cycle, the results from case study 2 suggest that there are direct correlations between training and technology innovation, but no significant correlations with organizational effectiveness.

Conclusion 3. In technology innovations that are mature, the results from case study 1 suggest that the technology innovation has no significant correlations with training, but rather the two constructs are related through organizational effectiveness (the business).

Conclusion 4. It was mentioned in the qualitative interviews from Chapter 4 that in case study 1, the organization may have benefitted more if training was offered earlier. The quantitative data (model) suggest that there may be a disconnect between the relationship of TI and TR, thereby supporting what was said in the interviews.

Conclusion 5. Through experience, the courses that were delivered in case study 2 were too early to be effective for the organization. The quantitative data (model) suggest that there may be a complete disconnect with OE.

Conclusion 6. The type of training (level of training maturity) may be dependent on the maturity of the technology innovation.

7.9 Reflection

The results found empirically through the case studies are based on the current state. The results are based solely on the current empirical data available. Hence, the results shown depict how the state currently is and what the new state is based on the current data. What the model does not depict is what the state could be if the input data was different. The results from this chapter can also be helpful to predict what TR and TIOE would look like based on the current data for TI. The outcome of the case specific operationalized conceptual models is dependent on the input data (i.e. the data that was queried).

CHAPTER 8
METHOD DEVELOPMENT

This chapter is represented as Phase V, shown in Figure 8, of the exploratory sequential mixed methods research design as first introduced and described in Chapter 1. The aim of this chapter was to develop a method for developing descriptive conceptual models to describe the relationship between TR, TI, and OE. This method was further evaluated by a small group of subject matter experts within Boeing, which provided insight on the usability of this method in a practical environment.

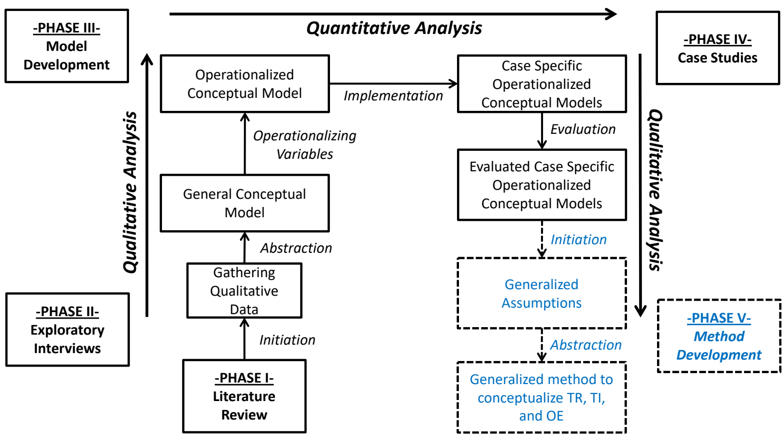


Figure 8. Phase V of the blended five-phased approach of the exploratory sequential mixed methods design based on Creswell (2009)

8.1 Motivation for Developing Method

The general method developed in this chapter captures the process involved in conceptualizing the relationships between TI, TR, and OE performed in Chapter 4 through Chapter 7. The method is general in nature and is applicable for any engineering company or organization comparable to Boeing. The method highlights the statistical techniques used for both the qualitative and quantitative data analysis. These statistical techniques may be performed using existing software within the company or organization, such as Microsoft Excel, or through existing third party software packages, such as Atlas.ti and SPSS. It is not within the scope of this research to develop the corresponding tool corresponding to the method developed in this research. Moreover, it is the intent of this research to develop a generalized method that companies and organizations may adopt to conceptualize the relationships between TI, TR, and OE. It is also the aim of this chapter to answer the fourth sub-research question first introduced in Chapter 1: *What general method can be proposed by utilizing the approaches for developing the conceptual models?*

8.2 Conceptual Models leading up to Method

The general conceptual model was developed in Chapter 5, shown in Figure 8-1, after the qualitative data analysis was performed to identify the general latent variables. The operationalized conceptual model was developed in Chapter 5, shown in Figure 8-2, after the latent variables identified in Chapter 4 were operationalized. The latent variables identified in the general conceptual model are the input for Gate 1 in the method proposed in this research. The operationalized variables identified in the operationalized conceptual model are the input for Gate 2 in the method proposed in this research.

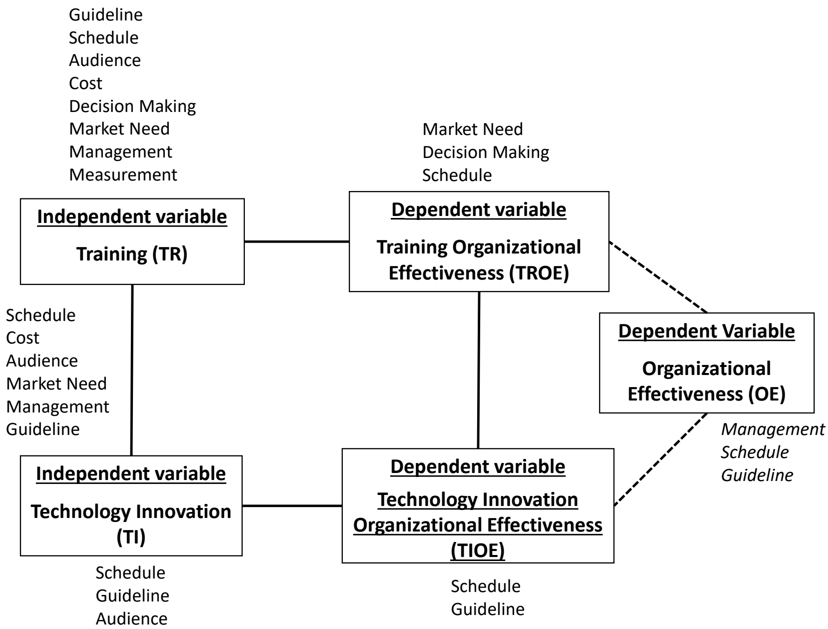


Figure 8-1. General Conceptual Model (Chapter 5)

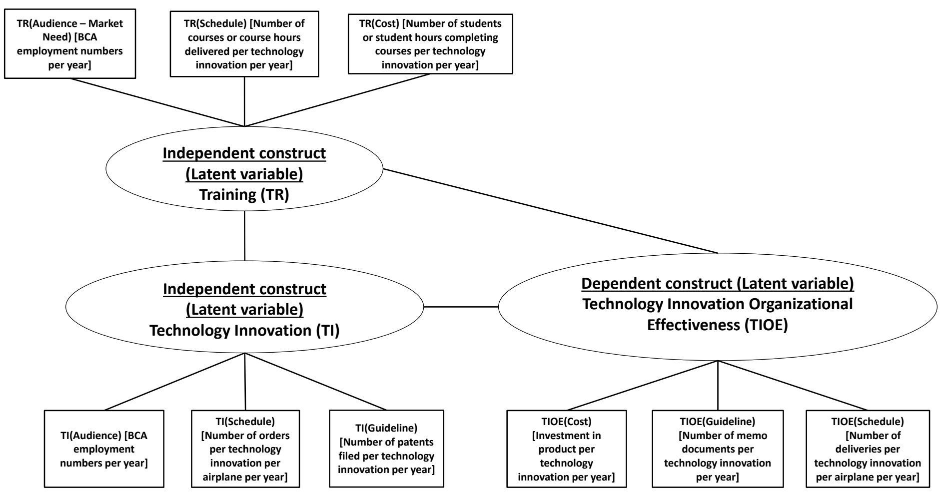


Figure 8-2. Operationalized Conceptual Model (Chapter 5)

8.3 Generalized Method

8.3.1 Gate 1. Qualitative Data Analysis

The aim of Gate 1, shown in Figure 8-3, is to operationalize the latent variables representing each of the three constructs. Once the latent variables are operationalized, quantitative data that are applicable to the organization using this method would be gathered. The operationalized variables and corresponding quantitative data resulting from Gate 1 is the input for Gate 2.

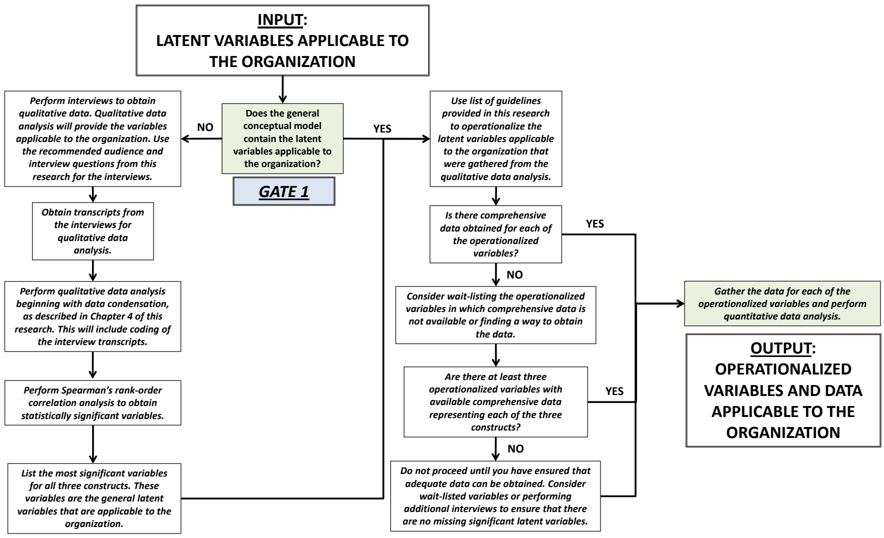


Figure 8-3. Generalized method for Gate 1 Qualitative Data Analysis

8.3.2 Gate 2. Quantitative Data Analysis

The aim for Gate 2, shown in Figure 8-4, is to develop the conceptual models showing the relationship between TR, TI, and OE. The conceptual models are developed by performing quantitative data analysis on the output data from Gate 1. The conceptual models resulting from Gate 2 is the input for Gate 3.

Gate 2 begins with a set of operationalized variables from the Operationalized Conceptual Model (descriptive conceptual model 2). Statistical analysis is performed on each bivariate set at current state of time (time lag = 0), producing Pearson's correlation matrix. The results are analyzed for each bivariate set at time lag = 0. If the results are not showing significant correlation where expected, a lagged cross correlation analysis is considered. If the results are showing significant correlation at lag = 0 within the construct, then any one of those operationalized variables may be used to draw conclusions in the relationships between the three constructs. When performing a lagged cross correlation analysis for each bivariate set, the result will be a Pearson's lagged correlation matrix. The results for each bivariate set at various lag/lead times are then analyzed. If the results are not showing significant correlation where expected in both lag = 0 and lagged cross correlation, then data set may not be comprehensive and that other unforeseen variables may be interfering the results. If the bivariate results are showing significant correlation at various lag and lead times AND fall under the same construct, then both constructs are necessary to be used together to draw conclusions in the relationships between the three constructs. Depending on what operationalized variable the analyst decides to designate as "x" (e.g. x – 1, means x leads y by 1 year; or x + 1, means x lags y by 1 year), that variable will then be analyzed directly with other operationalized variables from the other two constructs. The "x" variable will serve as the base point of comparison.

In addition to significant correlation coefficients indicating the strength between the bivariate, the arrow direction is dependent on what the analyst defines as "x". That is, if "x" represents TI[Cost] and "y" represents TR[Schedule], then the arrow would point from TI[Cost] to TR[Schedule]. If "x" represents TR[Schedule] and "y" represents TI[Cost], then the arrow would point from TR[Schedule] to TI[Cost]. Moreover, if lag = 0 between the bivariate, then a double arrow is used showing that there is a relationship between the two simultaneously and not one directly causes the other at a specific given time.

If the bivariate results are not showing significant correlation at various lag and lead times within the construct, then each of the operationalized variables within that construct needs to be analyzed separately when drawing conclusions in the relationships between the three constructs. This means that when analyzing the relationships between the constructs, the relationships will be described in terms of a specific operationalized variable.

The final set of conceptual models will give indicators as to what variables to pay attention to, thereby, giving an indication as to what and when to invest a technology innovation or training. It is intended that the results from this method be used when performing annual assessments on what and when to invest in technology innovation and training to positively affect an organization.

The results of this method are based on both qualitative and quantitative data, where the quantitative data analysis is intended to be performed by an analyst within the organization. It should be noted that the quantitative portion of this method will vary from organization to organization, depending on the input data set. The qualitative portion may be updated by the organization if the set of recommended operationalized variables does not apply. However, if this is the case, then it is recommended that a qualitative study using interviews be performed to determine the significant variables to consider in the quantitative study.

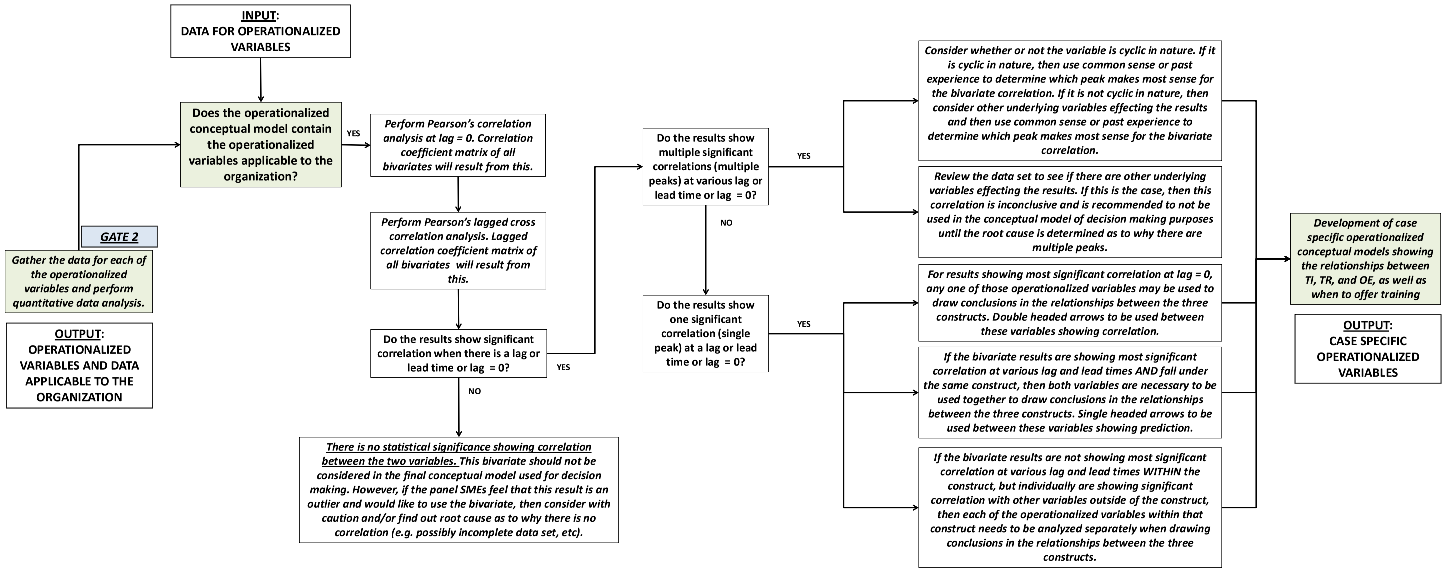


Figure 8-4. Generalized method for Gate 2 Quantitative Data Analysis

8.3.3 Gate 3. Evaluation Study

The aim for Gate 3, shown in Figure 8-5, is to validate the conceptual models showing the relationship between TR, TI, and OE with a group of SMEs in the organization. The panel review will help determine whether the results make sense and if it is necessary to proceed back to either Gate 1 or Gate 2 to verify the results. The outcome of Gate 3, and also of the entire method, are the revised conceptual models showing the relationship between TR, TI, and OE. These conceptual models are the deliverables for the decision makers in the organization to help with determining when to offer training for the given technology innovation being studied.

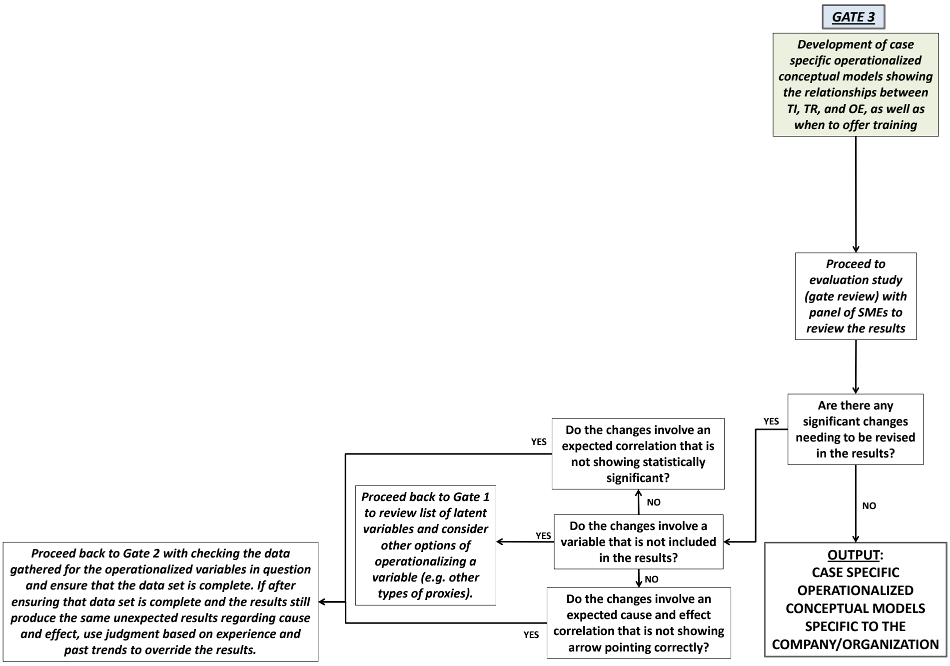


Figure 8-5. Generalized method for Gate 3 validation of qualitative data analysis results

8.4 Generalized Method Flowchart

The combination of Gate 1, Gate 2, and Gate 3 results in the Generalized Method flowchart shown on the next two pages in Figure 8-6. The final deliverable for this generalized method is descriptive conceptual models specific to the company or organization, describing the relationship between TR, TI, and OE.

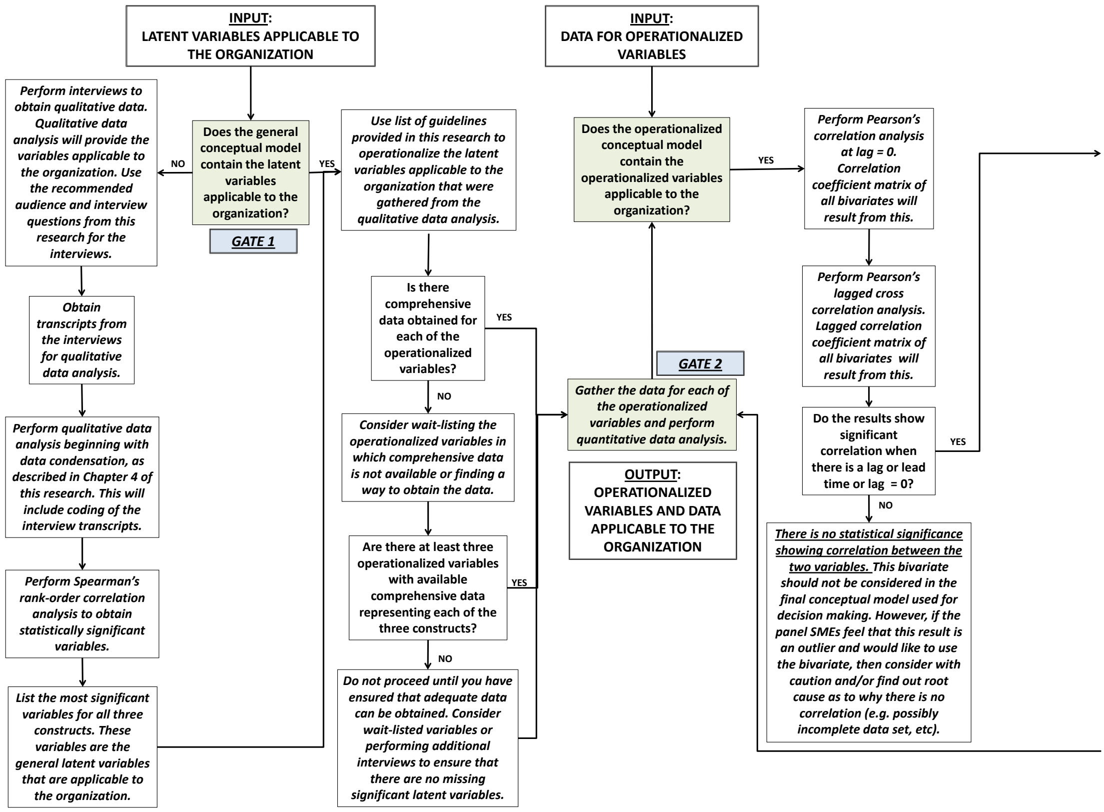
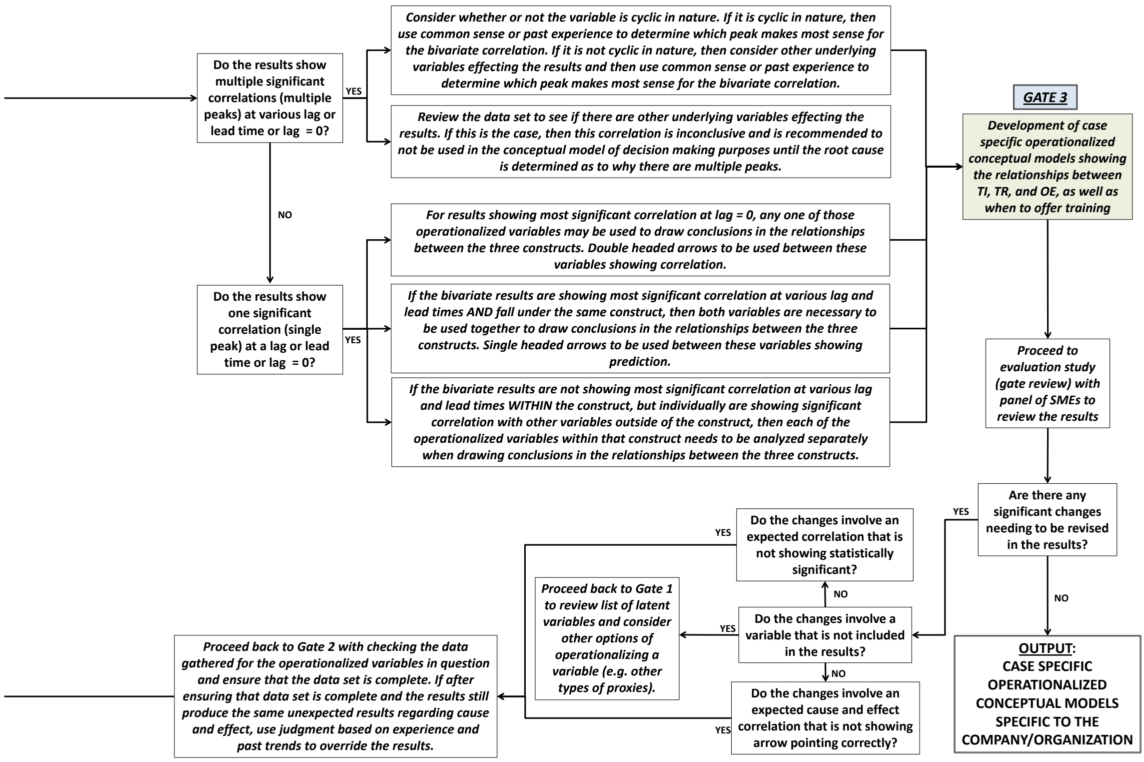


Figure 8-6. Method for conceptualizing the relationships between technology innovation (TI), training (TR), and organizational effectiveness (OE)


Do the results show multiple significant correlations (multiple peaks) at various lag or lead time or lag = 0?
YES
Consider whether or not the variable is cyclic in nature. If it is cyclic in nature, then use common sense or past experience to determine which peak makes most sense for the bivariate correlation. If it is not cyclic in nature, then consider other underlying variables effecting the results and then use common sense or past experience to determine which peak makes most sense for the bivariate correlation.
Review the data set to see if there are other underlying variables effecting the results. If this is the case, then this correlation is inconclusive and is recommended to not be used in the conceptual model of decision making purposes until the root cause is determined as to why there are multiple peaks.
NO
Do the results show one significant correlation (single peak) at a lag or lead time or lag = 0?
YES
For results showing most significant correlation at lag = 0, any one of those operationalized variables may be used to draw conclusions in the relationships between the three constructs. Double headed arrows to be used between these variables showing correlation.
If the bivariate results are showing most significant correlation at various lag and lead times AND fall under the same construct, then both variables are necessary to be used together to draw conclusions in the relationships between the three constructs. Single headed arrows to be used between these variables showing prediction.
If the bivariate results are not showing most significant correlation at various lag and lead times WITHIN the construct, but individually are showing significant correlation with other variables outside of the construct, then each of the operationalized variables within that construct needs to be analyzed separately when drawing conclusions in the relationships between the three constructs.
GATE 3
Development of case specific operationalized conceptual models showing the relationships between TI, TR, and OE, as well as when to offer training
Proceed to evaluation study (gate review) with panel of SMEs to review the results
Are there any significant changes needing to be revised in the results?
YES
NO
OUTPUT:
CASE SPECIFIC OPERATIONALIZED CONCEPTUAL MODELS SPECIFIC TO THE COMPANY/ORGANIZATION
Do the changes involve an expected correlation that is not showing statistically significant?
YES
NO
Do the changes involve a variable that is not included in the results?
YES
NO
Proceed back to Gate 1 to review list of latent variables and consider other options of operationalizing a variable (e.g. other types of proxies).
Do the changes involve an expected cause and effect correlation that is not showing arrow pointing correctly?
YES
Proceed back to Gate 2 with checking the data gathered for the operationalized variables in question and ensure that the data set is complete. If after ensuring that data set is complete and the results still produce the same unexpected results regarding cause and effect, use judgment based on experience and past trends to override the results.

8.5 General Guidelines for using Method

The general method begins with a set of operationalized variables from the general conceptual model (descriptive conceptual model 1) resulting from the qualitative data analysis performed in Chapter 4. Note that the operationalized conceptual model (referred to as 'conceptual model 2' in this research) will be different for each study done in an organization and is expected to change throughout the years as the data for the operationalized variables change. If the operationalized conceptual model changes, then the outcome of Gate 2 (referred to as 'conceptual model 3' in this research) will also be different for each study done in an organization using this general method. Boeing may choose to start at Gate 2 as the detailed case studies performed within this research in the development of the method were based on Boeing data. Non-Boeing companies should begin at Gate 1.

The user of this generalized method must exercise caution when considering any other sets of operationalized variables as only the operationalized variables described in this research has been fully analyzed. If the analyst is curious as to what additional operationalized variables to use, then it is recommended that a full qualitative study be performed within the organization using interviews and the approach described in Gate 1. Also, when operationalizing variables in Gate 1, ensure that reliable data can be collected for each of the three constructs. The approach for data collecting should be based on reliability, repeatability, and access to available data. In addition, use conservative data. Consider leading zeroes carefully. Use of leading zeroes will cause for un-conservative results and inflated significant correlation when in actuality, the correlations may not actually exist.

When defining the relationship between the bivariate, this refers to analyzing the strength (correlation coefficient and p value), and the cause and effect (arrow direction based on lead and lag times). No arrow indicates that significant correlation between the variables or constructs do not exist. Lag = 0 indicates correlation between the bivariate [double headed arrow]. Lag or lead time indicates one variable happens before the other variable (drives) [one headed arrow].

The technology innovation in this generalized method can be used for ANY technology innovation as it relates to OE and TR. Although this generalized method was intended for conceptualizing the relationships between TI, TR, and OE, the organization may choose to simplify the method for the purposes of observing TI, TR, and OE separately. It is possible to have a bivariate study observing the constructs TI and OE, TI and TR, and TR and OE relationships separately. Because of the extensive research performed on identifying the relationships between these three constructs, it is not recommended to generalize this method for ANY constructs without thorough research.

8.6 Guidelines for Gate 1 – Qualitative Data Analysis

It is recommended that engineering companies other than Boeing using this general method to begin at Gate 1.

8.6.1 Guidelines for Qualitative Analysis Interviews

The audience being considered for interviews need to be evenly distributed from the following categories: engineering manager, training manager, training SME, and engineering SME. It is mandatory that the interviews be recorded for the purposes of data analysis. The transcripts from the interviews will serve as the raw data for the qualitative data analysis.

8.6.2 List of General Interview Questions

The interview questions are based upon the audience and function (e.g. training SME, manager, subject matter expert (SME), etc.) of the person being interviewed. This approach ensures that there will be an evenly distributed amount of data addressing each of the three constructs of Organizational Effectiveness, Technology Innovation, and Training. All of the interview questions are intended to be open questions in the context of the three main constructs.

IQ1. What do you perceive as the main organizational goals for training or technology innovation?

IQ2. How does the training or engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?

IQ3. How does the training or engineering organization know when a new technology is being considered by the other organizations?

IQ4. How does the company manage the adaptation of its training programs to new technological developments and innovations?

IQ5. What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?

IQ6. Think of a successful training or technology innovation program that you have worked on in the past. How would you define a program as being <u>successful</u>? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?

IQ7. Think of an unsuccessful training or technology innovation program that you have worked on in the past. How would you define a program as being <u>unsuccessful</u>? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?

8.6.3 Guidelines for Operationalizing Variables

All of the quantitative data for the operationalized variables need to be in terms time and analyzed over time (e.g. 2000-2013). The quantitative data for the operationalized variables should be at a localized level for more accuracy. The higher level the data is collected, the higher the possibility of more unknown variables is creating noise in the data. It is recommended to consult SMEs and managers as to what they suggest to use as a proxy for representing the latent variable. In addition, review literature for examples of what others have used in operationalizing similar latent variables.

Determine if OE should be represented at an organizational level or a localized level. This is dependent on the company and/or organization and what construct is the driver. In the cases used for this research, engineering drives training and influences OE at a localized level within the engineering organization. Hence, in the context of this research, TIOE was used to represent OE at the TI localized level.

8.6.4 Guidelines for Analyzing the Qualitative Data

Use a tool or software similar to Atlas.ti to code the raw qualitative data. In addition, choose a tool that will color code and keep count of the frequencies of the variables. The coding process of the raw qualitative data is important to the analysis of the data by accurately capturing the variables that will be included in the general conceptual model. All of the descriptive conceptual models will be based off of this general conceptual model resulting from the qualitative data analysis. Hence, it is critical that this analysis is performed carefully.

8.7 Guidelines for Gate 2 – Quantitative Data Analysis

It is recommended that if Boeing is to continue this research to begin at Gate 2 as the case studies performed in this research were case specific to Boeing. Hence, the operationalized variables and data applicable to the organization from Gate 1 has already been generated for Boeing.

Ensure that reliable data can be collected for each of the three constructs. The approach for data collecting should be based on specific, reliable, repeatable, and accessible data. In addition, use conservative data. Consider leading zeroes carefully. Use of leading zeroes will cause for un-conservative results and inflated significant correlation when in actuality, the correlations may not actually exist.

When defining the relationship between the bivariate, this refers to analyzing the strength (correlation coefficient and p value), and the cause and effect (arrow direction based on lead and lag times). No arrow indicates that significant correlation between the variables or constructs do not exist. Lag = 0 indicates correlation between the bivariate [double headed arrow]. Lag or lead time indicates one variable happens before the other variable (drives) [one headed arrow].

Use a tool or software similar to SPSS to perform the cross correlation analysis for the bivariate sets. Several equations can also be inputted into the Microsoft Excel software to create the same cross correlation coefficient matrices that are found throughout this research. In addition, the lagged cross correlation analysis can also be done using Microsoft Excel.

8.8 Guidelines for Gate 3 – Evaluation Study

Once the case specific operationalized conceptual models are developed, the models should be reviewed by a panel of SMEs to ensure the accuracy of the data. The SMEs will also provide the context, reasons, and complexity for the numbers behind the quantitative data analysis. When selecting a panel of SMEs to evaluate the results from the quantitative data analysis, ensure that there is equal representation across the constructs. Ensure that there are training SMEs, engineering SMEs, and managers on the panel representing the constructs of TR, TI, and OE respectively. Have the SMEs and managers evaluate the strength between each of the bivariates, the direction in which each variable is influencing another, and the lag and lead times associated with each of the bivariates.

8.9 Discussion

Training SMEs and engineering SMEs were interviewed for the usability of this method. The SMEs all agreed that the method was useful in describing how to develop the conceptual models that were demonstrated in this research. Furthermore, the generalized method shows how any large engineering company comparable to Boeing can use this method to characterize the relationship between TR, TI, and OE. The SMEs suggested that for a company or organization to use this method, a common, generalized tool would need to be developed to aide in the qualitative and quantitative data analysis.

A few managers were also interviewed for the practicality of the method. They agreed that the guidelines were necessary to accompany the method. In addition, the managers described the method to be a systematic view of the three constructs that could be used as a guideline for annual decision making in terms of investment in training and technology innovation. The managers agreed with the SMEs regarding a possible tool to be developed if a company or organization were to use this method. Furthermore, for a large organization or company to use this method, a detailed, full validation study would need to be performed. Otherwise, the managers would consider the current method as being conceptual in terms of being implemented within a large engineering company or organization. For the method to be implemented within a large engineering company or organization, further thorough validation studies need to be completed, where the method is tested with data from several different technologies, at various maturity levels, from several different organizations. The managers agree that the validation study alone may take several years to perform. As this is out of the scope of this research, a full validation study will be one of the recommendations described in Chapter 9.

8.10 Conclusion

In general, this method may be used in any engineering company comparable to Boeing. Furthermore, by following the guidelines carefully, the method would be more effective and provide the user with accurate information. It is recommended for future research to perform in depth validation studies using this method in various companies for various different technologies at different maturity levels. An extensive validation study like this would be ideal to further this research, but is currently out of the scope of this research. For this method to be used extensively at companies, it has been suggested by the users that a complete validation study be completed in future studies. Hence, the outcome of this research is conceptual in nature until a complete validation study is performed, thus setting a stage for future research in this area.

CHAPTER 9

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

This chapter concludes this research. The aim for this chapter is to provide some discussion regarding the validity of the current research, as well as the scientific contribution that this research provides. This chapter also discusses the limitations of this research. In addition to answering the research questions set forth in Chapter 1, several conclusions will be made about the findings and observations made during this research. Finally, recommendations will be made for the practical applications of this general method along with recommendations for future research. It is also the aim of this chapter is to answer the main research question first introduced in Chapter 1: What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?

9.1 Discussion

In this discussion section, the validity of the research is discussed, including some comments on the use of mixed research methods in the current research. The scientific contribution is also summarized along with the limitations of this research.

9.1.1 Validity of the current research

To assess the validity of the total research design, the concepts of the three constructs Training (TR), Technology Innovation (TI), and Organizational Effectiveness (OE) were addressed. The concept of reliability, where this research study could be repeated with the same results, was ensured by the five phase process carried out during this research, as first described in Chapter 1 in Section 1.5.4. During each of the five phases, existing, scientific approaches were taken to develop the conceptual models proposed throughout this research. It is the combination of these scientific approaches in which a generalized method was proposed. Moreover, both qualitative and quantitative approaches were taken during the phases of this research. Because of the nature of the research, where the deliverable is directed towards a practical environment, a mixed methods approach best captures the complexities within companies. In addition, both the qualitative and quantitative approaches interact to provide the reasoning behind results that were observed. Simply looking at one approach does not adequately provide the depth and reasoning necessary to answer the main research question. It is the combination of both qualitative and quantitative methods that provide the rigor for this research. Hence, having a mixed methods approach in developing the generalized method contributes to the validity of the overall current research that was performed and described in this dissertation.

9.1.2 Scientific contribution

A generalized method that any engineering company can use to describe the relationship between TR, TI, and OE was proposed. The generalized method is intended to give a systematic view of the three constructs and how each construct interact; thereby affecting the system as a whole. As systems engineering generally focuses on how to design and manage complex systems (Blanchard and Fabrycky, 2006), the generalized method proposed in this research contributes to the field of systems engineering by providing a reliable, repeatable process that uses mixed methods and statistical analysis approaches to aid in decision making in organizations. Moreover, the generalized method proposed in this research was developed using a rigorous five-phased approach as described in Chapter 1. This five-phased approach included literature review from both the theory knowledge base and the practical knowledge base, as described in Chapter 2 and Chapter 3, respectively; exploratory interviews and model development using qualitative data analysis, as described in Chapter 4 and Chapter 5, respectively; detailed case studies using quantitative data analysis and evaluation of the results from the case studies using qualitative approaches, as described in Chapter 6 and Chapter 7, respectively; and method development, as described in Chapter 8. It is the rigor and scientific approach in which the elements within this generalized method was developed and demonstrated that contributes to the overall scientific body of knowledge.

9.1.3 Limitations of the research

The main limitations of this research included (1) the limited number of case studies performed, (2) the limited number of companies of similar and various sizes analyzed, (3) the accessibility of data that was publicly available or available between organizations, and (4) the statistical approach used during the quantitative data analysis. The number of case studies performed in this research was limited as it was not within the scope of this research. This research was intended to develop a method where the case studies were necessary to demonstrate the usability of the method. The number of companies and company sizes were limited as it was within the scope of this research to represent the majority of the five common sectors. The general method was based on the findings of significant correlations between the companies in four of the five sectors. Hence, the recommendations in Section 9.3 aim to address this limitation and recommend further validation of this method through studies with several companies of various company sizes.

The accessibility of data that was publicly available or available between organizations was limited. The input data for the quantitative data analysis for this research was limited by the accessibility of the data, as well as obtaining data that was publicly available. It was a challenge in an organization like Boeing to obtain data between organizations as some data is only accessible within the organizations. In addition, as it is important to companies to ensure that certain data remains private and not be publicly published, it was a challenge to find a way to obtain publicly available data that best represented the operationalized variables. If the general method will be used within companies and organizations, the guidelines described in Chapter 8 will guide and recommend the users on obtaining the best possible dataset for the operationalized variables to ensure accurate results. As demonstrated within this research, the results found from the qualitative data analysis were high level and did not have the desired level of granularity due to the limited dataset.

The statistical approach used during the quantitative data analysis was limited by the number of samples within each case study and the end users of this general method. Hence, a simple time series correlation analysis was performed. It was the intention to keep the statistical approach simple for practicality purposes. The end users would be able to take this method with a complete understanding of why and how the conceptual models were developed. In addition, using a more advanced statistical approach would limit the number of variables and lead to unreliability of the results. The current statistical approach uses bivariate correlation analysis, where the number of usable data is maximized as compared to using multivariate correlation analysis approach.

9.2 Conclusions

This section aims to provide the specific answers to the four sub-research questions, which thereby answering the main research as first introduced in Chapter 1. In addition, this section gives an overall general conclusion of the research by describing the deliverables and tangible outcomes of the research. The recommendations following the conclusions are based on the overall conclusions of this research.

9.2.1 Addressing the sub-research questions

In this dissertation, the main research question to be answered was:

What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?

In order to find the answer to this question, several sub-questions were defined, which are answered subsequently. Once these sub-questions are answered, the main research question will be confronted.

(1) What key variables are significant for training, technology innovation, and organizational effectiveness?

The key variables that are significant for training, technology innovation, and organizational effectiveness are general and were described in Chapter 2 through Chapter 5. Specifically, the key variables found in literature are shown at the end of Chapter 2 and Chapter 3 in Table 2-5 and Table 3-5, respectively. The variables found during the qualitative data analysis performed using data from the exploratory interviews from five companies are shown in Appendix 4F. These variables generally confirmed what was found in literature, but with more detail in the context of this research. The variables shown in the general conceptual model deduced in Chapter 5 may be used for any engineering company of similar size to Boeing, as shown during the qualitative analysis performed in Chapter 4. These general key variables can be found in Figure 5-2 in Chapter 5 on page 112. In addition, the key variables that were operationalized specific to the Boeing and are shown in the operationalized conceptual model can be found in Figure 5-4 in Chapter 5 on page 123.

The relationship between TI and TR may affect the overall OE through the localized organization level OE (i.e. TIOE and TROE). How the relationship between TI and TR affects the overall business OE is dependent on management support at the localized organization level. The managers at the localized organization level report to the higher level managers who have control of the business aspect of the company. Hence, as mentioned by several interviewees, it is critical to the success of TI and TR to have management support.

TI and TR may be driven by the Cost and Schedule assigned by the business aspect of the company (OE), where Cost and Schedule are directly related. The variable 'Cost' in terms of TI-TR refers to the funding needed for training. Funding is in terms of resources needed for the development, delivery, implementation, and evaluation of training. Moreover, as technology innovation continues to evolve constantly, it is necessary that the timing of the training for the engineers is aligned, so that the engineering workforce has the necessary skills to be effective within the organization. Hence, the 'Cost' and the 'Schedule' in terms of TI-TR are a direct function of each other.

TI and TR may be driven by the Audience and Market Need assigned by the business aspect of the company (OE), where Audience and Market Need are directly related. The audience refers to the workforce where the skill set within the company constantly changes. This is due to new employees, knowledge transfer from expert to novice engineers, retaining knowledge from people leaving the company, and current engineers learning a new skill set. Market need is determined by performing a training needs analysis to help identify any gaps in skills within the workforce. Hence, since market need is dependent on the gaps in skills within the workforce, and the audience refers to the workforce, market need is dependent on the gaps in skills within the audience.

Guideline, Decision Making, Management, and Measurement may be all directly related in context of the three constructs. As interpreted from the qualitative data from the interviews, Management refers to the management support needed in order for TI and TR to have a positive influence towards the overall business OE. For management support to be effective, standard guidelines and measurements within the company are used by managers to make decisions within the organization.

(2) What are the relationships between the key variables?

The relationships between the key variables are specific to the company and/or organization. As the data gathered for determining the relationships between the key variables was case specific to Boeing, the conclusions described here are specific to Boeing. Another large engineering company may have different conclusions to this research question. Hence, the conceptual models developed to describe the relationships between the key variables are case specific operationalized conceptual models. In addition, the key variables that show significance may also differ depending on how the operationalized variables were queried. The relationships between the key variables for both case studies can be found in Figure 6-1 to Figure 6-3 in Chapter 6 on page 147-148. It should be noted here that because there were only two case studies performed, representing the extreme cases, the conclusions for this sub-question (2) are general in nature. Further validation research in Section 9.3.1 will provide recommendations to continue this research.

The relationship between training, technology innovation, and organizational effectiveness may be dependent on the maturity level of the technology innovation. It was the intention of this research to use two extreme case studies to show if the maturity level of the technology innovation had any effect on the relationship between TR, TI, and OE. As observed in the case specific operationalized conceptual models from Chapter 6, there are apparent differences between a technology that is matured and a technology that is early in the maturity cycle. This may suggest that as the technology is early in the maturity cycle, the business (OE) is not heavily involved in the interactions between TR and TI. Moreover, as the technology becomes matured, the involvement with the business (OE) are directly linked to both TI and TR. Hence, the quantitative data analysis performed in this research from the two case studies suggest that the maturity level of the technology innovation affects the relationship between training, technology innovation, and organizational effectiveness.

In technology innovations that are early in the maturity cycle, the data from case study 2 suggest that there may be direct correlations between training and technology innovation, but no significant correlations with organizational effectiveness. In a large engineering corporation, it is not expected that technology innovations that are early in the maturity cycle to have support from the business in terms of funding, as there are no direct applications for the technology innovation. The technology innovation is still in research and development and until the technology innovation is proven to be applied, it is not common for the business to risk the investment. Moreover, in the context of the aerospace companies, the technology innovation is required to meet the guidelines set forth by the government agencies, which in turn ensures the safety aspect of the end product.

In technology innovations that are mature, the data from case study 1 suggest that technology innovation may have no significant correlations with training, but rather the two constructs may be related through organizational effectiveness (the business). In contrast to technology innovations that are early in the maturity cycle, as represented in case study 2, it is expected that the business (OE) become directly involved with TI and TR as the technology innovation becomes matured. Once the technology innovation is proven to be applied to the end product, the business may choose to heavily invest in the technology innovation. In the context of the aerospace companies, only technology innovations that are mature can be tested to meet the guidelines set forth by the government agencies. It is not common to begin testing of a product which contains technology innovations that are not production ready, as that would compromise the overall performance of the product in terms of safety and reliability.

The qualitative interviews from Chapter 4 suggest that for technology innovation that is mature, as represented in case study 1, the organization may have benefitted more if training was offered earlier. The quantitative data (model) from case study 1 shows that there is a disconnect between the relationship of TI and TR and no lag time between TR and OE, thereby supporting what was said in the interviews. This observation shows that the mixed methods approach gives validation towards analyzing the relationships between the three constructs of this research. It was observed in the qualitative data analysis that the organization may have benefitted more if training was offered earlier, which translates to the expectation that TR should have a lead time with respect to OE. The quantitative data analysis showed that where TR and OE had the most significant correlation was at lag = 0. This quantitative result validates the qualitative result by showing what is actually occurring in the practical environment based on the current data. The current data for TR contained the number of courses delivered over a period of time. The qualitative data suggests that if the number of courses delivered over a period of time occurred earlier, and not just shifted earlier, then the organization may have benefitted. As this is the case, for the quantitative data analysis, it was not possible to add more data points for earlier years in addition to the current number of data points as those data points did not exist; thereby, supporting the observation from the qualitative data analysis.

The qualitative interviews from Chapter 4 suggest that the courses that were delivered in case study 2 were too early to be effective for the organization. The quantitative data (model) shows that there is a complete disconnect with OE, thereby supporting what was said in the interviews. This observation also shows that the mixed methods approach gives validation towards analyzing the relationships between the three constructs of this research. It was observed in the qualitative data analysis that the organization did not benefit from training in case study 2 because it was offered too early. This translates to the expectation that TR should not have a significant relationship with OE. The quantitative result showed that there are no significant relationship between TR and OE; thereby, supporting the observation from the qualitative data analysis. In addition, as the quantitative data for case study 2 suggests that there is a complete disconnect with OE, this research suggests that it may be worthwhile for companies to train managers so that they are able to make a decision on whether to support technology innovations that are early in the technology maturity level.

The results from case study 1 and case study 2 suggest that the type of training (level of training maturity) may be dependent on the maturity of the technology innovation. As was expressed by the training SMEs during the evaluation of the case specific operationalized conceptual models in Chapter 7, the type of training and detail of training provided to the engineers is dependent on the maturity of the technology innovation. If the technology innovation is early in the maturity cycle, the content within the training would not be as detailed, which influences the type of training to be offered. An example of this was presented in the two case studies of this research, where for composites (matured technology), an extensive certificate program was developed. For nanotechnology (technology early in the maturity cycle), a two to three course was deemed sufficient for the engineers as the technology was not yet going to be applied on the airplane. Hence, the type of training is dependent on the maturity of the technology innovation. Moreover, the parameters of type of training and technology innovation maturity is in the context of selection of case studies and not for the key variables that were developed for the general method to represent the three constructs of this research.

(3) How do the developed conceptual models show when to offer training when technology changes to positively influence organizational effectiveness?

The lagged cross correlation analysis performed during the quantitative data analysis in Chapter 6 resulted in case specific operationalized conceptual models. The strength between each of the bivariate, as well as the inferred influences between the constructs was described in Chapter 7. It was the results from the quantitative data analysis that gave the level of significance and strength between each of the bivariate at a certain time period; thereby, quantifying the relationships between the bivariate. Moreover, because each bivariate contained two operationalized variables representing the corresponding construct, the strength between each bivariate inferred influences between the construct. This in turn resulted in case specific operationalized conceptual models that showed when to offer training when technology changes to positively influence organizational effectiveness. It was also observed during this research that the phrase “technology changes” refers to the technology maturity and not the type of technology.

(4) What general method can be proposed by utilizing the approaches for developing the conceptual models?

The general method that was proposed by utilizing the approaches for developing the conceptual models was described in Chapter 8, specifically in Figure 8-6 on page 190-191. The general method uses a mixed methods approach and consists of three gates, where Gate 1 and Gate 3 are qualitative in nature, and Gate 2 is generally quantitative. The general conceptual model and operationalized conceptual model was developed in Gate 1. The case specific operationalized conceptual model was developed in Gate 2. Gate 3 uses a panel of SMEs to evaluate the results from Gate 2 to provide further context behind the numbers that were presented. Furthermore, the limited number of case studies used for this research showed that the method does work and is practical based on the evaluation study performed in Gate 3. Because of the limited number of case studies, the detailed results and conclusions from Gate 2 that were performed in this research were general in nature. Further research will be suggested to address this in Section 9.3.1.

9.2.2 Addressing the main research question

Having answered all of the sub-questions in Section 9.2.1, it is now appropriate to answer the main research question:

What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?

A method that an engineering company can use to assess the influence of training and technology innovation on organizational effectiveness was first proposed and described in Chapter 8, specifically in Figure 8-6 on page 190-191. This general method contained three main gates, where depending on the company size and the type of company sector, the starting point for using this method may begin at Gate 1, Gate 2, or Gate 3. There are several guidelines for determining which gate to begin at as described in Chapter 8. Moreover, this general method demonstrates a mixed methods approach, where Gate 1 and Gate 3 are qualitative in nature and Gate 2 is generally quantitative. It is the combination of these mixed methods approaches that an engineering company can fully capture the complexities in a practical environment, and assess the influence of training and technology innovation on organizational effectiveness. Hence, in the context of this research, using purely a qualitative or quantitative research approach would not fully capture the complexities in a practical environment.

The result of this research study is a two-fold. The first result, which leads to additional future studies, includes the specific quantitative results found in Chapter 6 and 7. The second result of this research study is a generalized method that can be used by any engineering company. It is the combination of these two results that concludes this research and thereby answers the main research question first introduced in Chapter 1.

Based on the correlation analysis performed during the qualitative data analysis, it was determined that one generalized conceptual model can be used for companies of similar size as Boeing. The latent variables that came out of the qualitative study can be used by several companies. As various companies use the generalized method in developing the different descriptive conceptual models, depending on the type of company and the maturity of the technology innovation, the operationalized variables within the operationalized conceptual model may differ from company to company or from technology maturity to technology maturity. Because the generalized method in developing the descriptive conceptual models to describe the relationships between the three constructs of this research begins with the development of a generalized conceptual model, this method is intended to be usable in any company of various size and sectors. Depending on the company or organization using this method, the company may begin at Gate 1, Gate 2, or Gate 3. The guidelines described in Chapter 8 provide the guidance for any company or organization intending to use this generalized method for studying the relationships between TR, TI, and OE.

The level of granularity between TR, TI, and OE may differ in a large engineering company. As observed during the evaluation of the case specific operationalized conceptual models, the interviewees who represented the construct TI conveyed that the training courses were too high-level and not to the detailed level of what are practiced in the engineering organizations. The interviewees representing the TR construct conveyed that the type of training directly affects the level of detail that goes into designing the training. In a large engineering company, there appears to be disconnect between TI and TR due to the level of granularity differences between the training SMEs and the engineering SMEs. Because of the granularity differences, the quantitative data analysis becomes complex when querying the types of data needed to operationalize TI and TR. For example, in the two case studies analyzed in this research, the TR construct can be queried using the key words 'composites' or 'nanotechnology' when looking up courses. When searching for the same key words in the context of the operationalized variables for TI, those key words used of TR are much too broad. This thereby causes some results that need to be further examined and explained by SMEs, which further conveys the importance of Gate 3 of the generalized method. Simply looking at the numbers may give a false depiction of what is actually occurring in the practical environment. The quantitative results may indicate that there is a significant relationship between a bivariate, when in actuality, that result may be inconclusive due to the differences in granularity. The same can also be said for quantitative results that may indicate that there is not a significant relationship between a bivariate, when in actuality, that result may again be inconclusive due to the differences in granularity.

9.3 Recommendations

Since it was found that TI tends to drives TR, and OE tends to drive TI and TR, future recommendations will be based on varying the constructs TI and OE. For TI, different kinds of technology innovations at different levels of maturity will be recommended to be studies. For OE, different companies and organizations of various sizes will be recommended for studies.

9.3.1 Recommendations for practical applications and validation of the method

The recommendations suggested in this sub-section directly aim towards the practicality and validity of the generalized method proposed in this research, as well as the specific quantitative data analysis results found in this research. Specifically, these recommendations provide additional studies to be implemented within an engineering organization in order to use the generalized method proposed in this research in a practical environment. A summary of the recommendations are shown in Table 9-1.

Recommendation 1. Development of tool for the method to be used at a company or organization.

For the general method to be useful within an engineering company, a tool that accompanies this method would need to be developed. For the general method to be useful within an engineering company, a tool that accompanies this method would need to be developed. This tool would need to have the ability to store the data for the operationalized variables and perform the correlation analyses for each bivariate of interest. In addition to performing the analyses for each bivariate of interest, the output would be a series of correlation coefficient tables, as well as normalized comparison plots and correlation lag and lead plots as demonstrated within this research. It should be considered that the tool be universally used across the organizations within a company. Hence, the tool would need to be developed using the most common software that is utilized and accessible by everyone in the company. An example would be if Microsoft Excel is commonly and widely used within the company, then the correlation analysis would be performed using this software.

Recommendation 2. Validation of method through case studies for one technology innovation type at various levels of maturity for a single company of similar size as studied within the scope of this research.

The aim of this validation is to study the effect of technology maturity across several types of technology innovations for *one* company or organization to fully validate the general method. Ideally, the one company would be Boeing so that direct comparison with the Boeing case study results from this research can be compared to. Currently in this research, one type of technology innovation focusing in material sciences has been explored for two case studies varying in levels of maturity (TRL 1 and TRL 9). Additional studies in the material sciences area can include cases for materials representing maturity levels: TRL 2 through TRL 8.

9.3.2 Recommendations for future research

The recommendations suggested in this sub-section directly aim towards the conclusions from this research; thereby, recommending future research relating to this research. These recommendations include future research studies that vary the types of companies, company size, and technology types, and technology maturity levels. Hence, this research sets the foundation for future research by providing a method and corresponding guidelines to perform extensive research and validation studies in the context of studying the interactions between TR, TI, and OE.

Recommendation 3. Using the developed general method in this research, perform case studies for other technology innovation types at various levels of maturity in the same sectors of similar company size as studied within the scope of this research for comparison.

The aim for this future research is to study the effect of technology maturity across several types of technology innovations for companies or organizations of the *same* sectors that are similar to the companies studied within this research. The purpose would be to directly compare the results of an extensive study with the exploratory results found in this research, as well as the possible future research performed in Recommendation 2.

Recommendation 4. Using the developed general method in this research, perform case studies for other technology innovations at various levels of maturity in different sectors of similar company sizes for comparison with this research.

The aim for this future research is to study the effect of technology maturity across several types of technology innovations for companies or organizations of *different* sectors. The purpose would be to validate that this method is general and can be applied across different engineering companies in different sectors other than those sectors studied in this research.

Recommendation 5. Using the developed general method in this research, perform case studies for other technology innovations at various levels of maturity in the same sectors as studied within the scope of this research, but for smaller size companies.

The aim for this future research is to study the effect of different company sizes on the relationships between TR, TI, and OE and have direct comparison with the exploratory results found within this research. The research performed for this recommendation would be directly compared to the research study performed in Recommendation 3.

Recommendation 6. Using the developed general method in this research, perform case studies for other technology innovations at various levels of maturity in the different sectors as studied within the scope of this research, but for smaller size companies.

The aim for this future research is to study the effect of different company sizes on the relationships between TR, TI, and OE. The research performed for this recommendation would be directly compared to the research study performed in Recommendation 4.

Table 9-1. Summary of recommendations

Recommendation	TI Type	TI Maturity	Companies	Company Size*
Baseline - current research	*material sciences*	*two case studies representing two extreme progressive stages of technology maturities*	*Boeing*	*large*
Recommendation 2	*material sciences*	*at least one case study for each of the five progressive stages of technology maturities*	*Boeing or one company*	*large*
Recommendation 3	*IT, prototyping technologies/additive manufacturing, communications, etc.*	*at least one case study for each of the five progressive stages of technology maturities*	*several companies of the same sectors as studied in this research*	*large*
Recommendation 4	*IT, prototyping technologies/additive manufacturing, communications, etc.*	*at least one case study for each of the five progressive stages of technology maturities*	*several companies of different sectors as studied in this research*	*large*
Recommendation 5	*IT, prototyping technologies/additive manufacturing, communications, etc.*	*at least one case study for each of the five progressive stages of technology maturities*	*several companies of the same sectors as studied in this research*	*medium and small*
Recommendation 6	*IT, prototyping technologies/additive manufacturing, communications, etc.*	*at least one case study for each of the five progressive stages of technology maturities*	*several companies of different sectors as studied in this research*	*medium and small*

**Company size. large size company: > 100,000 employees; medium size company: > 25,000 < 100,000 employees; small size companies: < 25,000 employees*

APPENDICES

The appendix numbers indicate the chapter to which they refer to (i.e. Appendix 4A through Appendix 4F refers to Chapter 4, and Appendix 6A through Appendix 6D refers to Chapter 6).

APPENDIX 4A

DETAILED INTERVIEW QUESTIONS FOR QUALITATIVE DATA ANALYSIS

Appendix 4A lists the detailed interview questions specific to the function of the interviewee. Table 4A-1 gives a summary of interviewees representing the respective constructs. In total, there were 14 interviews, which included training managers, engineering managers, engineering SMEs, and training SMEs.

Table 4A-1. Summary of interviewees representing the respective constructs

Interviewee	Function	Boeing (B) or non-Boeing (NB)	Training	Technology Innovation	Organizational Effectiveness
Interviewee 1 [I1]	Training Manager	B	x		x
Interviewee 2 [I2]	Engineering Manager	NB	x	x	x
Interviewee 3 [I3]	Training Focal	B	x		x
Interviewee 4 [I4]	Engineering Manager	NB	x	x	x
Interviewee 5 [I5]	Engineering Focal	B		x	
Interviewee 6 [I6]	Engineering Focal	B	x	x	
Interviewee 7 [I7]	Training Focal	B	x		x
Interviewee 8 [I8]	Engineering Focal	NB	x	x	x
Interviewee 9 [I9]	Engineering Focal	B	x	x	
Interviewee 10 [I10]	Engineering Focal	NB	x	x	
Interviewee 11 [I11]	Engineering Focal	NB		x	
Interviewee 12 [I12]	Engineering Manager	B		x	x
Interviewee 13 [I13]	Engineering Focal	NB		x	x
Interviewee 14 [I14]	Training Manager	NB	x		x

Interviewee 1 [I1]

- *What do you perceive as the main organizational goals for training? How do these organizational goals align with the overall company goals?*

- *How would you define a project/program as being successful? Please describe a technical training project/program (supporting the Programs 787, 777, 767, 747, PD, etc.) that you perceived as being successful. What factors made this program successful? In your opinion, did this project closely align to company/organizational goals? Why and how?*

- *How would you define a project/program as being unsuccessful? Please describe a technical training project/program (supporting the Programs 787, 777, 767, 747, PD, etc.) that you perceived as being unsuccessful. What factors made this program unsuccessful? In your opinion, did this project closely align to company/organizational goals? Why and how?*

- *In your opinion, what characteristics does a technical training project/program need to have to positively influence organizational effectiveness?*
  - *What tools/guidelines/methodologies are used for making the decisions to invest in a training program? What main factors does the training organization consider?*

- *How does Structures University participate in the strategic planning process for the enterprise (e.g. strategic locations across Boeing sites, etc.)?*

- *How does Structures University know when a new technology is being considered by the other organizations (e.g. 787, 767, 777, PD, EO&T, BR&T, etc.)?*
    - *Is the training organization more reactive or proactive in this respect in your opinion?*
- *What is the strategic approach that Structures University is taking towards supporting each of the new Design Centers at Boeing sites outside of the Puget Sound (e.g. Charleston, Long Beach, Moscow, etc.)?*

Interviewee 2 [I2]

- *What do you perceive as the main organizational goals for engineering?*
- *How does the engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?*
- *How does the engineering organization know when to invest in a new technology?*
- *How does the engineering organization know when to train the workforce to align with new technology development?*
- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*
- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 3 [I3]

- *Describe a technical training project/program where you perceived as being successful. In your opinion, did this project closely align to company/organizational goals? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*
- *Describe a technical training project/program where you perceived as being a challenge (mainly what the challenges were that made the project/program difficult to be successful). In your opinion, did this project closely align to company/organizational goals? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*
- *What do you perceive as the main organizational goals for training? How do these organizational goals align with the overall company goals?*
- *How would you define a project/program being successful?*
- *What tools/guidelines/methodologies are used for determining when to offer training? For making the decisions to invest in a training program?*

- *How does the training leadership team participate in the strategic planning process for the enterprise?*

- *How does the training organization know when a new technology is being considered by the other organizations (e.g. 787, 767, 777, PD, EO&T, BR&T, etc.)?*

- *When planning for investing in training, how does technology investments from the enterprise affect the decision? (any examples?)*

- *How does the training organization know when to engage in conversations with the technology organizations to know when training is needed? (i.e. Is the training organization more reactive or proactive in this respect in your opinion.)*

Interviewee 4 [I4]

- *What do you perceive as the main organizational goals for engineering?*

- *How does the engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?*

- *How does the engineering organization know when to invest in a new technology?*

- *How does the engineering organization know when to train the workforce to align with new technology development?*

- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*

- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 5 [I5]

- *Describe a technology innovation project/program where you perceived as being successful. In your opinion, did this project closely align to company/organizational goals (e.g. airplane more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *Describe a technology innovation project/program where you perceived as being a challenge (mainly what the challenges were that made the project/program difficult to be successful). In your opinion, did this project closely align to company/organizational goals (e.g. airplane more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *How would you define a project/program being successful? Effective?*

- *Discussions regarding the 787 airframe or fuselage as a whole - looking forward to hearing some of the positive examples as well as some challenges that you have encountered while working on that program, especially when and how the decisions were made to use composites or not for this example. Also an example of when you perceived that it was not the right time to use composites, but the project/program continued to move forward with the decision to use composites. In what aspects did this present a challenge? (Note that this last topic may or may not apply to you)*

Interviewee 6 [I6]

- *Describe a technology innovation project/program where you perceived as being successful. In your opinion, did this project closely align to company/organizational goals (e.g. airplane more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *Describe a technology innovation project/program where you perceived as being a challenge (mainly what the challenges were that made the project/program difficult to be successful). In your opinion, did this project closely align to company/organizational goals (e.g. airplane more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *How would you define a project/program being successful? Effective?*

- *Looking forward to hearing some of the positive examples from the 777 as well as some challenges encountered from the 787 while working on those programs, especially when and how the decisions were made to use composites or not for the appropriate given examples. Also an example of when you perceived that it was not the right time to use composites, but the project/program continued to move forward with the decision to use composites. In what aspects did this present a challenge? (Note that this last topic may or may not apply to you)*

Interviewee 7 [I7]

- *What do you perceive as the main organizational goals for training? How do these organizational goals align with the overall company goals?*

- *How would you define a project/program as being successful?*

- *Describe a technical training project/program that you perceived as being successful. What factors made this program successful? In your opinion, did this project closely align to company/organizational goals? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *Describe a technical training project/program that you perceived as being unsuccessful. What factors made this program unsuccessful? In your opinion, did this project closely align to company/organizational goals? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *What tools/guidelines/methodologies are used for determining when to offer training? For making the decisions to invest in a training program?*

- *How does the training leadership team participate in the strategic planning process for the enterprise (e.g. goals of the LTD Strategic Business Partner group)?*

- *How does the training organization know when a new technology is being considered by the other organizations (e.g. 787, 767, 777, PD, EO&T, BR&T, etc.)?*

  - *Is the training organization more reactive or proactive in this respect in your opinion?*

- *How does training formed outside of LTD (e.g. Structures University, internal training developed by the programs, etc.) affect the LTD organization (in terms of rework, approaching customers to create a better business model regarding training, etc)?*

Interviewee 8 [I8]

- *Describe a technology innovation project/program where you perceived as being successful. In your opinion, did this project closely align to company/organizational goals (e.g. product being more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *Describe a technology innovation project/program where you perceived as being* **not** *as successful (mainly what the key factors were that made the project/program difficult to be successful). In your opinion, did this project closely align to company/organizational goals (e.g. product more robust, safer, lighter, or less expensive)? Why and how? How do you know there was an alignment/misalignment? What were the indicators?*

- *How would you define a project/program being successful? Effective?*

Interviewee 9 [I9]

- *Describe a technical training project/program where you perceived as being successful (e.g. Modern Aircraft Structures). In your opinion, did this project closely align to company/organizational goals (e.g. cost, less rework by engineers, etc.)? Why and how?*

- *In your opinion, do the composite certificate programs positively contribute to organizational effectiveness? Why and how?*

- *In your opinion, could the organization have benefitted more by having these certificate programs offered earlier than 2004-2005 (i.e. to support the earlier programs like 777, 747, etc.)? Do you perceive the timing of the composite certificate program to be just right or a little bit late?*

- *In what aspects do you think made MAS program successful?*

- *How was the MAS program developed in order to align to organizational needs? (e.g. having key technical fellows and engineers teach the course and help provide materials)*

- *How was the MAS program developed in order to align to technology needs? (e.g. composite technology, fitting to the 787 program, etc.)*

Interviewee 10 [I10]

- *What do you perceive as the main organizational goals for training?*
- *How does the Shell training organizations participate in the strategic planning process to best align to the organizational goals across the enterprise?*
- *How does Shell training organizations know when a new technology is being considered by the other organizations?*
- *How does Shell manage the adaptation of its training programs to new technological developments and innovations?*
- *What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?*
- *Can you please describe the tools/guidelines/methodologies that are used for determining when to offer and invest in a training program?*
- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*
- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 11 [I11]

- *What do you perceive as the main organizational goals for training?*
- *How does the Shell training organizations participate in the strategic planning process to best align to the organizational goals across the enterprise?*
- *How does Shell training organizations know when a new technology is being considered by the other organizations?*
- *How does Shell manage the adaptation of its training programs to new technological developments and innovations?*
- *What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?*
- *Can you please describe the tools/guidelines/methodologies that are used for determining when to offer and invest in a training program?*

- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*

- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 12 [I12]

- *What do you perceive as the main organizational goals for engineering?*

- *How does the engineering organization participate in the strategic planning process to best align to the organizational goals across the enterprise?*

- *How does the engineering organization know when to invest in a new technology?*

- *How does the engineering organization know when to train the workforce to align with new technology development?*

- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*

- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 13 [I13]

- *What do you perceive as the main organizational goals for training?*

- *How does the Shell training organizations participate in the strategic planning process to best align to the organizational goals across the enterprise?*

- *How does Shell training organizations know when a new technology is being considered by the other organizations?*

- *How does Shell manage the adaptation of its training programs to new technological developments and innovations?*

- *What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?*

- *Can you please describe the tools/guidelines/methodologies that are used for determining when to offer and invest in a training program?*

- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*

- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

Interviewee 14 [I14]

- *What do you perceive as the main organizational goals for training?*

- *How does the Shell training organizations participate in the strategic planning process to best align to the organizational goals across the enterprise?*

- *How does Shell training organizations know when a new technology is being considered by the other organizations?*

- *How does Shell manage the adaptation of its training programs to new technological developments and innovations?*

- *What are the key factors that are considered when making the decision to provide an effective training program towards technological developments and innovations?*

- *Think of a successful training program that you have worked on in the past. How would you define a program as being successful? What characteristics made this program successful? In your opinion, did this program closely align to company/organizational goals because of the characteristics mentioned earlier?*

- *Think of an unsuccessful training program that you have worked on in the past. How would you define a program as being unsuccessful? What characteristics made this program unsuccessful? In your opinion, did this program misalign to the company/organizational goals because of the characteristics mentioned earlier? What could have been done proactively in order for this program to be successful?*

APPENDIX 4B

SUB-EXPLORATORY QUESTIONS (SUB-EQS)

Appendix 4B describes and lists the sub-exploratory questions (sub-EQs) addressed in this research in the analysis of the qualitative data. The aim of the sub-EQs was to succinctly analyze the qualitative data and provide key variables to address the first research sub-question.

General - All 14 interviewees

Analysis of the data from across all 14 interviewees provides a general overview of the most important variables, as well as the correlations between the constructs and combined constructs. Statistical analysis was performed in SPSS to determine if the two individual constructs or two combined constructs being analyzed are related to each other. Specifically, the correlation analysis provided the magnitude and direction of association between the two constructs or combined constructs. In the process of the correlation analysis, specific variables that were considered most important that are related to each of the constructs and combined constructs surfaced. This list of variables was taken into account when determining what final variables to consider for the conceptual model development. It was not the intent in this research to prove cause and effect between the variables. The interest was to know if the change in one variable brings about a change in the other variable. This knowledge addressed the second research sub-question: *What are the relationships between the key variables?*

Question sub-EQ1 through sub-EQ2c aims to list the key variables that are most important across all 14 interviewees. This list will form a basis as to what variables to expect in the lists generated in the analysis of the groups of interest. In general, this question aligns with providing answers to the first research sub-question: *What key variables are significant for training, technology innovation, and organizational effectiveness?*

sub-EQ1. What are the most important variables across all 14 interviewees?

sub-EQ2a. What are the most important variables across all 14 interviewees relating to ***OE****? How strong are the relationships?*

sub-EQ2b. What are the most important variables across all 14 interviewees relating to ***TI****? How strong are the relationships?*

sub-EQ2c. What are the most important variables across all 14 interviewees relating to ***TR****? How strong are the relationships?*

sub-EQ3a through *sub*-EQ3c uses statistical analysis to determine any correlation between the constructs. Specifically, the magnitude and direction of the association between the constructs will be analyzed.

> *sub-EQ3a: Are the variables that are related to **TI** different than **TR**?*

> *sub-EQ3b: Are the variables that are related to **TI** different than **OE**?*

> *sub-EQ3c: Are the variables that are related to **TR** different than **OE**?*

sub-EQ4a through *sub*-EQ4c uses the information deduced from the statistical analysis performed in EQ3a through EQ3c to list the most important variables for both constructs being analyzed. Moreover, the statistical analysis verifies that there is no significant difference regarding the most important variables between the two constructs. Hence, the most important variables can be listed to represent both constructs being analyzed.

> *sub-EQ4a. What are the most important variables for both **TI** and **TR**?*

> *sub-EQ4b. What are the most important variables for both **TI** and **OE**?*

> *sub-EQ4c. What are the most important variables for both **TR** and **OE**?*

Boeing vs non-Boeing

The purpose of *sub*-EQ5a through *sub*-EQ8d is to determine if it is necessary to perform analysis separating Boeing and non-Boeing interviewees. If it is determined through correlation analysis that there is insignificant difference between the variables for Boeing and non-Boeing, then the continuation of the analysis will only include the comparisons between the groups of interest across all 14 interviewees instead of separating between Boeing and non-Boeing; thereby, justifying the sets of interest to analyze from Table 4-1 in Chapter 4.

Questions *sub*-EQ5a through *sub*-EQ5d dives into all 35 variables and lists the most important variables for Boeing and non-Boeing. The purpose of this analysis is to study the list of most important variables and determine if there are any correlations between the two groups of interest. Statistical analysis is used to determine if the most important variables for Boeing is different than non-Boeing. If through statistical analysis that it is determined that there is no significant difference between the most important variables for Boeing and the most important variables for non-Boeing, then it can be assumed that a common list of most important variables can be considered for both Boeing and non-Boeing.

sub-EQ5a. What are the most important variables for the ***Boeing Company****?*

sub-EQ5b. What are the most important variables for ***non-Boeing*** *interviewees?*

sub-EQ5c. Are the most important variables at ***Boeing*** *different than* ***non-Boeing****?*

sub-EQ5d. What are the most important variables for both Boeing and non-Boeing?

Questions *sub*-EQ6a through *sub*-EQ8d dives into the variables that are related to each construct with respect to Boeing and non-Boeing. The purpose of this analysis is to study the list of most important variables relating to the three constructs individually from a company standpoint. Statistical analysis is used to determine if the most important variables relating to each construct for Boeing is different than non-Boeing. If through statistical analysis that it is determined that there is no significant difference between the most important variables relating to each construct for Boeing and the most important variables relating to each construct for non-Boeing, then it can be assumed that a common list of most important variables relating to each construct can be considered for both Boeing and non-Boeing.

sub-EQ6a. What are the most important variables for the ***Boeing Company*** *relating to* ***OE****? How strong are the relationships?*

sub-EQ6b. What are the most important variables for the ***non-Boeing*** *interviewees relating to* ***OE****? How strong are the relationships?*

sub-EQ6c. Are the most important variables relating to ***OE*** *at Boeing different than non-Boeing?*

sub-EQ6d. What are the most important variables relating to ***OE*** *for both* ***Boeing*** *and* ***non-Boeing*** *interviewees? How strong are the relationships?*

sub-EQ7a. What are the most important variables for the ***Boeing Company*** *relating to* ***TI****? How strong are the relationships?*

sub-EQ7b. What are the most important variables for the ***non-Boeing*** *interviewees relating to* ***TI****? How strong are the relationships?*

sub-EQ7c. Are the most important variables relating to ***TI*** *at* ***Boeing*** *different than* ***non-Boeing****?*

sub-EQ7d. What are the most important variables relating to ***TI*** *for both* ***Boeing*** *and* ***non-Boeing*** *interviewees? How strong are the relationships?*

sub-EQ8a. What are the most important variables for the ***Boeing Company*** *relating to* ***TR****? How strong are the relationships?*

sub-EQ8b. What are the most important variables for the ***non-Boeing*** *interviewees relating to* ***TR****? How strong are the relationships?*

sub-EQ8c. Are the most important variables relating to ***TR*** *at* **Boeing** *different than* **non-Boeing***?*

sub-EQ8d. What are the most important variables relating to ***TR*** *for both* **Boeing** *and* **non-Boeing** *interviewees? How strong are the relationships?*

Manager vs non-manager

Questions *sub*-EQ9a through *sub*-EQ12d dives into all 35 variables and lists the most important variables for manager and non-manager. The purpose of this analysis is to study the list of most important variables and determine if there are any correlations between the two groups of interest.

Question *sub*-EQ9a through *sub*-EQ9d aims to list the key variables that are most important for manager and non-manager. Statistical analysis is used to determine if the most important variables for managers are different than non-managers. If through statistical analysis that it is determined that there is no significant difference between the most important variables for managers and the most important variables for non-managers, then it can be assumed that a common list of most important variables can be considered for both managers and non-managers.

sub-EQ9a. What are the most important variables mentioned by the **Managers***?*

sub-EQ9b. What are the most important variables mentioned by the **non-Managers***?*

sub-EQ9c. Are the most important variables mentioned by **managers** *different than* **non-managers***?*

sub-EQ9d. What are the most important variables mentioned by both the **managers** *and* **non-managers***?*

Questions *sub*-EQ10a through *sub*-EQ12d dives into the variables that are related to each construct with respect to managers and non-managers. The purpose of this analysis is to study the list of most important variables relating to the three constructs individually from a company standpoint.

Statistical analysis is used to determine if the most important variables relating to each construct for managers is different than non-managers. If through statistical analysis that it is determined that there is no significant difference between the most important variables relating to each construct for managers and the most important variables relating to each construct for non-managers, then it can be assumed that a common list of most important variables relating to each construct can be considered for both managers and non-managers.

sub-EQ10a. What are the most important variables for the **managers** *relating to* ***OE****? How strong are the relationships?*

sub-EQ10b. What are the most important variables for the **non-managers** *relating to* ***OE****? How strong are the relationships?*

sub-EQ10c. Are the most important variables relating to ***OE*** *for* **managers** *different than* **non-managers***?*

sub-EQ10d. What are the most important variables relating to ***OE*** *mentioned by both the* **managers** *and* **non-managers***?*

sub-EQ11a. What are the most important variables for the ***managers*** *relating to* ***TI****? How strong are the relationships?*

sub-EQ11b. What are the most important variables for the ***non-managers*** *relating to* ***TI****? How strong are the relationships?*

sub-EQ11c. Are the most important variables relating to ***TI*** *for the* ***managers*** *different than* ***non-managers****?*

sub-EQ11d. What are the most important variables relating to ***TI*** *mentioned by both the* ***managers*** *and* ***non-managers****?*

sub-EQ12a. What are the most important variables for the ***managers*** *relating to* ***TR****? How strong are the relationships?*

sub-EQ12b. What are the most important variables for the ***non-managers*** *relating to* ***TR****? How strong are the relationships?*

sub-EQ12c. Are the most important variables relating to ***TR*** *for the* ***managers*** *different than* ***non-managers****?*

sub-EQ12d. What are the most important variables relating to ***TR*** *mentioned by both the* ***managers*** *and* ***non-managers****?*

Training SMEs vs Engineering SMEs

Questions *sub*-EQ13a through *sub*-EQ15d dives into all 35 variables and lists the most important variables for training SMEs and engineering SMEs. The purpose of this analysis is to study the list of most important variables and determine if there are any correlations between the two groups of interest.

Question *sub*-EQ13a through *sub*-EQ13d aims to list the key variables that are most important for training SMEs and engineering SMEs. Statistical analysis is used to determine if the most important variables for training SMEs are different than engineering SMEs. If through statistical analysis that it is determined that there is no significant difference between the most important variables for training SMEs and the most important variables for engineering SMEs, then it can be assumed that a common list of most important variables can be considered for both training SMEs and engineering SMEs.

sub-EQ13a. What are the most important variables mentioned by the ***training SMEs****?*

sub-EQ13b. What are the most important variables mentioned by the ***engineering SMEs****?*

sub-EQ13c. Are the most important variables mentioned by ***training SMEs*** *different than* ***engineering SMEs****?*

sub-EQ13d. What are the most important variables mentioned by both the ***training SMEs*** *and* ***engineering SMEs****?*

Questions *sub*-EQ14a through *sub*-EQ15d dives into the variables that are related to the TI and TR construct with respect to the training SMEs and engineering SMEs. The purpose of this analysis is to study the list of most important variables relating to the two constructs individually from a company standpoint.

Statistical analysis is used to determine if the most important variables relating to the TI and TR constructs for training SMEs is different than engineering SMEs. If through statistical analysis that it is determined that there is no significant difference between the most important variables relating to the TI and TR constructs for training SMEs and the most important variables relating to the TI and TR constructs for engineering SMEs, then it can be assumed that a common list of most important variables relating to the TI and TR constructs can be considered for both training SMEs and engineering SMEs.

> *sub-EQ14a. What are the most important variables for the* ***training SMEs*** *relating to* ***TI****? How strong are the relationships?*
>
> *sub-EQ14b. What are the most important variables for the* ***engineering SMEs*** *relating to* ***TI****? How strong are the relationships?*
>
> *sub-EQ14c. Are the most important variables relating to* ***TI*** *for the* ***training SMEs*** *different than* ***engineering SMEs****?*
>
> *sub-EQ14d. What are the most important variables relating to* ***TI*** *mentioned by both the* ***training SMEs*** *and* ***engineering SMEs****?*
>
> *sub-EQ15a. What are the most important variables for the* ***training SMEs*** *relating to* ***TR****? How strong are the relationships?*
>
> *sub-EQ15b. What are the most important variables for the* ***engineering SMEs*** *relating to* ***TR****? How strong are the relationships?*
>
> *sub-EQ15c. Are the most important variables relating to* ***TR*** *for the* ***training SMEs*** *different than* ***engineering SMEs****?*
>
> *sub-EQ15d. What are the most important variables relating to* ***TR*** *mentioned by both the* ***training SMEs*** *and* ***engineering SMEs****?*

Engineering SMEs involved in Training vs Engineering SMEs not involved in training

Questions *sub*-EQ16a through *sub*-EQ18d dives into all 35 variables and lists the most important variables for engineering SMEs involved in training and engineering SMEs not involved in training. The purpose of this analysis is to study the list of most important variables and determine if there are any correlations between the two groups of interest.

Question *sub*-EQ16a through *sub*-EQ16d aims to list the key variables that are most important for engineering SMEs involved in training and engineering SMEs not involved in training. Statistical analysis is used to determine if the most important variables for engineering SMEs involved in training are different than engineering SMEs not involved in training. If through statistical analysis that it is determined that there is no significant difference between the most important variables for engineering SMEs involved in training and the most important variables for engineering SMEs not involved in training, then it can be assumed that a common list of most important variables can be considered for both engineering SMEs involved in training and engineering SMEs not involved in training.

> *sub-EQ16a. What are the most important variables mentioned by the* ***engineering SMEs involved in training****?*

> *sub-EQ16b. What are the most important variables mentioned by the* ***engineering SMEs not involved in training****?*

> *sub-EQ16c. Are the most important variables mentioned by* ***engineering SMEs involved in training*** *different than* ***engineering SMEs not involved in training****?*

> *sub-EQ16d. What are the most important variables mentioned by both the* ***engineering SMEs involved in training*** *and* ***engineering SMEs not involved in training****?*

Questions *sub*-EQ17a through *sub*-EQ18d dives into the variables that are related to the TI and TR construct with respect to engineering SMEs involved in training and engineering SMEs not involved in training. The purpose of this analysis is to study the list of most important variables relating to the two constructs of the TI and TR individually from a company standpoint.

Statistical analysis is used to determine if the most important variables relating to the TI and TR construct for engineering SMEs involved in training is different than engineering SMEs not involved in training. If through statistical analysis that it is determined that there is no significant difference between the most important variables relating to the TI and TR construct for engineering SMEs involved in training and the most important variables relating to the TI and TR construct for engineering SMEs not involved in training, then it can be assumed that a common list of most important variables relating to the TI and TR construct can be considered for both engineering SMEs involved in training and engineering SMEs not involved in training.

> *sub-EQ17a. What are the most important variables for the* ***engineering SMEs involved in training*** *relating to* ***TI****? How strong are the relationships?*

> *sub-EQ17b. What are the most important variables for the* ***engineering SMEs not involved in training*** *relating to* ***TI****? How strong are the relationships?*

> *sub-EQ17c. Are the most important variables relating to* ***TI*** *for the* ***engineering SMEs involved in training*** *different than* ***engineering SMEs not involved in training****?*

> *sub-EQ17d. What are the most important variables relating to* ***TI*** *mentioned by both the* ***engineering SMEs involved in training*** *and* ***engineering SMEs not involved in training****?*

> *sub-EQ18a. What are the most important variables for the* ***engineering SMEs involved in training*** *relating to* ***TR****? How strong are the relationships?*

> *sub-EQ18b. What are the most important variables for the* ***engineering SMEs not involved in training*** *relating to* ***TR****? How strong are the relationships?*

sub-EQ18c. Are the most important variables relating to ***TR*** *for the* **engineering SMEs involved in training** *different than* **engineering SMEs not involved in training***?*

sub-EQ18d. What are the most important variables relating to ***TR*** *mentioned by both the* **engineering SMEs involved in training** *and* **engineering SMEs not involved in training***?*

Engineering Manager vs Training Manager

Questions *sub*-EQ19a through *sub*-EQ22d dives into all 35 variables and lists the most important variables for engineering managers and training managers. The purpose of this analysis is to study the list of most important variables and determine if there are any correlations between the two groups of interest.

Question *sub*-EQ19a through *sub*-EQ19d aims to list the key variables that are most important for engineering manager and training managers. Statistical analysis is used to determine if the most important variables for engineering managers are different than training managers. If through statistical analysis that it is determined that there is no significant difference between the most important variables for engineering managers and the most important variables for training managers, then it can be assumed that a common list of most important variables can be considered for both engineering managers and training managers.

sub-EQ19a. What are the most important variables mentioned by the **engineering managers***?*

sub-EQ19b. What are the most important variables mentioned by the **training managers***?*

sub-EQ19c. Are the most important variables mentioned by **engineering managers** *different than* **training managers***?*

sub-EQ19d. What are the most important variables mentioned by both the **engineering managers** *and* **training managers***?*

Questions *sub*-EQ20a through *sub*-EQ22d dives into the variables that are related to each construct with respect to engineering managers and training managers. The purpose of this analysis is to study the list of most important variables relating to the three constructs individually from a company standpoint.

Statistical analysis is used to determine if the most important variables relating to each construct for engineering managers is different than training managers. If through statistical analysis that it is determined that there is no significant difference between the most important variables relating to each construct for engineering managers and the most important variables relating to each construct for training managers, then it can be assumed that a common list of most important variables relating to each construct can be considered for both engineering managers and training managers.

sub-EQ20a. What are the most important variables for the **engineering managers** *relating to* ***OE****? How strong are the relationships?*

sub-EQ20b. What are the most important variables for the **training managers** *relating to* ***OE****? How strong are the relationships?*

sub-EQ20c. Are the most important variables relating to ***OE*** *for* **engineering managers** *different than* **training managers***?*

sub-EQ20d. What are the most important variables relating to ***OE*** *mentioned by both the* **engineering managers** *and* **training managers***?*

sub-EQ21a. What are the most important variables for the **engineering managers** *relating to* ***TI****? How strong are the relationships?*

sub-EQ21b. What are the most important variables for the **training managers** *relating to* ***TI****? How strong are the relationships?*

sub-EQ21c. Are the most important variables relating to ***TI*** *for the* **engineering managers** *different than* **training managers***?*

sub-EQ21d. What are the most important variables relating to ***TI*** *mentioned by both the* **engineering managers** *and* **training managers***?*

sub-EQ22a. What are the most important variables for the **engineering managers** *relating to* ***TR****? How strong are the relationships?*

sub-EQ22b. What are the most important variables for the **training managers** *relating to* ***TR****? How strong are the relationships?*

sub-EQ22c. Are the most important variables relating to ***TR*** *for the* **engineering managers** *different than* **training managers***?*

sub-EQ22d. What are the most important variables relating to ***TR*** *mentioned by both the* **engineering managers** *and* **training managers***?*

APPENDIX 4C

EXAMPLE TABLES FROM CODING PROCESS FOR QUALITATIVE DATA ANALYSIS

Appendix 4C lists several examples of the coding process for the qualitative data reduction performed in this research. The example tables shown in this appendix contribute to the coding process as described in Section 4.5.2.

Table 4C-1. Example of raw data word count table

words	Total
ABLE	7
ABOUT	6
ACCESS	1
ACCOMPLISH	1
ACCOMPLISHED	1
ACCOUNTS	1
ACCURACY	1
ACROSS	5
ACTION	1
ACTUAL	1
ACTUALLY	2
ADDED	1
ADDITION	2
ADDITIONAL	1
ADDITIONALLY	1
ADDRESSED	1
ADJUSTED	1
ADOPT	1
AFFECT	2
AFFECTED	1
AGAIN	1
AGO	1
AGREEMENT	1
AHEAD	1

Table 4C-2. Example of word count table with the addition of coding categories

words	Word Count	Total	Coding Category
TIME	22	22	schedule
TRAINING	13	13	training
MONEY	12	12	cost
WEIGHT	11	11	weight
MANAGEMENT	10	10	management
TRL	9	9	TRL
NEED	7	7	market need
PERFORMANCE	7	7	performance
COST	5	5	cost
ENTERPRISE	5	5	market need
PARTNERS	5	5	market need
BAD	4	4	failure
DECIDE	4	4	decision making
DECISIONS	4	4	decision making
ENGINEERS	4	4	audience
EXPENSIVE	4	4	cost
INNOVATION	4	4	technology
KNOWLEDGE	4	4	training
MARKET	4	4	market need
ORGANIZATIONAL	4	4	organizational effectiveness
RELIABILITY	4	4	reliability
CLASS	3	3	training
COURSE	3	3	training
DECIDED	3	3	decision making
FAILURE	3	3	failure

Table 4C-3. Example of coding category filtered and listed with the corresponding words from the raw data

Coding Category	Words Related to Coding Category - First Cycle Coding
adopting	ADOPTS
audience	ENGINEERS
audience	RETIREES
audience	SUPPLIER
audience	SUPPLIERS
audience	PARTNER
audience	ENGINEERING
audience	ENGINEERING
benefit	BENEFITED
benefit	ADVANTAGES
benefit	BENEFIT
benefit	BENEFITED
benefit	BENEFIT
benefit	BENEFIT
benefit	BENEFIT
capacity	CAPACITY
capacity	CAPACITY
challenge	CHALLENGING
challenge	DIFFICULT
challenge	PROBLEMS
challenge	CHALLENGES
challenge	CHALLENGE
challenge	CHALLENGING

Table 4C-4. Example of individual coding categories with condensed corresponding words from raw data and corresponding coding type

Coding Category	Words Relating to Coding Category	Coding Type	Key words from Raw Data
competency	COMPETENCE	descriptive	COMPETENCE
competency		descriptive	COMPETENCE
competency		descriptive	COMPETENCE
competency	COMPETENCIES	descriptive	COMPETENCIES
competency		descriptive	COMPETENCIES
competency	COMPETENCY	descriptive	COMPETENCY
competency		descriptive	COMPETENCY
competent	COMPETENT	descriptive	COMPETENT
competent	MASTERY	descriptive	MASTERY
competency	SKILL	descriptive	SKILL
competent	SKILLED	descriptive	SKILLED

Table 4C-5. Summary of coding category, words from the raw data relating to the coding category, and the definitions of the coding category

Coding Category	Key Words Relating to Coding Category	Definitions	Reference
audience	applicants, audience, consumer, customer, employee, engineer, functions, learner, participants, partners, programs, stakeholders, students, supplier, trainee, workforce, human capital	Audience here is in terms of the training audience, where this includes people attending the course, as well as the people involved in investing in a training program	From Chapter 2: Tannenbaum (2002); Tannenbaum & Yukl (1992); Salas, Tannenbaum, Kraiger, & Smith-Jentsch (2012); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Morano (1973). Coding category mentioned in the interviews via key words relating to the coding category.
benefit	advantages, benefit, benefited	Benefit in this context is synonymous to success factors, where the organization is positively affected by the outcome.	Coding category mentioned in 57% of the interviews via key words relating to the coding category
challenge	accident, bad, challenge, challenging, complicated, detrimental, difficult, disadvantages, disastrous, discouraged, downfalls, fail, frustrating, incorrect, issues, lacks, misleading, mistakes, negative, problem, realignment, recurring, reduced, reduction, redundancies, redundancy, redundant, relearning, reteach, reteaching, retraining, rework, struggle, struggling, unsuccessful, weak	This is the antonym of success, where the organization is negatively affected by the outcome.	Coding category mentioned in 100% of the interviews via key words relating to the coding category
competency	competence, competencies, competency, competent, mastery, skill, skilled	These are the skills needed for engineers to perform successfully or efficiently.	Coding category mentioned in 36% of the interviews via key words relating to the coding category
cost	afford, amount, bankruptcy, budget, buy, cheap, cost, dollar, expenditure, expense, expensive, financial, fund, million, money, nonprofit, paid, pay, price, profit, profitability, revenue, sales, savings, sell, spend, spent, profit	Cost is the monetary expense within a company or organization, where this monetary expense is either gained, invested, or spent.	From Chapter 2: [T] Tannenbaum (2002); Tannenbaum & Yukl (1992); Salas, Tannenbaum, Kraiger, & Smith-Jentsch (2012); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Morano (1973); Casner-Lotto (1988); Aragon-Sanchez, Barba-Aragon, and Sanz-Valle (2003); Park & Jacobs (2011); Hubbard (2009); Noe & Colquitt (2002); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Kraiger (2002); Bartel (2000); [TI] Ciptono (2006); Thompson and Ewer (1989); Leong et al (1990); Shipton, West, Dawson, Birdi, and Patterson (2006); Xue, Ray, and Sambamurthy (2012); Betz (1987); Thurow (1992); [OE] Huselid (1995); Boudreau and Ramstad (2005); Boiral (2012); Jiang, Hu, and Baer (2012); Rosli & Mahmood (2013); Xue, Ray, and Sambamurthy (2012); Wang (2010); Delaney & Huselid (1996); Cameron (1986). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
customer	customer, stakeholder	Customer and audience are synonymous, where your audience can be your customer and vice versa. The term customer in the sense here is where they help provide financial support to the program.	Coding category mentioned in 43% of the interviews via key words relating to the coding category
decision making	advisor, adviser, approval, approve, assessment, assumption, decide, decision, deciding, determination, determine, determining, gate, indicators, invest, overpromising, priorities, promises, risk, signatures, signing	Decision making in this context are the steps taken in order to come to a decision, whether this is to offer a new course, invest in training, invest in a new technology, etc. The key words listed undert his category all relate to the decision making process at the various companies and organizations.	From Chapter 2: Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Noe & Colquitt (2002). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
failure	bad, fail, misalignment, problem, unsuccessful	Failure is synonymous with challenge and is the antonym of success. The key words under this category all relate to each other and are synonymous with failure.	Coding category mentioned in 71% of the interviews via key words relating to the coding category
guideline	approach, certification, compliance, components, criteria, criterion, critical, crucial, discipline, experience, framework, guidance, guideline, imperative, initiatives, mandatory, method, objective, process, regulations, regulatory, require, scope, size, skill, standards	Guideline is the overarching category for a general rule or principle to follow. In this research, guidelines apply to all three constructs and help aid in the decision making process.	Coding category mentioned in 86% of the interviews via key words relating to the coding category
indicator	aspect, drive, driving, emerges, emerging, enabled, enabling, factor, forecast, indicator, key, predict, reason	Indicator is the category for factors used in the decision making process	Coding category mentioned in 79% of the interviews via key words relating to the coding category
knowledge transfer	coach, conference, mentor, forum, seminars, transfer, workshop	Knowledge transfer refers to the transfer of knowledge through formal and informal training	From Chapter 2: Baldwin & Ford (1988); Grossman & Salas (2011). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.

management	approval, chief, direction, director, executive, involved, involvement, lead, manage, manager, managing, motivated, motivation, promoting, proponent, proposal, stakeholders, supervisor, support, visibility	Management is a broad category that refers to the key stakeholders and decision makers at the company or organization	From Chapter 2: Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Noe & Colquitt (2002); Colquitt, LePine, & Noe (2000); Noe (1986); Noe & Schmitt (1986); Quinones (1997); Holton III (1996); Aguinis and Kraiger (2009); [OE] Jiang, Hu, and Baer (2012); Angle and Perry (1981); Huselid & Day (1991). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
market need	competitive, competitors, demand, enterprise, market, need, partner	Market need is a category that defines what the factors are in order to keep a company competitive	From Chapter 2: Boudreau and Ramstad (2005). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
measurement	analyses, analysis, analyze, analyzing, assess, benchmark, certification, certified, certify, challenged, evaluate, evaluation, exam, feedback, mapping, measure, measuring, metric, quantify, results, ROI, trend	Measurement is a general category relating any term that involves measuring or evaluating the benefits or success of the three constructs	From Chapter 2: Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Kraiger (2002); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Bartel (2000); Cannon-Bowers & Salas (1997); Aguinis and Kraiger (2009). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
mentoring	coach, mentor	Mentoring is the act of transferring knowledge.	Coding category mentioned in 57% of the interviews via key words relating to the coding category
organizational effectiveness	affect, business, effect, goal, organization, organize, strategic, strategies, strategy	Organizational effectiveness is used as a general category for any key words relating to the business or organizational strategies and goals	From Chapter 2: Huselid (1995); Walker, Damanpour, Devece (2010); Aragon-Sanchez, Barba-Aragon, and Sanz-Valle (2003); van Eerde, Tang, and Talbot (2008); Aguinis and Kraiger (2009); Rosli & Mahmood (2013); Hubbard (2009); Delaney & Huselid (1996); Boudreau and Ramstad (2005); Boiral (2012); Jiang, Hu, and Baer (2012); Xue, Ray, and Sambamurthy (2012); Wang (2010); Shipton, West, Dawson, Birdi, and Patterson (2006); Park & Jacobs (2011); Cameron (1986); Huselid & Becker (2011); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Angle and Perry (1981); Huselid & Day (1991). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
outsourcing	outsourced, outsourcing	Outsourcing refers to contracting work outside of the organization or company	Coding category mentioned in 29% of the interviews via key words relating to the coding category
performance	accuracy, accurate, capabilities, capability, durability, optimization, outperform, perform, power, productivity, proficiency, quality, reliability, reliable, robust	Performance is a general category mentioned by managers and employees when describing organizational effectiveness and success	From Chapter 2: Casner-Lotto (1988); Kontoghiorghes 2004; Sels (2002); Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009); Noe & Colquitt (2002); Kraiger (2002); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Bartel (2000); Baldwin & Ford (1988); Grossman & Salas (2011); Cannon-Bowers & Salas (1997); Kanki et al. (2010); [OE] Huselid (1995); Walker, Damanpour, Devece (2010); Aragon-Sanchez, Barba-Aragon, and Sanz-Valle (2003); van Eerde, Tang, and Talbot (2008); Rosli & Mahmood (2013); Hubbard (2009); Delaney & Huselid (1996). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
relationship	affect, combination, comparison, dependent, depending, depends, effect, enable, enabling, importance, important, increased, increases, independent, influence, integrate, integrating, integration, interact, involvement, lacking, relationship	Relationship refers to the way in which two or more concepts, objects, or people are connected, or the state of being connected	Coding category mentioned in 100% of the interviews via key words relating to the coding category
research	research	Research refers to the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions. In the context of this research, this term should relate to the technology innovation construct.	Coding category mentioned in 79% of the interviews via key words relating to the coding category
safety	safe, safer, safety	Safety is one of the factors that is considered in the aerospace industry	Coding category mentioned in 43% of the interviews via key words relating to the coding category
risk	risk	Risk is one of the factors that is considered in the decision making process	Coding category mentioned in 14% of the interviews via key words relating to the coding category
schedule	ahead, annual, biannual, date, day, deadlines, duration, faster, fastest, hour, immediately, late, long, milestones, month, outdated, quick, rapid, schedule, scheduling, speed, time, timing, week, year	Schedule refers to the time constraints for deadlines within the company due to money constraints, resource constraints, or market needs	From Chapter 2: Salas, Tannenbaum, Kraiger, & Smith-Jentsch (2012); Tannenbaum (2002); Tannenbaum & Yukl (1992); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009); Morano (1973); Noe & Colquitt (2002); Ford, Quinones, Sego, & Sorra (1992); Quinones, Ford, Sego, & Smith (1995); Casner-Lotto (1988). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.

SME	expert, SME	Subject matter experts in this research refers to the experts in the technology innovation area	Coding category mentioned in 71% of the interviews via key words relating to the coding category
staffing	resource, staff	Staffing in this context refers to the resources needed to perform deliverables	From Chapter 2: [cost] Ciptono (2006); Kamm (1987); Tidd et al (2005); Huselid (1995); [OE] Boudreau and Ramstad (2005). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
success	accomplish, accurate, advantage, align, benefit, best, better, effective, efficiency, efficient, excellent, improve, outstanding, pass, positive, precisely, succeed, success	Success is a category relating to the accomplishment of a purpose or goal	Coding category mentioned in 86% of the interviews via key words relating to the coding category
teaching	adviser, coaches, experience, expert, faculty, geologists, geoscientist, instructor, lecturer, professors, SMEs, specialists, taught, teach, teacher, teaching, trainer	Teaching is a category which refers to SMEs or trainers teaching a course	From Chapter 2: Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Aguinis and Kraiger (2009). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
technology	adopting, composite, gartner, hype, innovation, innovative, maturation, maturity, nanotechnology, paper, papers, patent, publish, readiness, technological, technologies, technologists, technology	Technology is a category for the construct of technology innovation	From Chapter 2: Gartner (2010); Jarvenpaa and Makinen (2008); Xue, Ray, and Sambamurthy (2012); Ciptono (2006); Thompson and Ewer (1989); Leong et al (1990); Shipton, West, Dawson, Birdi, and Patterson (2006); Kamm (1987); Tidd et al (2005); Betz (1987); Thurow (1992). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
training	academia, academic, class, classroom, competencies, competency, content, course, curriculum, deliver, deploy, design, determining, develop, educate, educating, education, enrollment, evaluation, formal, framework, implement, informal, instructor, kirkpatrick, knowledge, learn, lecture, lessons, localized, methodology, program, taught, teach, train, universities, unversity, untrained	Training is a category for the construct of training	From Chapter 2: Goldstein (1993); Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012); Aguinis and Kraiger (2009); Noe & Colquitt (2002); Tannenbaum (2002); Tannenbaum & Yukl (1992); Goldstein (1993); Rossett (1987); Holton III (1996); Sels (2002); van Eerde, Tang, and Talbot (2008); Arthur Jr., Bennett Jr., Edens, and Bell (2003); Morano (1973); Casner-Lotto (1988); Aragon-Sanchez, Barba-Aragon, and Sanz-Valle (2003); Park & Jacobs (2011); Hubbard (2009); Kontoghiorghes 2004; Ford, Quinones, Sego, & Sorra (1992); Quinones, Ford, Sego, & Smith (1995); Kanki et al. (2010). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
TRL	level, TRL	Technology readiness level is used in the context of technology innovation	From Chapter 2: Gartner (2010); Jarvenpaa and Makinen (2008). From Interviews: Coding category mentioned in the interviews via key words relating to the coding category.
value	valuable, value	Value is a category which refers to the monetary worth of something; importance or beneficial of something;	Coding category mentioned in 64% of the interviews via key words relating to the coding category
weight	pound, weight	In aerospace, weight refers to how heavy the structure is which directly affects the performance of the airplane as well as the overall costs	Coding category mentioned in 7% of the interviews via key words relating to the coding category
adopting	adopts	Adopting is a category which refers to adopting a technology innovation	Coding category mentioned in 14% of the interviews via key words relating to the coding category
capacity	capacity	Capacity is a category which refers to the maximum amount that something can contain	Coding category mentioned in 14% of the interviews via key words relating to the coding category
expectation	expectation	Expectation is a category which refers to a strong belief that something will happen or be the case in the future	Coding category mentioned in 14% of the interviews via key words relating to the coding category

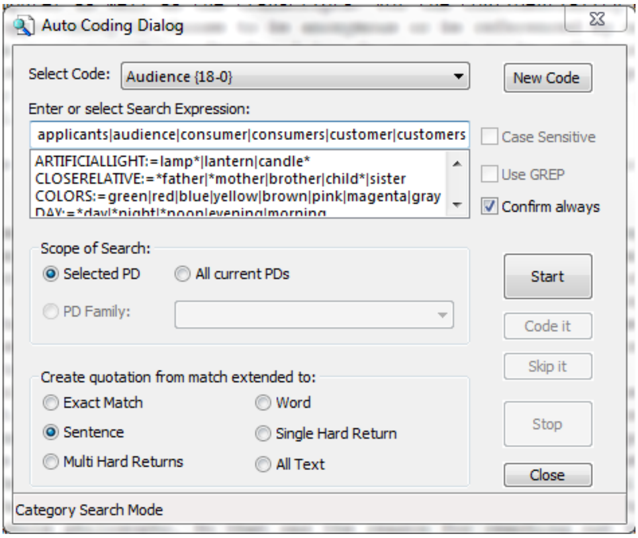


Figure 4C-6. Auto Coding Dialog window showing how the coding is created relative to the quotations

APPENDIX 4D

SYNTAX TABLE USED FOR CODING PROCESS

Appendix 4D contains the syntax table used for describing the coding process from Section 4.5.2. These were the exact words that were used in the data reduction of the raw qualitative data that was captured in the interviews.

Table 4D-1. Syntax used within ATLAS.ti as the units of analysis for coding the 14 interview transcripts

Audience:=applicants | audience | consumer | consumers | customer | customers | employee | employees | engineer | engineering | engineers | function | functions | learner | learners | participants | partner | partners | program | programs | stakeholder | stakeholders | students | supplier | suppliers | trainee | trainees | workforce | human capital

Benefit:=advantage | advantages | benefit | benefited

Challenge:=accident | bad | badly | challenge | challenges | challenging | complicated | detrimental | difficult | difficulties | difficulty | disadvantages | disastrous | discouraged | downfalls | fail | failed | fails | failure | failures | frustrating | incorrect | issues | lacks | misleading | mistakes | negative | problem | problems | realignment | recurring | reduced | reduction | redundancies | redundancy | redundant | relearning | reteach | reteaching | retraining | rework | struggle | struggling | unsuccessful | weak | weaknesses

Competency:=competence | competencies | competency | competent | mastery | skill | skilled

Cost:=afford | affordable | amount | bankruptcy | budget | buy | cheap | cheaper | cheapest | cost | costing | costly | costs | dollar | dollars | expenditure | expense | expenses | expensive | financial | fund | funded | funding | million | millions | money | nonprofit | profit | paid | pay | paying | price | prices | profitability | revenue | sales | savings | sell | selling | spend | spending | spent

Customer:=customer | customers | stakeholder

Decision Making:=advisor | adviser | advisors | advisory | approval | approve | assessment | assumption | decide | decided | decides | decisions | decision | deciding | determination | determine | determines | determining | gate | gates | indicators | invest | invested | investing | investment | investments | overpromising | priorities | promises | risk | signatures | signing

Failure:=bad | fail | failed | misalignment | problem | unsuccessful

Guideline:=approach | certification | compliance | components | criteria | criterias | criterion | critical | crucial | discipline | experience | framework | frameworks | guidance | guideline | guidelines | imperative | initiatives | mandatory | method | methodologies | methodology | methods | objective | objectives | process | processes | regulations | regulatory | require | required | requirement | requirements | requires | scope | size | sizes | skill | skills | standards

Indicator:=aspect | aspects | drive | driven | driver | drivers | drives | driving | emerges | emerging | enabled | enabling | factor | factors | forecast | indicator | indicators | key | predict | predicting | prediction | predictiv e | reason | reasons

Knowledge Transfer:=coaching | conference | conferences | mentor | mentoring | forum | forums | seminars | transfer | workshop | workshops

Management:=approval | chief | chiefs | direction | director | directors | executive | executives | involved | involvement | lead | leader | leaders | leadership | leaderships | leads | manage | managed | management | ma nager | managing | motivated | motivation | promoting | proponent | proposal | proposals | stakeholders | s upervisor | support | supporting | visibility

Market Need:=competitive | competitors | demand | enterprise | market | marketable | marketing | need | needed | needing | needs | partner | partnering | partners

Measurement:=analyses | analysis | analyze | analyzing | assess | assessing | assessment | assessments | ben chmark | benchmarking | certification | certified | certify | certifying | challenged | evaluate | evaluated | eval uation | evaluations | exams | feedback | mapping | measure | measured | measurement | measurements | me asuring | metric | metrics | quantify | results | ROI | trend | trending | trends

Mentoring:=coach | coaching | mentor | mentoring | mentors | mentorship

Organizational Effectiveness:=affect | affecting | business | effect | effectiveness | goal | goals | organization | organizatio nal | organizationally | organizations | organize | strategic | strategies | strategy

Outsourcing:=outsourced | outsourcing

Performance:=accuracy | accurate | capabilities | capability | durability | optimization | outperform | perfo rm | performance | power | productivity | proficiency | quality | reliability | reliable | robust | robustness

Relationship:=affect | affected | combination | comparison | dependent | depending | depends | effect | en able | enabling | importance | important | increased | increases | independent | independently | influence | in fluences | integrate | integrated | integrating | integration | interact | interactions | involvement | lacking | rel ationship | relationships

Research:=research

Safety:=safe | safer | safety

Risk:=risk | risks

Schedule:=ahead | annual | biannual | date | dates | day | days | deadlines | duration | faster | fastest | hour | hours | immediately | late | long | longer | milestones | month | monthly | months | outdated | quick | quicker | quickly | rapid | rapidly | schedule | scheduled | schedules | scheduling | speed | time | timeframe | timelines | times | timing | week | weeks | year | yearly | years

SME:=expert | expertise | experts | SME | SMEs

Staffing:=resource | resources | staff | staffing

Success:=accomplish | accomplished | accomplishments | accurate | advantage | advantages | align | aligned | aligning | alignment | aligns | benefit | best | better | effective | effectively | effectiveness | efficiency | efficient | excellent | improve | improvement | outstanding | pass | positive | positively | precisely | succeed | success | successes | successful | successfully

Teaching:=adviser | coaches | experience | expert | expertise | experts | faculty | geologists | geoscientist | geoscientists | instructor | instructors | lecturer | lecturers | professors | SMEs | specialists | taught | teach | teacher | teachers | teaching | trainer | trainers

Technology:=adopting | composite | composites | gartner | hype | innovation | innovations | innovative | maturation | maturity | nanotechnology | paper | papers | patent | patents | publish | published | readiness | technological | technologically | technologies | technologists | technology

Training:=academia | academic | academics | class | classes | classroom | competencies | competency | content | course | courses | curriculum | deliver | deliverables | delivered | delivering | delivery | deploy | deployed | deployment | deploys | design | designed | designing | determining | develop | developed | developer | developers | developing | development | developments | develops | educate | educating | education | enrollment | evaluation | formal | formalize | formalized | formally | framework | implement | implementation | implemented | implementing | informal | instructor | kirkpatrick | knowledge | learn | learned | learning | lecture | lecturess | lessons | localized | methodology | program | taught | teach | teaching | train | trained | training | trainings | universities | unversity | untrained

TRL:=level | levels | TRL

Value:=valuable | value | valued

Weight:=pound | pounds | weight | weights

Adopting:=adopt | adopts

Capacity:=capacity

Expectation:=expectation | expectations

APPENDIX 4E
FIGURES OF SCATTER PLOTS

Appendix 4E lists scatter plots for all interviews showing a general positive trend between the constructs.

All 14 interviewees

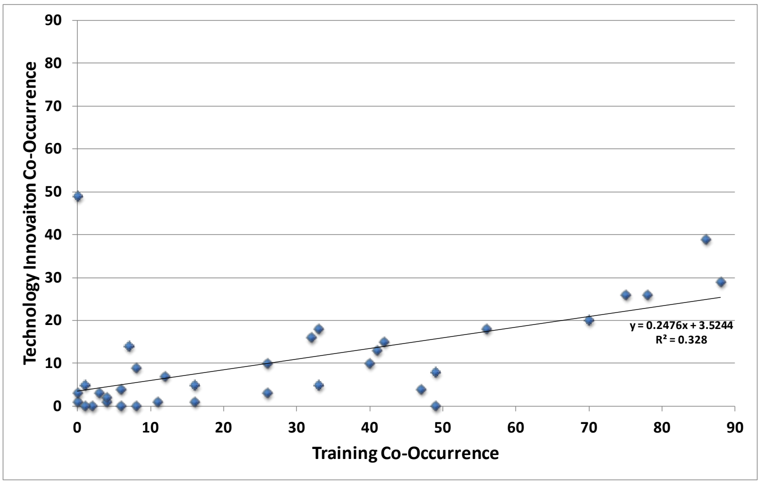


Figure 4E-1a. Scatter plot for TI and TR

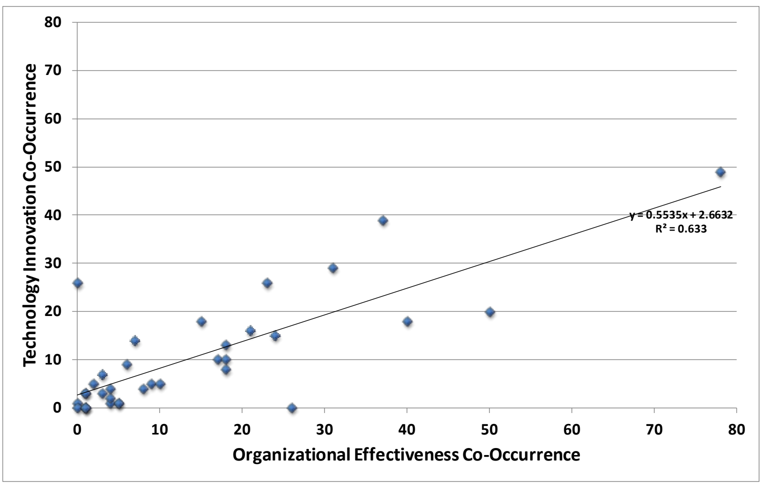


Figure 4E-1b. Scatter plot for TI and OE

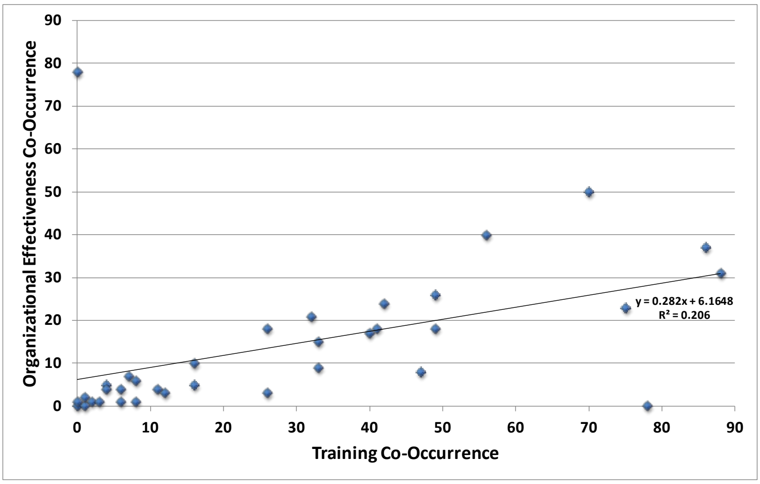


Figure 4E-1c. Scatter plot for OE and TR

Boeing and Non-Boeing

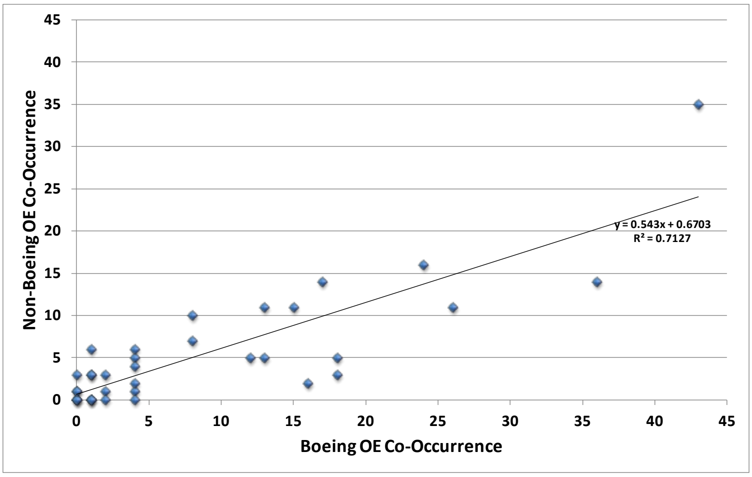


Figure 4E-2a. Scatter plot for non-Boeing and Boeing OE

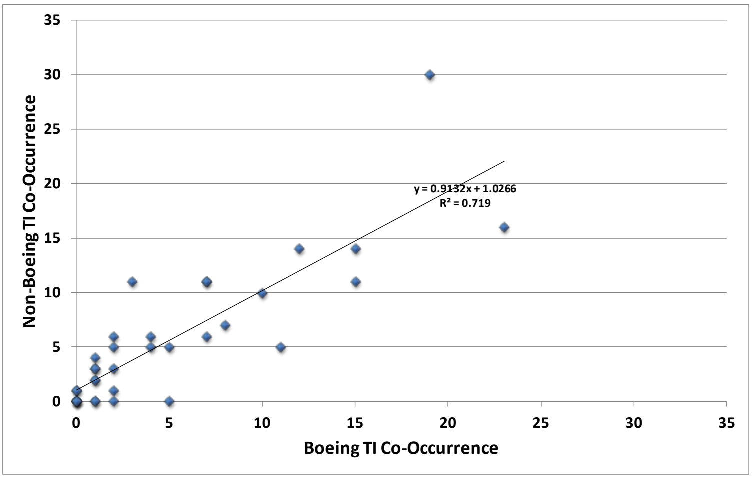


Figure 4E-2b. Scatter plot for non-Boeing and Boeing TI

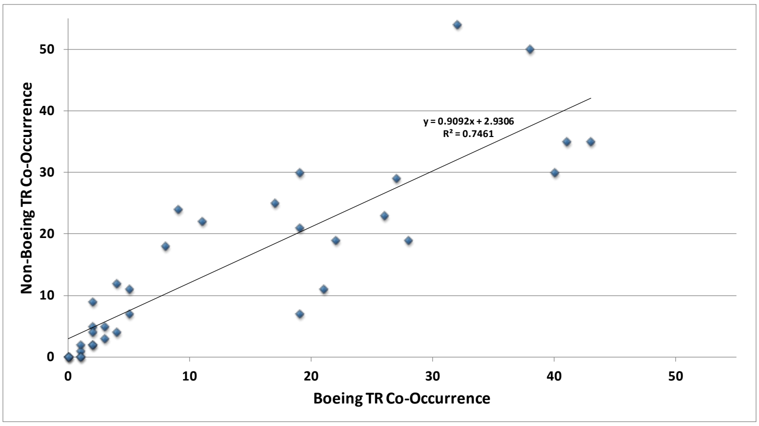


Figure 4E-2c. Scatter plot for non-Boeing and Boeing TR

Manager and Non-Manager

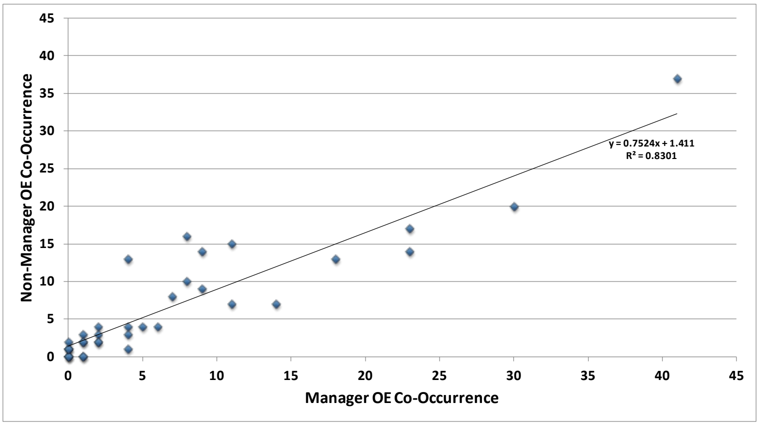


Figure 4E-3a. Scatter plot for non-manager and manager OE

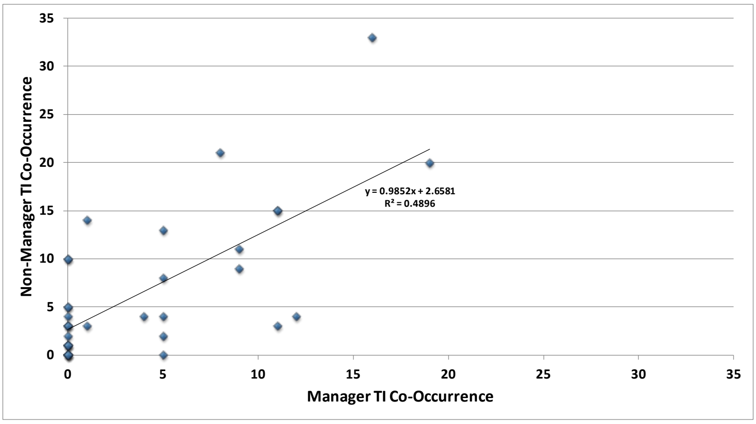


Figure 4E-3b. Scatter plot for non-manager and manager TI

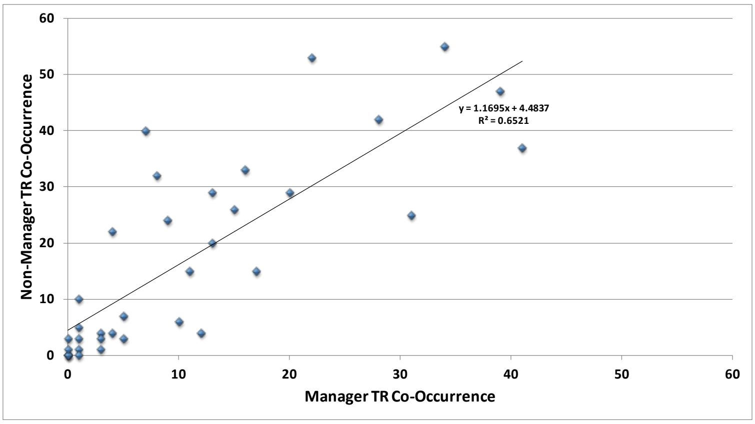


Figure 4E-3c. Scatter plot for non-manager and manager TR

Training SMEs and Engineering SMEs

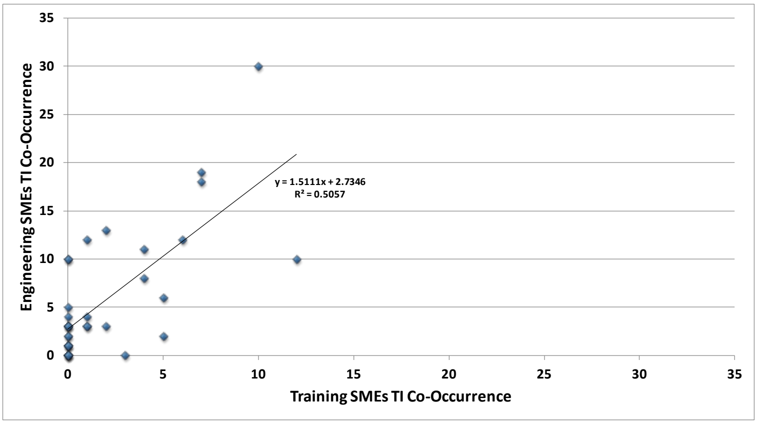


Figure 4E-4a. Scatter plot for engineering and training SMEs TI

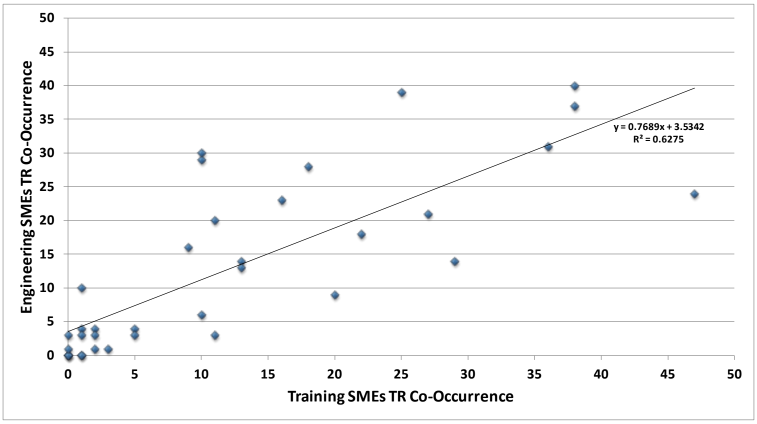


Figure 4E-4b. Scatter plot for engineering and training SMEs TR

Engineering SMEs involved in Training and Engineering SMEs not involved in Training

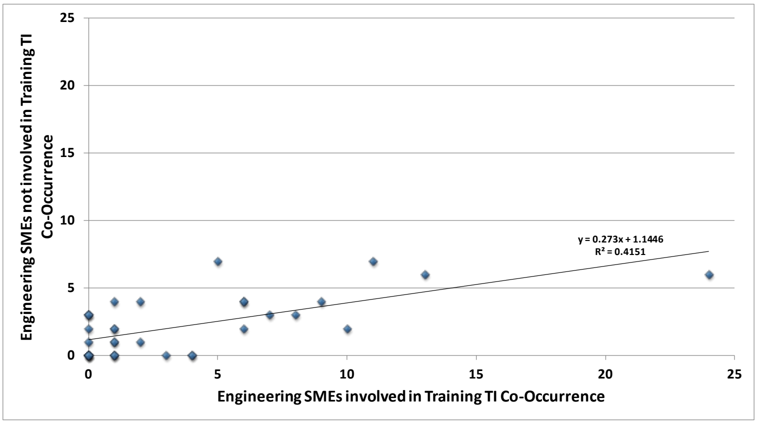


Figure 4E-5a. Scatter plot for engineering SMEs TI

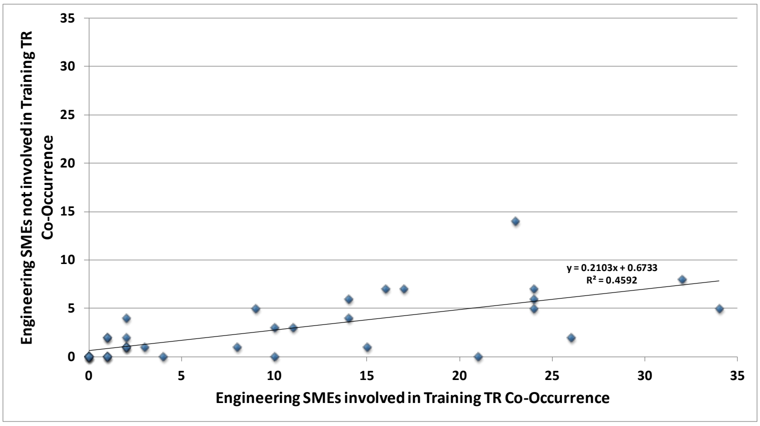


Figure 4E-5b. Scatter plot for engineering SMEs TR

Training Managers and Engineering Managers

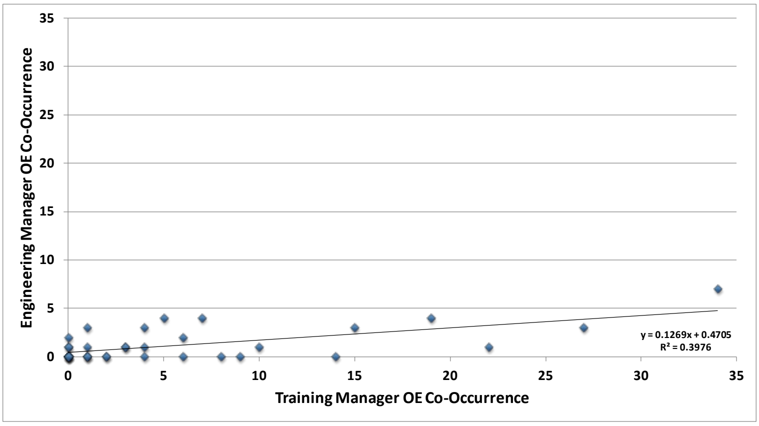


Figure 4E-6a. Scatter plot for managers OE

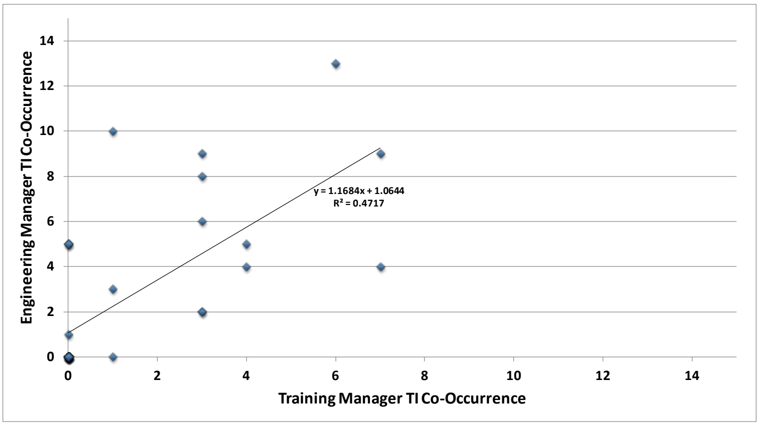


Figure 4E-6b. Scatter plot for managers TI

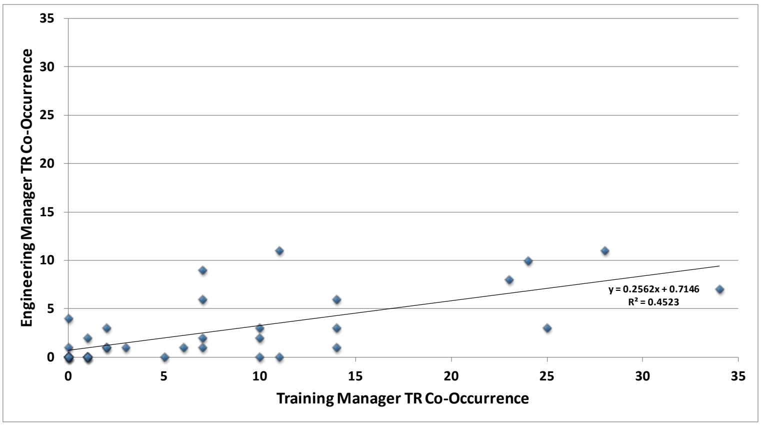


Figure 4E-6c. Scatter plot for managers TR

APPENDIX 4F

ADDRESSING SUB-EXPLORATORY QUESTIONS (SUB-EQS)

Appendix 4F addresses all of the sub-EQs as first introduced in Appendix 4B. The contents in Appendix 4F gives the results for the qualitative data analysis for this research as described in Chapter 4.

Addressing Sub-Exploratory Questions (sub-EQs)

When addressing the exploratory questions sub-EQ1 through sub-EQ22d, the format and order will remain consistent with Appendix 4B. The sub-EQs will be grouped into sets, where the sets contain the groups of interest or combined groups of interest that are being analyzed. There are six sets of interests that the sub-EQs are divided into: All 14 interviewees, Boeing versus non-Boeing, Managers versus training managers, Training SMEs versus Engineering SMEs, Engineering SMEs involved in training versus Engineering SMEs not involved in training, and Training Manager versus Engineering Manager.

<u>All 14 interviewees</u>

sub-*EQ1. What are the most important variables across all 14 interviewees?*

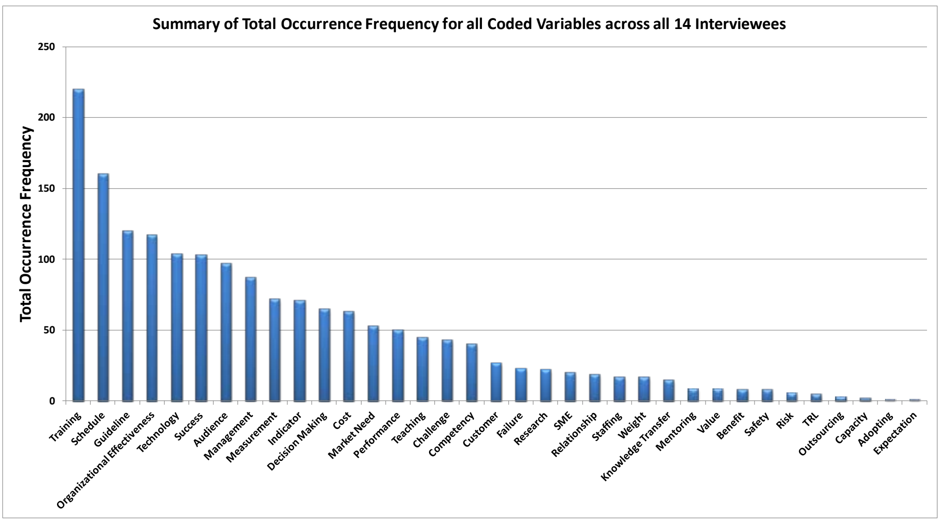


Figure 4F-1. Summary of total occurrence frequency for all coded variables across all 14 interviewees

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables across all 14 interviewees are Training, Schedule, Guideline, Organizational Effectiveness, and Technology.

sub-*EQ2a. What are the most important variables across all 14 interviewees relating to **OE**? How strong are the relationships?*

Table 4F-1. Summary of the most important variables across all 14 interviewees relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking
Training	78	1
Success	50	2
Management	40	3
Schedule	37	4
Guideline	31	5
Technology	26	6
Cost	24	7
Audience	23	8
Indicator	21	9
Measurement	18	11
Performance	18	11
Market Need	18	11
Challenge	17	13
Decision Making	15	14
Staffing	10	15
Competency	9	16
Teaching	8	17
Research	7	18
Relationship	6	19
Knowledge Transfer	5	20.5
Benefit	5	20.5
Failure	4	23
Value	4	23
Safety	4	23
SME	3	25.5
Customer	3	25.5
Weight	2	27
Mentoring	1	30
Outsourcing	1	30
TRL	1	30
Risk	1	30
Capacity	1	30
Organizational Effectiveness	0	34
Adopting	0	34
Expectation	0	34

Variable	Organizational Effectiveness C-Coefficient	Organizational Effectiveness C-Coefficient Ranking
Success	0.21	1
Training	0.19	2
Management	0.16	3
Schedule	0.11	4
Guideline	0.1	6
Indicator	0.1	6
Cost	0.1	6
Technology	0.09	9
Performance	0.09	9
Audience	0.09	9
Measurement	0.08	12
Challenge	0.08	12
Market Need	0.08	12
Decision Making	0.07	14
Staffing	0.06	15
Competency	0.05	16
Teaching	0.04	19
Research	0.04	19
Relationship	0.03	19
Knowledge Transfer	0.03	19
Benefit	0.03	19
SME	0.02	24
Customer	0.02	24
Value	0.02	24
Failure	0.02	24
Safety	0.02	24
TRL	0.01	29.5
Weight	0.01	29.5
Mentoring	0.01	29.5
Outsourcing	0.01	29.5
Risk	0.01	29.5
Capacity	0.01	29.5
Organizational Effectiveness	0	34
Adopting	0	34
Expectation	0	34

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables across all 14 interviewees relating to OE are Training, Success, Management, Schedule, and Guideline.

sub-*EQ2b. What are the most important variables across all 14 interviewees relating to* ***TI****? How strong are the relationships?*

Table 4F-2. Summary of the most important variables across all 14 interviewees relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence
Training	49	1
Schedule	39	2
Guideline	29	3
Audience	26	4.5
Organizational Effectiveness	26	4.5
Success	20	6
Management	18	7.5
Decision Making	18	7.5
Indicator	16	9
Cost	15	10
Research	14	11
Market Need	13	12
Performance	10	13.5
Challenge	10	13.5
Relationship	9	15
Measurement	8	16
Customer	7	17
Staffing	5	19
Competency	5	19
Weight	5	19
Teaching	4	21.5
Value	4	21.5
SME	3	24
TRL	3	24
Risk	3	24
Safety	2	26
Knowledge Transfer	1	28.5
Benefit	1	28.5
Failure	1	28.5
Adopting	1	28.5
Technology	0	33
Mentoring	0	33
Outsourcing	0	33
Capacity	0	33
Expectation	0	33

Variable	Technology Innovation C-Coefficient	Technology Innovation C-Coefficient Ranking
Schedule	0.12	1
Training	0.11	2.5
Audience	0.11	2.5
Guideline	0.1	4
Decision Making	0.09	6
Research	0.09	6
Organizational Effectiveness	0.09	6
Success	0.08	8.5
Indicator	0.08	8.5
Management	0.07	10
Cost	0.06	12
Market Need	0.06	12
Relationship	0.06	12
Performance	0.05	14.5
Challenge	0.05	14.5
Measurement	0.04	16.5
Customer	0.04	16.5
Staffing	0.03	19.5
Competency	0.03	19.5
Value	0.03	19.5
Weight	0.03	19.5
Teaching	0.02	23.5
SME	0.02	23.5
TRL	0.02	23.5
Risk	0.02	23.5
Knowledge Transfer	0.01	28
Benefit	0.01	28
Failure	0.01	28
Safety	0.01	28
Adopting	0.01	28
Technology	0	33
Mentoring	0	33
Outsourcing	0	33
Capacity	0	33
Expectation	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables across all 14 interviewees relating to TI are Training, Schedule, Guideline, Audience, and Organizational Effectiveness.

sub-*EQ2c. What are the most important variables across all 14 interviewees relating to **TR**? How strong are the relationships?*

Table 4F-3. Summary of the most important variables across all 14 interviewees relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Guideline	88	1
Schedule	86	2
Organizational Effectiveness	78	3
Audience	75	4
Success	70	5
Management	56	6
Technology	49	8
Measurement	49	7
Teaching	47	9
Cost	42	10
Market Need	41	11
Challenge	40	12
Decision Making	33	13
Competency	33	14
Indicator	32	15
Performance	26	16.5
SME	26	16.5
Staffing	16	18.5
Knowledge Transfer	16	18.5
Customer	12	20
Failure	11	21
Relationship	8	22.5
Mentoring	8	22.5
Research	7	24
Value	6	25.5
Outsourcing	6	25.5
Benefit	4	27.5
Safety	4	27.5
TRL	3	29
Capacity	2	30
Weight	1	31.5
Expectation	1	31.5
Training	0	34
Risk	0	34
Adopting	0	34

Variable	Training C-Coefficient	Training C-Coefficient Ranking
Guideline	0.21	1
Audience	0.19	2.5
Organizational Effectiveness	0.19	2.5
Schedule	0.18	4.5
Success	0.18	4.5
Management	0.14	6
Measurement	0.13	7.5
Teaching	0.13	7.5
Market Need	0.11	10
Challenge	0.11	10
Technology	0.11	10
Cost	0.1	12
Competency	0.09	13
Decision Making	0.08	14.5
Indicator	0.08	14.5
Performance	0.07	16.5
SME	0.07	16.5
Staffing	0.05	18.5
Knowledge Transfer	0.05	18.5
Customer	0.03	20.5
Failure	0.03	20.5
Research	0.02	24
Relationship	0.02	24
Value	0.02	24
Mentoring	0.02	24
Outsourcing	0.02	24
TRL	0.01	28.5
Benefit	0.01	28.5
Safety	0.01	28.5
Capacity	0.01	28.5
Training	0	33
Weight	0	33
Risk	0	33
Adopting	0	33
Expectation	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables across all 14 interviewees relating to TR are Guideline, Schedule, Organizational Effectiveness, Audience, and Success.

sub-*EQ3a: Are the variables that are related to **TI** different than **TR**?*

H0: The variables do not have a rank-order relationship in the population represented by TI and TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by TI and TR.

					Technology innovation Co-Occurrence	Training Co-Occurrence
Spearman's rho	Technology innovation Co-Occurrence	Correlation Coefficient			1.000	.572**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.002
			Std. Error		.000	.160
			95% Confidence Interval	Lower	1.000	.226
				Upper	1.000	.849
	Training Co-Occurrence	Correlation Coefficient			.572**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.002	.000
			Std. Error		.160	.000
			95% Confidence Interval	Lower	.226	1.000
				Upper	.849	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-2. SPSS output of TI and TR co-occurrence using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.572 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Technology Innovation (TI) and Training (TR). Because there is a rank order relationship between the variables in the population represented by TI and TR, the most important variables for TI and TR are similar. This result confirms that there is a relationship between TI and TR and that the two constructs share similar variables. Hence, EQ4a will list the variables that are common to both of the constructs across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.572 indicates a relatively moderate positive relationship between TI and TR. The relationship is neither weak nor strong.

sub-*EQ3b: Are the variables that are related to* ***TI*** *different than* ***OE****?*

H0:The variables do not have a rank-order relationship in the population represented by TI and OE.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by TI and OE.

					Technology Innovation Co-Occurrence	Organizational Effectiveness Co-Occurrence
Spearman's rho	Technology Innovation Co-Occurrence	Correlation Coefficient			1.000	.678**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.013
			Std. Error		.000	.155
			95% Confidence Interval	Lower	1.000	.333
				Upper	1.000	.912
	Organizational Effectiveness Co-Occurrence	Correlation Coefficient			.678**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.013	.000
			Std. Error		.155	.000
			95% Confidence Interval	Lower	.333	1.000
				Upper	.912	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-3. SPSS output of TI and OE co-occurrence using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.678 (p<0.01) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 (p<0.01). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Technology Innovation (TI) and Organizational Effectiveness (OE). Because there is a rank order relationship between the variables in the population represented by TI and OE, the most important variables for TI and OE are similar. This result confirms that there is a relationship between TI and OE and that the two constructs share similar variables. Hence, EQ4b will list the variables that are common to both of the constructs across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.678 indicates a relatively moderate positive relationship between TI and OE. The relationship is neither weak nor strong.

sub-*EQ3c: Are the variables that are related to **TR** different than **OE**?*

H0:The variables do not have a rank-order relationship in the population represented by TR and OE.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by TR and OE.

					TR Co-occurrence	OE Co-occurrence
Spearman's rho	TR Co-occurrence	Correlation Coefficient			1.000	.629**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.007
			Std. Error		.000	.182
			95% Confidence Interval	Lower	1.000	.219
				Upper	1.000	.919
	OE Co-occurrence	Correlation Coefficient			.629**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.007	.000
			Std. Error		.182	.000
			95% Confidence Interval	Lower	.219	1.000
				Upper	.919	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-4. SPSS output of TR and OE co-occurrence using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.629 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training (TR) and Organizational Effectiveness (OE). Because there is a rank order relationship between the variables in the population represented by TR and OE, the most important variables for TR and OE are similar. This result confirms that there is a relationship between TR and OE and that the two constructs share similar variables. Hence, EQ4c will list the variables that are common to both of the constructs across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.629 indicates a relatively moderate positive relationship between TI and OE. The relationship is neither weak nor strong.

sub-*EQ4a. What are the most important variables for both **TI** and **TR**?*

Table 4F-4. Summary of the most important variables for both TI and TR

Variable	Technology innovation Co-Occurrence	Training Co-Occurrence	Technology innovation Co-Occurrence Ranking	Training Co-Occurrence Ranking	Difference between Ranking
Decision Making	18	33	7.5	13.5	-6
Indicator	16	32	9	15	-6
Schedule	39	86	2	2	0
Cost	15	42	10	10	0
Audience	26	75	4.5	4	0.5
Success	20	70	6	5	1
Market Need	13	41	12	11	1
Organizational Effectiveness	26	78	4.5	3	1.5
Management	18	56	7.5	6	1.5
Guideline	29	88	3	1	2

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables for both TI and TR are Schedule, Cost, Audience, Success, Market Need, Organizational Effectiveness, Management, and Guideline.

sub-*EQ4b. What are the most important variables for both **TI** and **OE**?*

Table 4F-5. Summary of the most important variables for both TI and OE

Variable	Organizational Effectiveness Co-Occurrence	Technology Innovation Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking	Technology Innovation Co-Occurrence Ranking	Difference between Ranking
Management	40	18	3	7.5	-4.5
Success	50	20	2	6	-4
Cost	24	15	7	10	-3
Training	78	49	1	1	0
Indicator	21	16	9	9	0
Schedule	37	39	4	2	2
Guideline	31	29	5	3	2
Audience	23	26	8	4.5	3.5
Market Need	18	13	16.5	12	4.5
Decision Making	15	18	14	7.5	6.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables for both TI and OE are Training, Indicator, Schedule, and Guideline.

sub-*EQ4c. What are the most important variables for both **TR** and **OE**?*

Table 4F-6. Summary of the most important variables for both TR and OE

Variables	OE Co-occurrence	TR Co-occurrence	OE Co-occurrence Ranking	TR Co-occurrence Ranking	Difference between Ranking
Indicator	21	32	9	15	-6
Performance	18	26	11	16.5	-5.5
Success	50	70	2	5	-3
Management	40	56	3	6	-3
Cost	24	42	7	10	-3
Technology	26	49	6	7.5	-1.5
Market Need	18	41	11	11	0
Decision Making	15	33	14	13.5	0.5
Challenge	17	40	13	12	1
Schedule	37	86	4	2	2
Measurement	18	49	11	7.5	3.5
Guideline	31	88	5	1	4
Audience	23	75	8	4	4

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables for both TR and OE are Market Need, Decision Making, Technology, Challenge, and Schedule.

<u>Boeing vs non-Boeing</u>

The purpose of EQ8a-EQ17c is to determine if it is necessary to perform full qualitative analysis separating Boeing and non-Boeing interviewees. If it is determined through statistical analysis that there is insignificant difference between the variables for Boeing and non-Boeing, then the continuation of the analysis will only include the comparisons between the groups of interest across all 14 interviewees instead of separating between Boeing and non-Boeing. The following EQ18 through EQ45 will assume that there is insignificant difference between the variables for Boeing and non-Boeing interviewees.

sub-*EQ5a. What are the most important variables for the* ***Boeing Company****?*

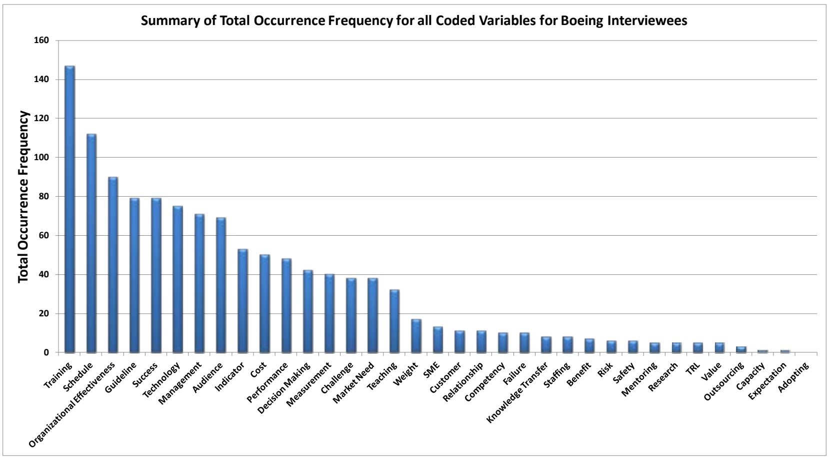


Figure 4F-5. Summary of total occurrence frequency for all coded variables for Boeing interviewees

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by the Boeing interviewees are Training, Schedule, Organizational Effectiveness, Guideline, and Success.

sub-*EQ5b. What are the most important variables for* ***non-Boeing*** *interviewees?*

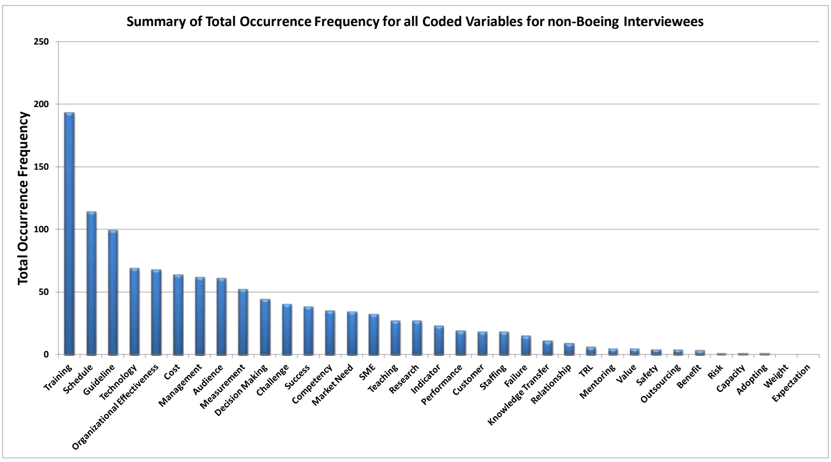


Figure 4F-6. Summary of total occurrence frequency for all coded variables for non-Boeing interviewees

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by the non-Boeing interviewees are Training, Schedule, Guideline, Technology, and Organizational Effectiveness.

sub-*EQ5c. Are the most important variables at* ***Boeing*** *different than* ***non-Boeing****?*

H0: The variables do not have a rank-order relationship in the population represented by Boeing and Non-boeing interviewees.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Boeing and Non-boeing interviewees.

					Boeing	non-Boeing
Spearman's rho	Boeing	Correlation Coefficient			1.000	.864**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.012
			Std. Error		.000	.065
			95% Confidence Interval	Lower	1.000	.696
				Upper	1.000	.948
	non-Boeing	Correlation Coefficient			.864**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.012	.000
			Std. Error		.065	.000
			95% Confidence Interval	Lower	.696	1.000
				Upper	.948	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-7. SPSS output for Boeing and non-Boeing using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.864 ($p<0.01$) and the critical value for Spearman's correlation is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Boeing and Non-boeing interviewees. Because there is a rank order relationship between the variables in the population represented by Boeing and Non-boeing interviewees, the most important variables mentioned by the Boeing and Non-boeing interviewees are similar. This result confirms that the conceptual model to be developed can be used by organizations both internal and external to Boeing. Hence, EQ7 through EQ13 will list the variables that are specific to each of the constructs and combination of constructs for both Boeing and non-Boeing interviewees. EQ14 through EQ17 will dive deeper into the comparison between the variables that are specific to each of the constructs and combination of constructs for both Boeing and non-Boeing interviewees. Because one conceptual model can be used by both Boeing and non-Boeing, as shown earlier with the Spearman's correlation, the list of variables that are the same that surface for the constructs and combination of constructs for both Boeing and non-Boeing interviewees are considered in the conceptual model.

Moreover, it should be noted that because it has been determined that there is a rank order relationship between the variables in the population represented by Boeing and Non-boeing interviewees, the assumption that there is insignificant difference between the variables for Boeing and non-Boeing interviewees made in Section 4.3.5 when listing the exploratory questions is acceptable. What can be concluded from this is that in continuing the qualitative data analysis, it is not necessary to separate the groups of interest into Boeing and non-Boeing interviewees. For each combination of groups of interest being analyzed, all 14 interviewees are considered.

sub-*EQ5d. What are the most important variables for both Boeing and non-Boeing?*

Table 4F-7. Summary of the most important variables for both Boeing and non-Boeing

Variable	Boeing	non-Boeing	Boeing Ranking	non-Boeing Ranking	Difference between Ranking
Indicator	53	23	9	18	-9
Performance	48	19	11	19	-8
Success	79	38	4.5	12	-7.5
Organizational Effectiveness	90	68	3	5	-2
Customer	11	18	19.5	20.5	-1
Teaching	32	27	16	16.5	-0.5
Audience	69	61	8	8	0
Management	71	62	7	7	0
Schedule	112	114	2	2	0
Training	147	193	1	1	0
Market Need	38	34	14.5	14	0.5
Guideline	79	99	4.5	3	1.5
Decision Making	42	44	12	10	2
Technology	75	69	6	4	2
SME	13	32	18	15	3
Challenge	38	40	14.5	11	3.5
Measurement	40	52	13	9	4
Cost	50	64	10	6	4

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Boeing and non-Boeing interviewees are Audience, Management, Schedule, Training, Teaching, Market Need, Customer, Guideline, Organizational Effectiveness, Decision Making, and Technology.

sub-*EQ6a. What are the most important variables for the* ***Boeing Company*** *relating to* ***OE****?*

Table 4F-8. Summary of the most important variables for Boeing relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking
Training	43	1
Success	36	2
Schedule	26	3
Management	24	4
Audience	18	5.5
Indicator	18	5.5
Guideline	17	7
Performance	16	8
Technology	15	9
Measurement	13	10.5
Cost	13	10.5
Challenge	12	12
Market Need	8	13.5
Decision Making	8	13.5
Teaching	4	17.5
Competency	4	17.5
Relationship	4	17.5
Staffing	4	17.5
Benefit	4	17.5
Value	4	17.5
Customer	2	22
Weight	2	22
Knowledge Transfer	2	22
Research	1	26.5
Safety	1	26.5
Mentoring	1	26.5
Failure	1	26.5
TRL	1	26.5
Risk	1	26.5
Organizational Effectiveness	0	32.5
SME	0	32.5
Outsourcing	0	32.5
Capacity	0	32.5
Expectation	0	32.5
Adopting	0	32.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Boeing interviewees relating to OE are Training, Success, Schedule, and Management.

sub-*EQ6b. What are the most important variables for the* **non-Boeing** *interviewees relating to* ***OE***?

Table 4F-9. Summary of the most important variables for non-Boeing relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking
Training	35	1
Management	16	2
Success	14	3.5
Guideline	14	3.5
Technology	11	6
Cost	11	6
Schedule	11	6
Market Need	10	8
Decision Making	7	9
Research	6	10.5
Staffing	6	10.5
Audience	5	13.5
Measurement	5	13.5
Competency	5	13.5
Challenge	5	13.5
Teaching	4	16
SME	3	19
Indicator	3	19
Knowledge Transfer	3	19
Failure	3	19
Safety	3	19
Performance	2	22.5
Relationship	2	22.5
Customer	1	25.5
Outsourcing	1	25.5
Benefit	1	25.5
Capacity	1	25.5
Organizational Effectiveness	0	31.5
Value	0	31.5
Mentoring	0	31.5
TRL	0	31.5
Adopting	0	31.5
Risk	0	31.5
Expectation	0	31.5
Weight	0	31.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Boeing interviewees relating to OE are Training, Management, Success, and Guideline.

sub-*EQ6c. Are the most important variables relating to **OE** at Boeing different than non-Boeing?*

H0:The variables do not have a rank-order relationship in the population represented by Boeing and non-Boeing in relation to OE.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Boeing and non-Boeing in relation to OE.

					Boeing OE Co-Occurrences	Non-Boeing OE Co-Occurrences
Spearman's rho	Boeing OE Co-Occurrences	Correlation Coefficient			1.000	.748**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.015
			Std. Error		.000	.087
			95% Confidence Interval	Lower	1.000	.532
				Upper	1.000	.867
	Non-Boeing OE Co-Occurrences	Correlation Coefficient			.748**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.015	.000
			Std. Error		.087	.000
			95% Confidence Interval	Lower	.532	1.000
				Upper	.867	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-8. SPSS output for Boeing OE and non-Boeing OE using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.748 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of OE. Because there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of OE, the most important variables for Boeing and Non-Boeing interviewees in terms of OE are similar. This result confirms that there is a relationship between Boeing and Non-Boeing interviewees in terms of OE and that the two groups of interest share similar variables. Hence, EQ6d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.748 indicates a relatively strong positive relationship between Boeing and Non-Boeing interviewees in terms of OE.

sub-*EQ6d. What are the most important variables relating to **<u>OE</u>** for both **Boeing** and **non-Boeing** interviewees?*

Table 4F-10. Summary of the most important variables for Boeing and non-Boeing relating to OE

Variable	Boeing OE Co-Occurrences	Non-Boeing OE Co-Occurrences	Boeing OE Co-Occurrences Ranking	Non-Boeing OE Co-Occurrences Ranking	Differences between Ranking
Schedule	26	11	3	6	-3
Success	36	14	2	3.5	-1.5
Training	43	35	1	1	0
Management	24	16	4	2	2
Technology	15	11	9	6	3
Guideline	17	14	7	3.5	3.5
Cost	13	11	10.5	6	4.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Boeing and non-Boeing interviewees in relation to OE are Training, Success, and Management.

sub-*EQ7a. What are the most important variables for the* **Boeing Company** *relating to* ***TI****?*

Table 4F-11. Summary of the most important variables for Boeing relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Schedule	23	1
Training	19	2
Guideline	15	3.5
Organizational Effectiveness	15	3.5
Audience	12	5
Indicator	11	6
Success	10	7
Cost	8	8
Management	7	10
Market Need	7	10
Decision Making	7	10
Challenge	5	12.5
Weight	5	12.5
Performance	4	14.5
Relationship	4	14.5
Research	3	16
Measurement	2	19
Staffing	2	19
Customer	2	19
Safety	2	19
Risk	2	19
Teaching	1	25
Competency	1	25
Benefit	1	25
Value	1	25
Failure	1	25
TRL	1	25
SME	1	25
Technology	0	32
Knowledge Transfer	0	32
Mentoring	0	32
Outsourcing	0	32
Capacity	0	32
Expectation	0	32
Adopting	0	32

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Boeing interviewees relating to TI are Schedule, Training, Guideline, Organizational Effectiveness, and Audience.

sub-*EQ7b. What are the most important variables for the* ***non-Boeing*** *interviewees relating to* ***TI****?*

Table 4F-12. Summary of the most important variables for non-Boeing relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Training	30	1
Schedule	16	2
Guideline	14	3.5
Audience	14	3.5
Management	11	6.5
Decision Making	11	6.5
Research	11	6.5
Organizational Effectiveness	11	6.5
Success	10	9
Cost	7	10
Market Need	6	12
Measurement	6	12
Performance	6	12
Challenge	5	15.5
Indicator	5	15.5
Relationship	5	15.5
Customer	5	15.5
Competency	4	18
Staffing	3	20
Teaching	3	20
Value	3	20
SME	2	22.5
TRL	2	22.5
Knowledge Transfer	1	25
Adopting	1	25
Risk	1	25
Technology	0	31
Failure	0	31
Safety	0	31
Outsourcing	0	31
Benefit	0	31
Capacity	0	31
Mentoring	0	31
Expectation	0	31
Weight	0	31

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Boeing interviewees relating to TI are Training, Schedule, Guideline, and Audience.

sub-*EQ7c. Are the most important variables relating to* ***TI*** *at* ***Boeing*** *different than* ***non-Boeing****?*

H0:The variables do not have a rank-order relationship in the population represented by Boeing and non-Boeing in relation to TI.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Boeing and non-Boeing in relation to TI.

					Boeing TI Co-Occurrences	Non-Boeing TI Co-Occurrences
Spearman's rho	Boeing TI Co-Occurrences	Correlation Coefficient			1.000	.840**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.008
			Std. Error		.000	.069
			95% Confidence Interval	Lower	1.000	.654
				Upper	1.000	.931
	Non-Boeing TI Co-Occurrences	Correlation Coefficient			.840**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.008	.000
			Std. Error		.069	.000
			95% Confidence Interval	Lower	.654	1.000
				Upper	.931	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-9. SPSS output for Boeing TI and non-Boeing TI using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.840 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of TI. Because there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of TI, the most important variables for Boeing and Non-Boeing interviewees in terms of TI are similar. This result confirms that there is a relationship between Boeing and Non-Boeing interviewees in terms of TI and that the two groups of interest share similar variables. Hence, EQ7d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.840 indicates a relatively strong positive relationship between Boeing and Non-Boeing interviewees in terms of TI.

sub-*EQ7d. What are the most important variables relating to* ***TI*** *for both* **Boeing** *and* **non-Boeing** *interviewees?*

Table 4F-13. Summary of the most important variables for both Boeing and non-Boeing relating to TI

Variable	Boeing TI Co-Occurrences	Non-Boeing TI Co-Occurrences	Boeing TI Co-Occurrences Ranking	Non-Boeing TI Co-Occurrences Ranking	Differences between Ranking
Organizational Effectiveness	15	11	4	6.5	-2.5
Schedule	23	16	1	2	-1
Guideline	15	14	3	3.5	-0.5
Training	19	30	2	1	1
Audience	12	14	5	3.5	1.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Boeing and non-Boeing interviewees in relation to TI are Schedule, Guideline, Training, and Audience.

sub-*EQ8a. What are the most important variables for the* ***Boeing Company*** *relating to* ***TR****?*

Table 4F-14. Summary of the most important variables for Boeing relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Organizational Effectiveness	43	1
Audience	41	2
Success	40	3
Guideline	38	4
Schedule	32	5
Teaching	28	6
Management	27	7
Measurement	26	8
Market Need	22	9
Indicator	21	10
Challenge	19	12
Performance	19	12
Technology	19	12
Cost	17	14
Decision Making	11	15
Competency	9	16
SME	8	17
Customer	5	18.5
Knowledge Transfer	5	18.5
Relationship	4	20.5
Staffing	4	20.5
Mentoring	3	22.5
Outsourcing	3	22.5
Research	2	26
Safety	2	26
Benefit	2	26
Value	2	26
Failure	2	26
Weight	1	30.5
TRL	1	30.5
Capacity	1	30.5
Expectation	1	30.5
Training	0	34
Risk	0	34
Adopting	0	34

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Boeing interviewees relating to TR are Organizational Effectiveness, Audience, Success, Guideline, and Schedule.

sub-*EQ8b. What are the most important variables for the* ***non-Boeing*** *interviewees relating to* ***TR****?*

Table 4F-15. Summary of the most important variables for non-Boeing relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Schedule	54	1
Guideline	50	2
Audience	35	3.5
Organizational Effectiveness	35	3.5
Success	30	5.5
Technology	30	5.5
Management	29	7
Cost	25	8
Competency	24	9
Measurement	23	10
Decision Making	22	11
Challenge	21	12
Market Need	19	13.5
Teaching	19	13.5
SME	18	15
Staffing	12	16
Indicator	11	17.5
Knowledge Transfer	11	17.5
Failure	9	19
Performance	7	20.5
Customer	7	20.5
Research	5	22.5
Mentoring	5	22.5
Relationship	4	24.5
Value	4	24.5
Outsourcing	3	26
TRL	2	28
Safety	2	28
Benefit	2	28
Capacity	1	30
Training	0	33
Adopting	0	33
Risk	0	33
Expectation	0	33
Weight	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Boeing interviewees relating to TR are Schedule, Guideline, Audience, and Organizational Effectiveness.

sub-*EQ8c. Are the most important variables relating to* ***TR*** *at* ***Boeing*** *different than* ***non-Boeing****?*

H0:The variables do not have a rank-order relationship in the population represented by Boeing and non-Boeing in relation to TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Boeing and non-Boeing in relation to TR.

					Boeing TR Co-Occurrences	Non-Boeing TR Co-Occurrences
Spearman's rho	Boeing TR Co-Occurrences	Correlation Coefficient			1.000	.924**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.012
			Std. Error		.000	.036
			95% Confidence Interval	Lower	1.000	.835
				Upper	1.000	.961
	Non-Boeing TR Co-Occurrences	Correlation Coefficient			.924**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.012	.000
			Std. Error		.036	.000
			95% Confidence Interval	Lower	.835	1.000
				Upper	.961	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-10. SPSS output for Boeing TR and non-Boeing TR using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.924 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of TR. Because there is a rank order relationship between the variables in the population represented by Boeing and Non-Boeing interviewees in terms of TR, the most important variables for Boeing and Non-Boeing interviewees in terms of TR are similar. This result confirms that there is a relationship between Boeing and Non-Boeing interviewees in terms of TR and that the two groups of interest share similar variables. Hence, EQ8d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.924 indicates a relatively strong positive relationship between Boeing and Non-Boeing interviewees in terms of TR.

sub-*EQ8d. What are the most important variables relating to **TR** for both **Boeing** and **non-Boeing** interviewees?*

Table 4F-16. Summary of the most important variables for Boeing and non-Boeing relating to TR

Variable	Boeing TR Co-Occurrences	Non-Boeing TR Co-Occurrences	Boeing TR Co-Occurrences Ranking	Non-Boeing TR Co-Occurrences Ranking	Differences between Ranking
Indicator	21	11	10	17.5	-7.5
Teaching	28	19	6	13.5	-7.5
Market Need	22	19	9	13.5	-4.5
Success	40	30	3	5.5	-2.5
Organizational Effectiveness	43	35	1	3.5	-2.5
Measurement	26	23	8	10	-2
Audience	41	35	2	3.5	-1.5
Challenge	19	21	12	12	0
Management	27	29	7	7	0
Guideline	38	50	4	2	2
Decision Making	11	22	15	11	4
Schedule	32	54	5	1	4
Cost	17	25	14	8	6
Technology	19	30	12	5.5	6.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Boeing and non-Boeing interviewees in relation to TR are Challenge, Management, Measurement, Audience, and Guideline.

<u>Manager vs non-manager</u>

sub-*EQ9a. What are the most important variables mentioned by the **Managers**?*

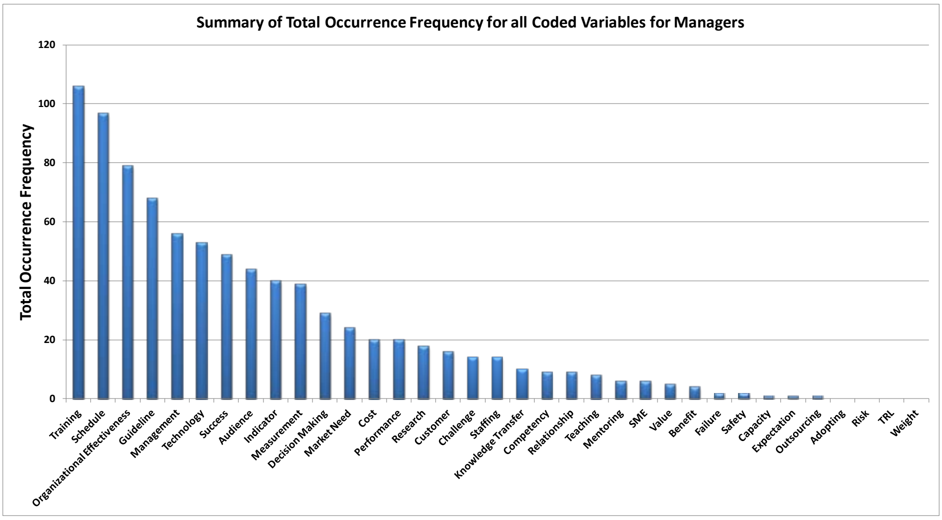


Figure 4F-11. Summary of total occurrence frequency for all coded variables for managers

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Manager interviewees are Training, Schedule, Organizational Effectiveness, Guideline, and Management.

sub-*EQ9b. What are the most important variables mentioned by the* **non-Managers**?

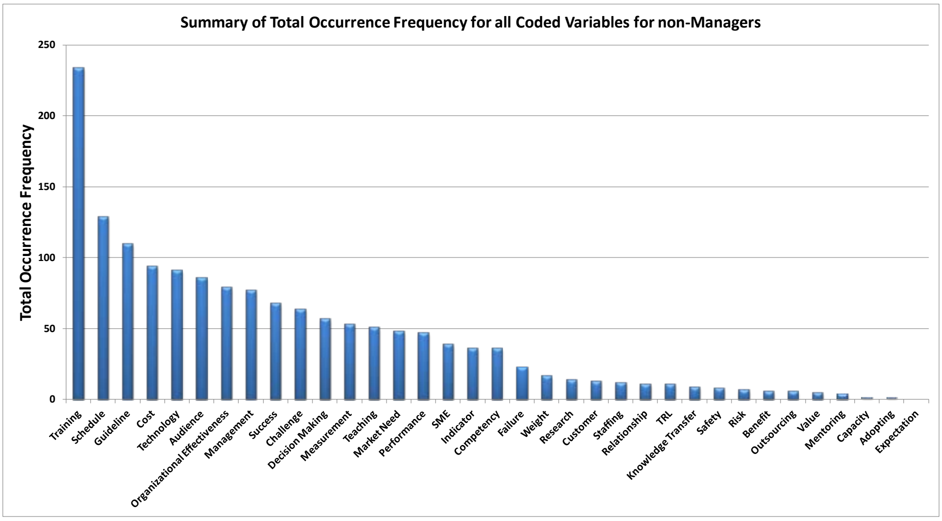


Figure 4F-12. Summary of total occurrence frequency for all coded variables for non-managers

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Manager interviewees are Training, Schedule, Guideline, Cost, and Technology.

sub-*EQ9c. Are the most important variables mentioned by* **managers** *different than* **non-managers**?

H0:The variables do not have a rank-order relationship in the population represented by Managers and Training managers.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Managers and Training managers.

					Manager	Non-Manager
Spearman's rho	Manager	Correlation Coefficient			1.000	.845**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.013
			Std. Error		.000	.055
			95% Confidence Interval	Lower	1.000	.709
				Upper	1.000	.918
	Non-Manager	Correlation Coefficient			.845**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.013	.000
			Std. Error		.055	.000
			95% Confidence Interval	Lower	.709	1.000
				Upper	.918	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-12. SPSS output for manager and non-manager using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.845 ($p<0.01$) and the critical value for Spearman's correlation is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship in the population represented by Managers and non-managers. Because there is a rank order relationship in the population represented by Managers and non-managers, the most important variables mentioned by the Managers and non-managers are similar. This result confirms that the conceptual model to be developed can be used by both Managers and non-managers.

sub-*EQ9d. What are the most important variables mentioned by both the* ***managers*** *and* ***non-managers****?*

Table 4F-17. Summary of the most important variables for both managers and non-managers

Variable	Manager	Non-Manager	Manager Ranking	Non-Manager Ranking	Difference between Ranking
Indicator	40	36	9	17.5	-8.5
Customer	16	13	16	22	-6
Research	18	14	15	21	-6
Staffing	14	12	17.5	23	-5.5
Organizational Effectiveness	79	79	3	7	-4
Management	56	77	5	8	-3
Market Need	24	48	12	14	-2
Measurement	39	53	10	12	-2
Success	49	68	7	9	-2
Performance	20	47	13.5	15	-1.5
Decision Making	29	57	11	11	0
Schedule	97	129	2	2	0
Training	106	234	1	1	0
Technology	53	91	6	5	1
Guideline	68	110	4	3	1
Audience	44	86	8	6	2
Challenge	14	64	17.5	10	7.5
Cost	20	94	13.5	4	9.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Manager and non-Manager interviewees are Decision Making, Schedule, Training, Market Need, Measurement, Success, Performance, Technology, Guideline, and Audience.

sub-*EQ10a. What are the most important variables for the* **managers** *relating to* ***OE****?*

Table 4F-18. Summary of the most important variables for managers relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizatinal Effectiveness Co-Occurrence Ranking
Training	41	1
Success	30	2
Management	23	3.5
Schedule	23	3.5
Guideline	18	5
Indicator	14	6
Technology	11	7.5
Market Need	11	7.5
Audience	9	9.5
Performance	9	9.5
Measurement	8	11.5
Cost	8	11.5
Decision Making	7	13
Staffing	6	14
Competency	5	15
Research	4	17.5
Knowledge Transfer	4	17.5
Challenge	4	17.5
Teaching	4	17.5
Relationship	2	21.5
Value	2	21.5
Benefit	2	21.5
Safety	2	21.5
Customer	1	26
Mentoring	1	26
SME	1	26
Capacity	1	26
Failure	1	26
Organizational Effectiveness	0	32
Expectation	0	32
Outsourcing	0	32
Adopting	0	32
Risk	0	32
TRL	0	32
Weight	0	32

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Manager interviewees in relation to OE are Training, Success, Management, Schedule, and Guideline.

sub-*EQ10b. What are the most important variables for the* **non-managers** *relating to* ***OE****?*

Table 4F-19. Summary of the most important variables for non-managers relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizatinal Effectiveness Co-Occurrence Ranking
Training	37	1
Success	20	2
Management	17	3
Cost	16	4
Technology	15	5
Audience	14	6.5
Schedule	14	6.5
Challenge	13	8.5
Guideline	13	8.5
Measurement	10	10
Performance	9	11
Decision Making	8	12
Market Need	7	13.5
Indicator	7	13.5
Teaching	4	16.5
Competency	4	16.5
Relationship	4	16.5
Staffing	4	16.5
Failure	3	20
Research	3	20
Benefit	3	20
SME	2	24
Customer	2	24
Value	2	24
Weight	2	24
Safety	2	24
TRL	1	28.5
Knowledge Transfer	1	28.5
Outsourcing	1	28.5
Risk	1	28.5
Organizational Effectiveness	0	33
Mentoring	0	33
Adopting	0	33
Capacity	0	33
Expectation	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Manager interviewees in relation to OE are Training, Success, Management, Cost, and Technology.

sub-*EQ10c. Are the most important variables relating to* ***OE*** *for* **managers** *different than* **non-managers***?*

H0:The variables do not have a rank-order relationship in the population represented by Managers and non-Managers in relation to OE.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Managers and non-Managers in relation to OE.

					Manager OE Co-Occurrence	Non-Manager OE Co-Occurrence
Spearman's rho	Manager OE Co-Occurrence	Correlation Coefficient			1.000	.902**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.009
			Std. Error		.000	.037
			95% Confidence Interval	Lower	1.000	.809
				Upper	1.000	.954
	Non-Manager OE Co-Occurrence	Correlation Coefficient			.902**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.009	.000
			Std. Error		.037	.000
			95% Confidence Interval	Lower	.809	1.000
				Upper	.954	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-13. SPSS output for manager OE and non-manager OE using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.902 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of OE. Because there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of OE, the most important variables for Manager and Non-Manager interviewees in terms of OE are similar. This result confirms that there is a relationship between Manager and Non-Manager interviewees in terms of OE and that the two groups of interest share similar variables. Hence, EQ10d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.902 indicates a relatively strong positive relationship between Manager and Non-Manager interviewees in terms of OE.

sub-*EQ10d. What are the most important variables relating to **OE** mentioned by both the **managers** and **non-managers**?*

Table 4F-20. Summary of the most important variables for managers and non-managers relating to OE

Variable	Manager OE Co-Occurrence	Non-Manager OE Co-Occurrence	Manager OE Co-Occurrence Ranking	Non-Manager OE Co-Occurrence Ranking	Difference between Ranking
Guideline	18	13	5	8.5	-3.5
Schedule	23	14	3.5	6.5	-3
Success	30	20	2	2	0
Training	41	37	1	1	0
Management	23	17	3.5	3	0.5
Technology	11	15	7.5	5	2.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Manager and non-Manager interviewees in relation to OE are Success, Training, and Management.

sub-*EQ11a. What are the most important variables for the* **managers** *relating to* ***TI***?

Table 4F-21. Summary of the most important variables for managers relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Schedule	19	1
Training	16	2
Indicator	12	3
Audience	11	5
Research	11	5
Organizational Effectiveness	11	5
Success	9	7.5
Management	9	7.5
Guideline	8	9
Market Need	5	12
Decision Making	5	12
Staffing	5	12
Relationship	5	12
Customer	5	12
Measurement	4	15
Cost	1	16.5
Value	1	16.5
Technology	0	26.5
Performance	0	26.5
Competency	0	26.5
Knowledge Transfer	0	26.5
Challenge	0	26.5
Teaching	0	26.5
Benefit	0	26.5
Safety	0	26.5
Mentoring	0	26.5
SME	0	26.5
Capacity	0	26.5
Failure	0	26.5
Expectation	0	26.5
Outsourcing	0	26.5
Adopting	0	26.5
Risk	0	26.5
TRL	0	26.5
Weight	0	26.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Manager interviewees in relation to TI are Schedule, Training, Indicator, Audience, Research, and Organizational Effectiveness.

sub-*EQ11b. What are the most important variables for the* ***non-managers*** *relating to* ***TI****?*

Table 4F-22. Summary of the most important variables for non-managers relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Training	33	1
Guideline	21	2
Schedule	20	3
Audience	15	4.5
Organizational Effectiveness	15	4.5
Cost	14	6
Decision Making	13	7
Success	11	8
Challenge	10	9.5
Performance	10	9.5
Management	9	11
Market Need	8	12
Competency	5	13.5
Weight	5	13.5
Measurement	4	16.5
Indicator	4	16.5
Teaching	4	16.5
Relationship	4	16.5
Research	3	21
SME	3	21
Value	3	21
TRL	3	21
Risk	3	21
Customer	2	24.5
Safety	2	24.5
Failure	1	27.5
Benefit	1	27.5
Knowledge Transfer	1	27.5
Adopting	1	27.5
Technology	0	32.5
Staffing	0	32.5
Outsourcing	0	32.5
Mentoring	0	32.5
Capacity	0	32.5
Expectation	0	32.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Manager interviewees in relation to TI are Training, Guideline, Schedule, Audience, and Organizational Effectiveness.

sub-*EQ11c. Are the most important variables relating to* ***TI*** *for the* ***managers*** *different than* ***non-managers****?*

H0:The variables do not have a rank-order relationship in the population represented by Managers and non-Managers in relation to TI.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Managers and non-Managers in relation to TI.

					Manager TI Co-Occurrence	Non-Manager TI Co-Occurrence
Spearman's rho	Manager TI Co-Occurrence	Correlation Coefficient			1.000	.615**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.006
			Std. Error		.000	.117
			95% Confidence Interval	Lower	1.000	.341
				Upper	1.000	.802
	Non-Manager TI Co-Occurrence	Correlation Coefficient			.615**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.006	.000
			Std. Error		.117	.000
			95% Confidence Interval	Lower	.341	1.000
				Upper	.802	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-14. SPSS output for manager TI and non-manager TI using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.615 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of TI. Because there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of TI, the most important variables for Manager and Non-Manager interviewees in terms of TI are similar. This result confirms that there is a relationship between Manager and Non-Manager interviewees in terms of TI and that the two groups of interest share similar variables. Hence, EQ11d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.615 indicates a relatively moderate positive relationship between Manager and Non-Manager interviewees in terms of TI. The relationship is neither weak nor strong.

sub-*EQ11d. What are the most important variables relating to **TI** mentioned by both the **managers** and **non-managers**?*

Table 4F-23. Summary of the most important variables for managers and non-managers relating to TI

Variable	Manager TI Co-Occurrence	Non-Manager TI Co-Occurrence	Manager TI Co-Occurrence Ranking	Non-Manager TI Co-Occurrence Ranking	Difference between Ranking
Schedule	19	20	1	3	-2
Audience	11	15	5	4.5	0.5
Organizational Effectiveness	11	15	5	4.5	0.5
Training	16	33	2	1	1

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Manager and non-Manager interviewees in relation to TI are Audience, Organizational Effectiveness, Schedule, and Training.

sub-*EQ12a. What are the most important variables for the* **managers** *relating to* ***TR****?*

Table 4F-24. Summary of the most important variables for managers relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Organizational Effectiveness	41	1
Schedule	39	2
Guideline	34	3
Management	31	4
Success	28	5
Audience	22	6
Measurement	20	7
Indicator	17	8
Technology	16	9
Market Need	15	10
Decision Making	13	11.5
Cost	13	11.5
Knowledge Transfer	12	13
Performance	11	14
Staffing	10	15
Competency	9	16
Challenge	8	17
Teaching	7	18
Customer	5	19.5
Mentoring	5	19.5
Relationship	4	21.5
SME	4	21.5
Research	3	24
Value	3	24
Benefit	3	24
Safety	1	28
Capacity	1	28
Failure	1	28
Expectation	1	28
Outsourcing	1	28
Training	0	33
Adopting	0	33
Risk	0	33
TRL	0	33
Weight	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Manager interviewees in relation to TR are Organizational Effectiveness, Schedule, Guideline, Management, and Success.

sub-*EQ12b. What are the most important variables for the* **non-managers** *relating to* ***TR****?*

Table 4F-25. Summary of the most important variables for non-managers relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Guideline	55	1
Audience	53	2
Schedule	47	3
Success	42	4
Teaching	40	5
Organizational Effectiveness	37	6
Technology	33	7
Challenge	32	8
Cost	29	9.5
Measurement	29	9.5
Market Need	26	11
Management	25	12
Competency	24	13
SME	22	14
Decision Making	20	15
Performance	15	16.5
Indicator	15	16.5
Failure	10	18
Customer	7	19
Staffing	6	20
Outsourcing	5	21
Relationship	4	23
Research	4	23
Knowledge Transfer	4	23
Value	3	26.5
TRL	3	26.5
Safety	3	26.5
Mentoring	3	26.5
Weight	1	30
Benefit	1	30
Capacity	1	30
Training	0	33.5
Risk	0	33.5
Adopting	0	33.5
Expectation	0	33.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the non-Manager interviewees in relation to TR are Guideline, Audience, Schedule, Success, and Teaching.

sub-*EQ12c. Are the most important variables relating to* ***TR*** *for the* **managers** *different than* **non-managers***?*

H0:The variables do not have a rank-order relationship in the population represented by Managers and non-Managers in relation to TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Managers and non-Managers in relation to TR.

					Manager TR Co-Occurrence	Non-Manager TR Co-Occurrence
Spearman's rho	Manager TR Co-Occurrence	Correlation Coefficient			1.000	.861**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.013
			Std. Error		.000	.053
			95% Confidence Interval	Lower	1.000	.717
				Upper	1.000	.921
	Non-Manager TR Co-Occurrence	Correlation Coefficient			.861**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.013	.000
			Std. Error		.053	.000
			95% Confidence Interval	Lower	.717	1.000
				Upper	.921	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-15. SPSS output for manager TR and non-manager TR using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.861 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of TR. Because there is a rank order relationship between the variables in the population represented by Manager and Non-Manager interviewees in terms of TR, the most important variables for Manager and Non-Manager interviewees in terms of TR are similar. This result confirms that there is a relationship between Manager and Non-Manager interviewees in terms of TR and that the two groups of interest share similar variables. Hence, EQ12d will list the variables that are common to both of the constructs across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.861 indicates a relatively strong positive relationship between Manager and Non-Manager interviewees in terms of TR.

sub-*EQ12d. What are the most important variables relating to **TR** mentioned by both the **managers** and **non-managers**?*

Table 4F-26. Summary of the most important variables for managers and non-managers relating to TR

Variable	Manager TR Co-Occurrence	Non-Manager TR Co-Occurrence	Manager TR Co-Occurrence Ranking	Non-Manager TR Co-Occurrence Ranking	Difference between Ranking
Indicator	17	15	8	16.5	-8.5
Management	31	25	4	12	-8
Organizational Effectiveness	41	37	1	6	-5
Decision Making	13	20	11.5	15	-3.5
Performance	11	15	14	16.5	-2.5
Measurement	20	29	7	9.5	-2.5
Market Need	15	26	10	11	-1
Schedule	39	47	2	3	-1
Success	28	42	5	4	1
Cost	13	29	11.5	9.5	2
Technology	16	33	9	7	2
Guideline	34	55	3	1	2
Audience	22	53	6	2	4

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Manager and non-Manager interviewees in relation to TR are Market Need, Schedule, Success, Cost, Technology, and Guideline.

<u>Training SMEs vs Engineering SMEs</u>

sub-*EQ13a. What are the most important variables mentioned by the **training SMEs**?*

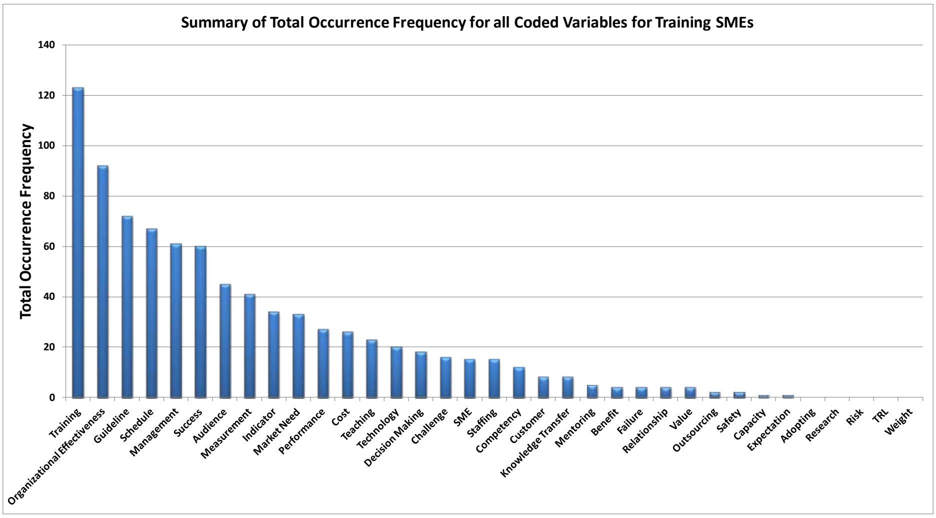


Figure 4F-16. Summary of total occurrence frequency for all coded variables for training SMEs

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Training SMEs are Training, Organizational Effectiveness, Guideline, Schedule, and Management.

sub-*EQ13b. What are the most important variables mentioned by the* ***engineering SMEs****?*

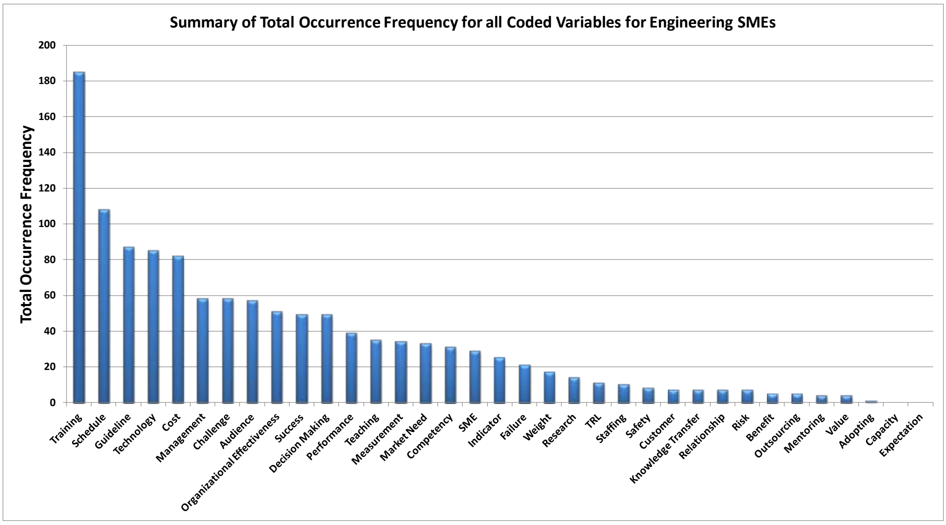


Figure 4F-17. Summary of total occurrence frequency for all coded variables for engineering SMEs

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Engineering SMEs are Training, Schedule, Guideline, Technology, and Cost.

sub-*EQ13c. Are the most important variables mentioned by* ***training SMEs*** *different than* ***engineering SMEs****?*

H0:The variables do not have a rank-order relationship in the population represented by Training SMEs and Engineering SMEs.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Training SMEs and Engineering SMEs.

					Training Focals	Technology SMEs
Spearman's rho	Training Focals	Correlation Coefficient			1.000	.813**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.014
			Std. Error		.000	.056
			95% Confidence Interval	Lower	1.000	.665
				Upper	1.000	.897
	Technology SMEs	Correlation Coefficient			.813**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.014	.000
			Std. Error		.056	.000
			95% Confidence Interval	Lower	.665	1.000
				Upper	.897	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-18. SPSS output for training SMEs and engineering SMEs using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.813 ($p<0.01$) and the critical value for Spearman's correlation is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship in the population represented by Training SMEs and Engineering SMEs. Because there is a rank order relationship in the population represented by Training SMEs and Engineering SMEs, the most important variables mentioned by the Training SMEs and the Engineering SMEs are similar. This result confirms that the conceptual model to be developed can be used by both Training SMEs and the Engineering SMEs.

sub-*EQ13d. What are the most important variables mentioned by both the* ***training SMEs*** *and* ***engineering SMEs****?*

Table 4F-27. Summary of the most important variables for training SMEs and engineering SMEs

Variable	Training Focals	Technology SMEs	Training Focals Ranking	Technology SMEs Ranking	Difference between Ranking
Indicator	34	25	9	18	-9
Organizational Effectiveness	92	51	2	9	-7
Measurement	41	34	8	14	-6
Market Need	33	33	10	15	-5
Success	60	49	6	10.5	-4.5
Management	61	58	5	6.5	-1.5
Performance	27	39	11	12	-1
Audience	45	57	7	8	-1
Teaching	23	35	13	13	0
Guideline	72	87	3	3	0
Training	123	185	1	1	0
SME	15	29	17.5	17	0.5
Schedule	67	108	4	2	2
Competency	12	31	19	16	3
Decision Making	18	49	15	10.5	4.5
Cost	26	82	12	5	7
Challenge	16	58	16	6.5	9.5
Technology	20	85	14	4	10

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Training SMEs and Engineering SMEs are Teaching, Guideline, Training, Management, Performance, Audience, SME, and Schedule.

sub-*EQ14a. What are the most important variables for the* **training SMEs** *relating to* ***TI****?*

Table 4F-28. Summary of the most important variables for training SMEs relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Organizational Effectiveness	12	1
Training	10	2
Guideline	7	3.5
Schedule	7	3.5
Audience	6	5
Indicator	5	6.5
Market Need	5	6.5
Management	4	8.5
Success	4	8.5
Staffing	3	10
Cost	2	11.5
Measurement	2	11.5
Research	1	14.5
Relationship	1	14.5
Competency	1	14.5
Decision Making	1	14.5
Outsourcing	0	26
Capacity	0	26
Expectation	0	26
Adopting	0	26
Risk	0	26
TRL	0	26
Weight	0	26
SME	0	26
Customer	0	26
Mentoring	0	26
Benefit	0	26
Failure	0	26
Safety	0	26
Value	0	26
Teaching	0	26
Knowledge Transfer	0	26
Challenge	0	26
Technology	0	26
Performance	0	26

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Training SMEs interviewees in relation to TI are Organizational Effectiveness, Training, Guideline, Schedule, and Audience.

sub-*EQ14b. What are the most important variables for the* ***engineering SMEs*** *relating to* ***TI****?*

Table 4F-29. Summary of the most important variables for engineering SMEs relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Training	30	1
Schedule	19	2
Guideline	18	3
Cost	13	4
Audience	12	5.5
Decision Making	12	5.5
Success	11	7
Organizational Effectiveness	10	9
Performance	10	9
Challenge	10	9
Management	8	11
Market Need	6	12
Weight	5	13
Teaching	4	14.5
Competency	4	14.5
TRL	3	19
Value	3	19
Risk	3	19
SME	3	19
Relationship	3	19
Research	3	19
Measurement	3	19
Customer	2	24
Safety	2	24
Indicator	2	24
Knowledge Transfer	1	27.5
Adopting	1	27.5
Failure	1	27.5
Benefit	1	27.5
Mentoring	0	32.5
Capacity	0	32.5
Expectation	0	32.5
Outsourcing	0	32.5
Staffing	0	32.5
Technology	0	32.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs interviewees in relation to TI are Training, Schedule, Guideline, and Cost.

sub-*EQ14c. Are the most important variables relating to* ***TI*** *for the* ***training SMEs*** *different than* ***engineering SMEs****?*

H0:The variables do not have a rank-order relationship in the population represented by Training SMEs and Engineering SMEs in relation to TI.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Training SMEs and Engineering SMEs in relation to TI.

					Training SMEs TI Co-Occurrence	Engineering SMEs TI Co-Occurrence
Spearman's rho	Training SMEs TI Co-Occurrence	Correlation Coefficient			1.000	.625**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.012
			Std. Error		.000	.124
			95% Confidence Interval	Lower	1.000	.335
				Upper	1.000	.815
	Engineering SMEs TI Co-Occurrence	Correlation Coefficient			.625**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.012	.000
			Std. Error		.124	.000
			95% Confidence Interval	Lower	.335	1.000
				Upper	.815	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-19. SPSS output for training SMEs TI and engineering SMEs TI using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.625 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training SME and Engineering SME interviewees in terms of TI. Because there is a rank order relationship between the variables in the population represented by Training SME and Engineering SME interviewees in terms of TI, the most important variables for Training SME and Engineering SME interviewees in terms of TI are similar. This result confirms that there is a relationship between Training SME and Engineering SME interviewees in terms of TI and that the two groups of interest share similar variables. Hence, EQ14d will list the variables that are common to both of the groups of interest across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.625 indicates a relatively moderate positive relationship between Training SME and Engineering SME interviewees in terms of TI. The relationship is neither weak nor strong.

sub-*EQ14d. What are the most important variables relating to* ***TI*** *mentioned by both the* ***training SMEs*** *and* ***engineering SMEs****?*

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. In this case, there were no variables that fit the ranking criteria because the highest co-occurrence value was less than ten; therefore, all of the variables were omitted from being considered as the most important variables for the two groups of interest.

sub-*EQ15a. What are the most important variables for the* ***training SMEs*** *relating to* ***TR****?*

Table 4F-30. Summary of the most important variables for training SMEs relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Organizational Effectiveness	47	1
Guideline	38	2.5
Schedule	38	2.5
Success	36	4
Measurement	29	5
Management	27	6
Audience	25	7
Market Need	22	8
Indicator	20	9
Teaching	18	10
Cost	16	11
Decision Making	13	12.5
Performance	13	12.5
Competency	11	14.5
Knowledge Transfer	11	14.5
Staffing	10	16.5
Challenge	10	18
Technology	10	16.5
SME	9	19
Customer	5	20.5
Mentoring	5	20.5
Relationship	3	22
Outsourcing	2	24
Benefit	2	24
Value	2	24
Research	1	28
Capacity	1	28
Expectation	1	28
Failure	1	28
Safety	1	28
Training	0	33
Adopting	0	33
Risk	0	33
TRL	0	33
Weight	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Training SMEs interviewees in relation to TR are Organizational Effectiveness, Guideline, Schedule, Success, and Measurement.

sub-*EQ15b. What are the most important variables for the* ***engineering SMEs*** *relating to* ***TR****?*

Table 4F-31. Summary of the most important variables for engineering SMEs relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Guideline	40	1
Audience	39	2
Schedule	37	3
Success	31	4
Technology	30	5
Challenge	29	6
Teaching	28	7
Organizational Effectiveness	24	8
Cost	23	9
Management	21	10
Competency	20	11
Market Need	18	12
SME	16	13
Decision Making	14	14.5
Measurement	14	14.5
Performance	13	16
Failure	10	17
Indicator	9	18
Staffing	6	19
Research	4	21
Customer	4	21
Outsourcing	4	21
TRL	3	25
Value	3	25
Safety	3	25
Knowledge Transfer	3	25
Mentoring	3	25
Weight	1	29
Relationship	1	29
Benefit	1	29
Training	0	33
Risk	0	33
Adopting	0	33
Capacity	0	33
Expectation	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs interviewees in relation to TR are Guideline, Audience, Schedule, Success, and Technology.

sub-*EQ15c. Are the most important variables relating to* ***TR*** *for the* ***training SMEs*** *different than* ***engineering SMEs****?*

H0: The variables do not have a rank-order relationship in the population represented by Training SMEs and Engineering SMEs in relation to TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Training SMEs and Engineering SMEs in relation to TR.

					Training SMEs TR Co-Occurrence	Engineering SMEs TR Co-Occurrence
Spearman's rho	Training SMEs TR Co-Occurrence	Correlation Coefficient			1.000	.838**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[b]	Bias		.000	-.014
			Std. Error		.000	.054
			95% Confidence Interval	Lower	1.000	.700
				Upper	1.000	.908
	Engineering SMEs TR Co-Occurrence	Correlation Coefficient			.838**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[b]	Bias		-.014	.000
			Std. Error		.054	.000
			95% Confidence Interval	Lower	.700	1.000
				Upper	.908	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-20. SPSS output for training SMEs TR and engineering SMEs TR using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.838 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training SME and Engineering SME interviewees in terms of TR. Because there is a rank order relationship between the variables in the population represented by Training SME and Engineering SME interviewees in terms of TR, the most important variables for Training SME and Engineering SME interviewees in terms of TR are similar. This result confirms that there is a relationship between Training SME and Engineering SME interviewees in terms of TR and that the two groups of interest share similar variables. Hence, EQ15d will list the variables that are common to both of the groups of interest across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.838 indicates a relatively strong positive relationship between Training SME and Engineering SME interviewees in terms of TR.

sub-*EQ15d. What are the most important variables relating to* ***TR*** *mentioned by both the* ***training SMEs*** *and* ***engineering SMEs****?*

Table 4F-32. Summary of the most important variables for training SMEs and engineering SMEs relating to TR

Variable	Training SMEs TR Co-Occurrence	Engineering SMEs TR Co-Occurrence	Training SMEs TR Co-Occurrence Ranking	Engineering SMEs TR Co-Occurrence Ranking	Difference between Ranking
Measurement	29	14	5	14.5	-9.5
Organizational Effectiveness	47	24	1	8	-7
Market Need	22	18	8	12	-4
Management	27	21	6	10	-4
Performance	13	13	12.5	16	-3.5
Decision Making	13	14	12.5	14.5	-2
Schedule	38	37	2.5	3	-0.5
Success	36	31	4	4	0
Guideline	38	40	2.5	1	1.5
Cost	16	23	11	9	2
Teaching	18	28	10	7	3
Competency	11	20	14.5	11	3.5
Audience	25	39	7	2	5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Training SMEs and Engineering SMEs in relation to TR are Schedule, Success, Decision Making, Guideline, and Cost.

Engineering SMEs involved in Training vs Engineering SMEs not involved in training

sub-*EQ16a. What are the most important variables mentioned by the **engineering SMEs involved in training**?*

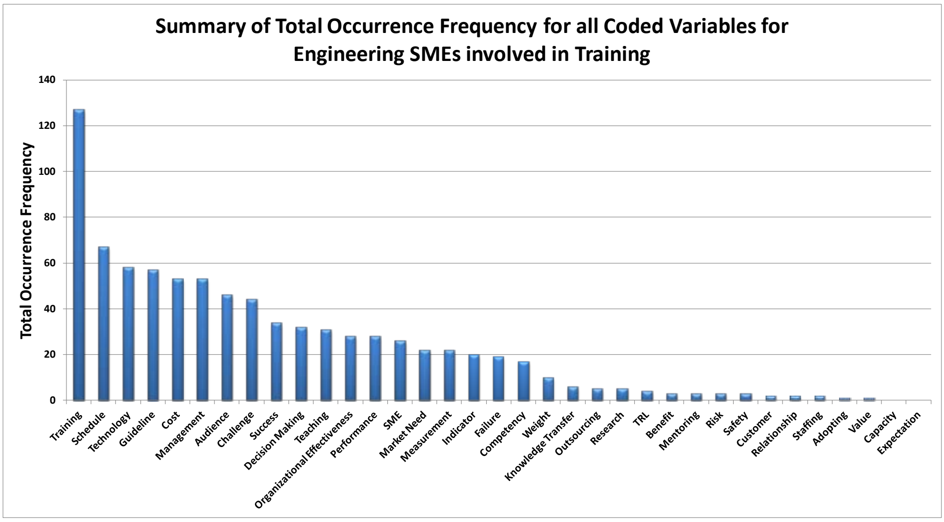


Figure 4F-21. Summary of total occurrence frequency for all coded variables for engineering SMEs involved in training

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Engineering SMEs involved in Training are Training, Schedule, Technology, Guideline, Cost, and Management.

sub-*EQ16b. What are the most important variables mentioned by the* ***engineering SMEs not involved in training****?*

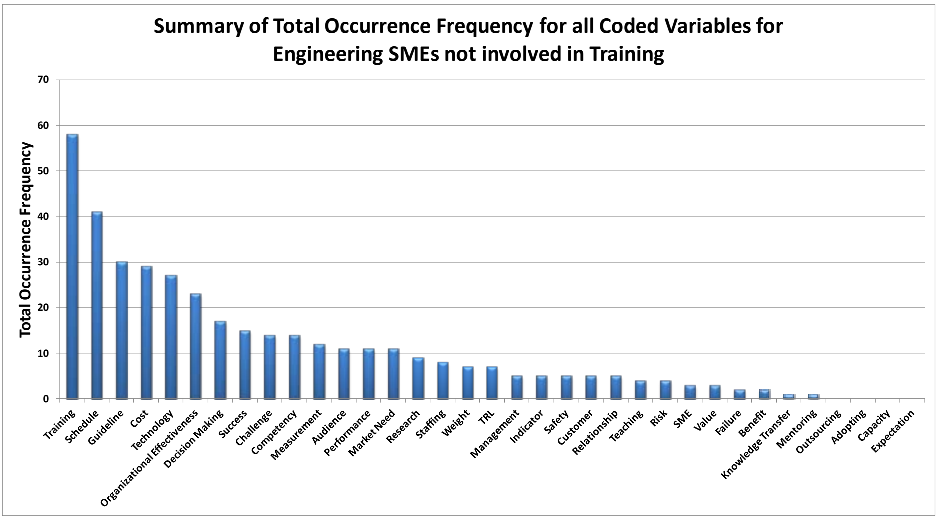


Figure 4F-22. Summary of total occurrence frequency for all coded variables for engineering SMEs not involved in training

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Engineering SMEs not involved in Training are Training, Schedule, Guideline, Cost, and Technology.

sub-*EQ16c. Are the most important variables mentioned by* ***engineering SMEs involved in training*** *different than* ***engineering SMEs not involved in training****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training.

					Technology SMEs not involved in Training	Technology SMEs involved in Training
Spearman's rho	Technology SMEs not involved in Training	Correlation Coefficient			1.000	.763**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.017
			Std. Error		.000	.093
			95% Confidence Interval	Lower	1.000	.527
				Upper	1.000	.894
	Technology SMEs involved in Training	Correlation Coefficient			.763**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.017	.000
			Std. Error		.093	.000
			95% Confidence Interval	Lower	.527	1.000
				Upper	.894	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-23. SPSS output for engineering SMEs not involved in training and engineering SMEs involved in training using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.763 ($p<0.01$) and the critical value for Spearman's correlation is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training. Because there is a rank order relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training, the most important variables mentioned by the Engineering SMEs not involved in Training and Engineering SMEs involved in Training are similar. This result confirms that the conceptual model to be developed can be used by both Engineering SMEs not involved in Training and Engineering SMEs involved in Training.

sub-*EQ16d. What are the most important variables mentioned by both the* ***engineering SMEs involved in training*** *and* ***engineering SMEs not involved in training****?*

Table 4F-33. Summary of the most important variables for engineering SMEs involved in training and engineering SMEs not involved in training

Variable	Technology SMEs not involved in Training	Technology SMEs involved in Training	Technology SMEs not involved in Training Ranking	Technology SMEs involved in Training Ranking	Difference between Ranking
Competency	14	17	9	19	-10
Organizational Effectiveness	23	28	6	12.5	-6.5
Measurement	12	22	11	15.5	-4.5
Decision Making	17	32	7	10	-3
Market Need	11	22	13	15.5	-2.5
Cost	29	53	4	5.5	-1.5
Success	15	34	8	9	-1
Guideline	30	57	3	4	-1
Schedule	41	67	2	2	0
Training	58	127	1	1	0
Performance	11	28	13	12.5	0.5
Challenge	14	44	10	8	2
Technology	27	58	5	3	2
Audience	11	46	13	7	6

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables.

The most important variables mentioned by both Engineering SMEs involved in Training and Engineering SMEs not involved in Training are Schedule, Training, Cost, Success, Guideline, Performance, Challenge, and Technology.

sub-*EQ17a. What are the most important variables for the* **engineering SMEs involved in training** *relating to* ***TI****?*

Table 4F-34. Summary of the most important variables for engineering SMEs involved in training relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Training	24	1
Schedule	13	2
Guideline	11	3
Audience	10	4
Cost	9	5
Success	8	6
Performance	7	7
Organizational Effectiveness	6	9
Challenge	6	9
Management	6	9
Decision Making	5	11
Competency	4	12.5
Teaching	4	12.5
Research	3	14
SME	2	15.5
Market Need	2	15.5
Knowledge Transfer	1	20.5
Adopting	1	20.5
Risk	1	20.5
Failure	1	20.5
Safety	1	20.5
Weight	1	20.5
Measurement	1	20.5
Indicator	1	20.5
Customer	0	30
Mentoring	0	30
Staffing	0	30
TRL	0	30
Value	0	30
Capacity	0	30
Expectation	0	30
Outsourcing	0	30
Benefit	0	30
Relationship	0	30
Technology	0	30

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs involved in Training in relation to TI are Training, Schedule, Guideline, Audience, and Cost.

sub-*EQ17b. What are the most important variables for the* ***engineering SMEs not involved in training*** *relating to* ***TI****?*

Table 4F-35. Summary of the most important variables for engineering SMEs not involved in training relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Decision Making	7	1.5
Guideline	7	1.5
Schedule	6	3.5
Training	6	3.5
Organizational Effectiveness	4	7
Market Need	4	7
Weight	4	7
Cost	4	7
Challenge	4	7
TRL	3	12
Value	3	12
Relationship	3	12
Performance	3	12
Success	3	12
Customer	2	17
Risk	2	17
Audience	2	17
Management	2	17
Measurement	2	17
Indicator	1	21.5
SME	1	21.5
Safety	1	21.5
Benefit	1	21.5
Teaching	0	29.5
Knowledge Transfer	0	29.5
Mentoring	0	29.5
Research	0	29.5
Adopting	0	29.5
Capacity	0	29.5
Expectation	0	29.5
Outsourcing	0	29.5
Competency	0	29.5
Failure	0	29.5
Staffing	0	29.5
Technology	0	29.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs not involved in Training in relation to TI are Decision Making, Guideline, Schedule, and Training.

sub-*EQ17c. Are the most important variables relating to* ***TI*** *for the* ***engineering SMEs involved in training*** *different than* ***engineering SMEs not involved in training****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training in relation to TI.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training in relation to TI.

					Engineering SMEs involved in Training TI Co-Occurrence	Engineering SMEs not involved in Training TI Co-Occurrence
Spearman's rho	Engineering SMEs involved in Training TI Co-Occurrence	Correlation Coefficient			1.000	.559**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.015
			Std. Error		.000	.137
			95% Confidence Interval	Lower	1.000	.213
				Upper	1.000	.752
	Engineering SMEs not involved in Training TI Co-Occurrence	Correlation Coefficient			.559**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.015	.000
			Std. Error		.137	.000
			95% Confidence Interval	Lower	.213	1.000
				Upper	.752	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-24. SPSS output for engineering SMEs not involved in training TI and engineering SMEs involved in training TI using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.559 ($p<0.01$) and the critical value for Spearman's correlation for $N=35$ ($df=33$) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TI. Because there is a rank order relationship between the variables in the population represented by Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TI, the most important variables for Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TI are similar. This result confirms that there is a relationship between Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TI and that the two groups of interest share similar variables. Hence, EQ17d will list the variables that are common to both of the groups of interest across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.559 indicates a relatively moderate positive relationship between Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TI. The relationship is neither weak nor strong.

sub-*EQ17d. What are the most important variables relating to* ***TI*** *mentioned by both the* ***engineering SMEs involved in training*** *and* ***engineering SMEs not involved in training****?*

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. In this case, there were no variables that fit the ranking criteria because the highest co-occurrence value was less than ten; therefore, all of the variables were omitted from being considered as the most important variables for the two groups of interest.

sub-*EQ18a. What are the most important variables for the* ***engineering SMEs involved in training*** *relating to* ***TR****?*

Table 4F-36. Summary of the most important variables for engineering SMEs involved in training relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Audience	34	1
Guideline	32	2
Teaching	26	3
Success	24	5
Challenge	24	5
Technology	24	5
Schedule	23	7
Management	21	8
Organizational Effectiveness	17	9
Cost	16	10
SME	15	11
Competency	14	12.5
Market Need	14	12.5
Measurement	11	14
Performance	10	15.5
Failure	10	15.5
Decision Making	9	17
Indicator	8	18
Outsourcing	4	19
Research	3	20
Knowledge Transfer	2	23
Safety	2	23
Customer	2	23
Mentoring	2	23
Staffing	2	23
Weight	1	28
TRL	1	28
Value	1	28
Benefit	1	28
Relationship	1	28
Training	0	33
Adopting	0	33
Risk	0	33
Capacity	0	33
Expectation	0	33

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs involved in Training in relation to TR are Audience, Guideline, Teaching, Success, Challenge, and Technology.

sub-*EQ18b. What are the most important variables for the* ***engineering SMEs not involved in training*** *relating to* ***TR****?*

Table 4F-37. Summary of the most important variables for engineering SMEs not involved in training relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Schedule	14	1
Guideline	8	2
Organizational Effectiveness	7	4
Cost	7	4
Success	7	4
Competency	6	6.5
Technology	6	6.5
Decision Making	5	9
Challenge	5	9
Audience	5	9
Market Need	4	11.5
Staffing	4	11.5
Performance	3	13.5
Measurement	3	13.5
TRL	2	16.5
Value	2	16.5
Customer	2	16.5
Teaching	2	16.5
Indicator	1	21.5
SME	1	21.5
Safety	1	21.5
Knowledge Transfer	1	21.5
Mentoring	1	21.5
Research	1	21.5
Training	0	30
Weight	0	30
Relationship	0	30
Risk	0	30
Management	0	30
Benefit	0	30
Adopting	0	30
Capacity	0	30
Expectation	0	30
Outsourcing	0	30
Failure	0	30

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering SMEs not involved in Training in relation to TR are Schedule, Guideline, Organizational Effectiveness, Cost, and Success.

sub-*EQ18c. Are the most important variables relating to* ***TR*** *for the* ***engineering SMEs involved in training*** *different than* ***engineering SMEs not involved in training****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training in relation to TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering SMEs not involved in Training and Engineering SMEs involved in Training in relation to TR.

						Engineering SMEs involved in Training TR Co-Occurrence	Engineering SMEs not involved in Training TR Co-Occurrence
Spearman's rho	Engineering SMEs involved in Training TR Co-Occurrence	Correlation Coefficient				1.000	.726**
		Sig. (2-tailed)				.	.000
		N				35	35
		Bootstrap[c]	Bias			.000	-.014
			Std. Error			.000	.099
			95% Confidence Interval	Lower		1.000	.494
				Upper		1.000	.870
	Engineering SMEs not involved in Training TR Co-Occurrence	Correlation Coefficient				.726**	1.000
		Sig. (2-tailed)				.000	.
		N				35	35
		Bootstrap[c]	Bias			-.014	.000
			Std. Error			.099	.000
			95% Confidence Interval	Lower		.494	1.000
				Upper		.870	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-25. SPSS output for engineering SMEs not involved in training TR and engineering SMEs involved in training TR using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.726 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TR. Because there is a rank order relationship between the variables in the population represented by Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TR, the most important variables for Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TR are similar. This result confirms that there is a relationship between Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TR and that the two groups of interest share similar variables. Hence, EQ18d will list the variables that are common to both of the groups of interest across all interviewees.

Since the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, and the obtained correlation value of 0.726 indicates a relatively strong positive relationship between Engineering SME involved in Training and Engineering SME not involved in Training interviewees in terms of TR.

sub-*EQ18d. What are the most important variables relating to* ***TR*** *mentioned by both the* ***engineering SMEs involved in training*** *and* ***engineering SMEs not involved in training****?*

Table 4F-38. Summary of the most important variables for engineering SMEs involved in training and engineering SMEs not involved in training relating to TR

Variable	Engineering SMEs involved in Training TR Co-Occurrence	Engineering SMEs not involved in Training TR Co-Occurrence	Engineering SMEs involved in Training TR Co-Occurrence Ranking	Engineering SMEs not involved in Training TR Co-Occurrence Ranking	Difference between Ranking
Schedule	23	14	7	1	6

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. In this case, there were no variables that fit the ranking criteria; therefore, no variables can be listed as the most important variables for both Engineering SMEs involved in Training and Engineering SMEs not involved in Training in relation to TR.

Engineering Manager vs Training Manager

sub-*EQ19a. What are the most important variables mentioned by the* ***engineering managers****?*

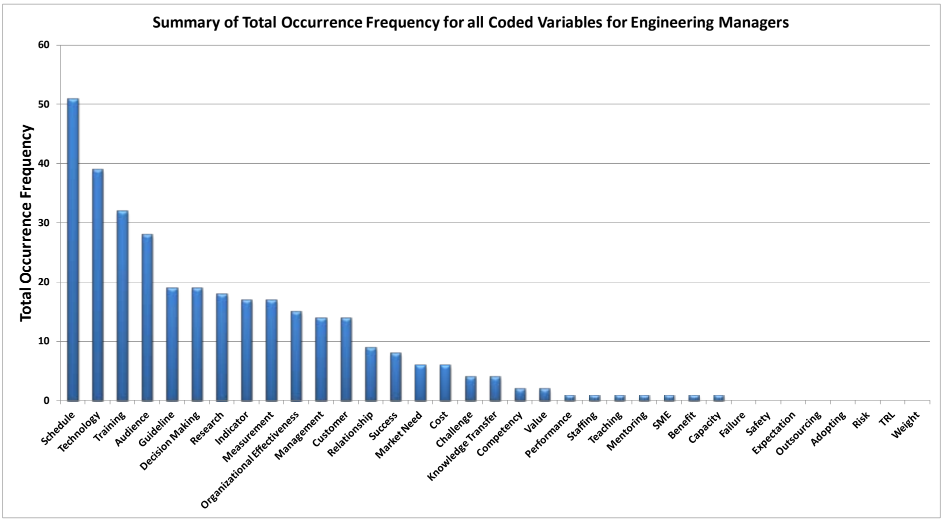


Figure 4F-26. Summary of total occurrence frequency for all coded variables for engineering managers

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Engineering Managers are Schedule, Technology, Training, Audience, Guideline, and Decision Making.

sub-*EQ19b. What are the most important variables mentioned by the* ***training managers****?*

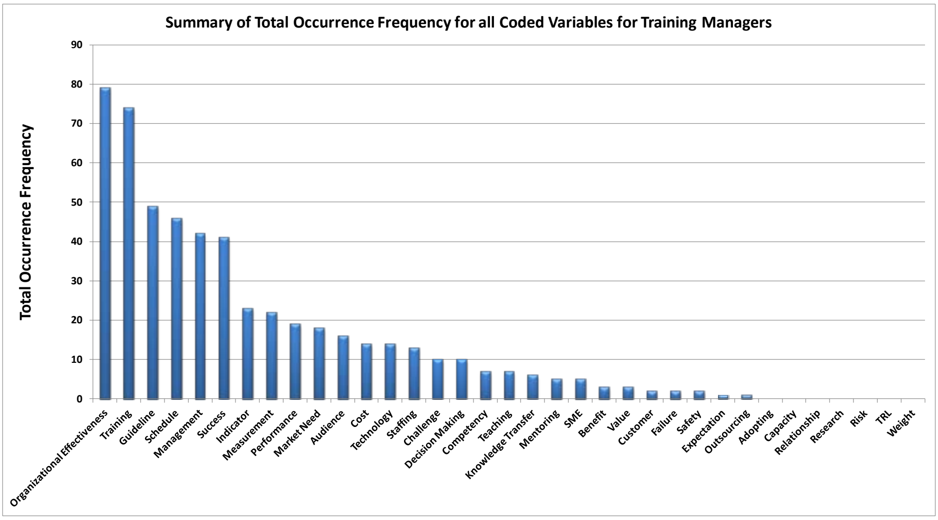


Figure 4F-27. Summary of total occurrence frequency for all coded variables for training managers

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five will be considered as the most important variables. The most important variables mentioned by Training Managers are Organizational Effectiveness, Training, Guideline, Schedule, and Management.

sub-*EQ19c. Are the most important variables mentioned by* ***engineering managers*** *different than* ***training managers****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering Managers and Training Managers.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers.

					Engineering Manager	Training Manager
Spearman's rho	Engineering Manager	Correlation Coefficient			1.000	.678**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.015
			Std. Error		.000	.118
			95% Confidence Interval	Lower	1.000	.395
				Upper	1.000	.864
	Training Manager	Correlation Coefficient			.678**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.015	.000
			Std. Error		.118	.000
			95% Confidence Interval	Lower	.395	1.000
				Upper	.864	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-28. SPSS output for engineering manager and training manager using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.678 ($p<0.01$) and the critical value for Spearman's correlation is 0.680 ($p<0.01$). Since the obtained value for Spearman's correlation is less than the critical value for Spearman's correlation, the null hypothesis is retained. Hence, there is no rank order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers. Because there is no rank order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers, the most important variables mentioned by the Engineering Managers and Training Managers are different. This result confirms that the conceptual model to be developed cannot be used by both Engineering Managers and Training Managers; thereby substantiating that separate conceptual models will need to be developed for Engineering Managers and Training Managers.

sub-*EQ19d. What are the most important variables mentioned by both the* ***engineering managers*** *and* ***training managers****?*

Table 4F-39. Summary of the most important variables for engineering managers and training managers

Variable	Engineering Manager	Training Manager	Engineering Manager Ranking	Training Manager Ranking	Difference between Ranking
Technology	39	14	2	12.5	-10.5
Audience	28	16	4	11	-7
Schedule	51	46	1	4	-3
Measurement	17	22	8.5	8	0.5
Training	32	74	3	2	1
Indicator	17	23	8.5	7	1.5
Guideline	19	49	5.5	3	2.5
Management	14	42	11.5	5	6.5
Organizational Effectiveness	15	79	10	1	9

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variables mentioned by both Engineering Managers and Training Managers are Measurement, Training, and Indicator.

sub-*EQ20a. What are the most important variables for the* **engineering managers** *relating to* ***OE****?*

Table 4F-40. Summary of the most important variables for engineering managers relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking
Training	7	1
Audience	4	3
Schedule	4	3
Technology	4	3
Decision Making	3	6.5
Guideline	3	6.5
Research	3	6.5
Success	3	6.5
Cost	2	9.5
Relationship	2	9.5
Benefit	1	14.5
Capacity	1	14.5
Competency	1	14.5
Customer	1	14.5
Knowledge Transfer	1	14.5
Management	1	14.5
Market Need	1	14.5
Teaching	1	14.5
Adopting	0	27
Challenge	0	27
Expectation	0	27
Failure	0	27
Indicator	0	27
Measurement	0	27
Mentoring	0	27
Organizational Effectiveness	0	27
Outsourcing	0	27
Performance	0	27
Risk	0	27
Safety	0	27
SME	0	27
Staffing	0	27
TRL	0	27
Value	0	27
Weight	0	27

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering Managers in relation to OE are Training, Audience, Schedule, and Technology.

sub-*EQ20b. What are the most important variables for the* ***training managers*** *relating to* ***OE****?*

Table 4F-40. Summary of the most important variables for training managers relating to OE

Variable	Organizational Effectiveness Co-Occurrence	Organizational Effectiveness Co-Occurrence Ranking
Training	34	1
Success	27	2
Management	22	3
Schedule	19	4
Guideline	15	5
Indicator	14	6
Market Need	10	7
Performance	9	8
Measurement	8	9
Technology	7	10
Staffing	6	11.5
Cost	6	11.5
Audience	5	13
Challenge	4	15
Competency	4	15
Decision Making	4	15
Knowledge Transfer	3	17.5
Teaching	3	17.5
Value	2	19.5
Safety	2	19.5
Mentoring	1	23
SME	1	23
Benefit	1	23
Research	1	23
Failure	1	23
Organizational Effectivene	0	30.5
Customer	0	30.5
Expectation	0	30.5
Outsourcing	0	30.5
Adopting	0	30.5
Capacity	0	30.5
Relationship	0	30.5
Risk	0	30.5
TRL	0	30.5
Weight	0	30.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Training Managers in relation to OE are Training, Success, Management, Schedule, and Guideline.

sub-*EQ20c. Are the most important variables relating to* ***OE*** *for* ***engineering managers*** *different than* ***training managers****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering Managers and Training Managers in relation to OE.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers in relation to OE.

					Training Manager OE Co-Occurrence	Engineering Manager OE Co-Occurrence
Spearman's rho	Training Manager OE Co-Occurrence	Correlation Coefficient			1.000	.468**
		Sig. (2-tailed)			.	.005
		N			35	35
		Bootstrap[c]	Bias		.000	-.012
			Std. Error		.000	.143
			95% Confidence Interval	Lower	1.000	.151
				Upper	1.000	.704
	Engineering Manager OE Co-Occurrence	Correlation Coefficient			.468**	1.000
		Sig. (2-tailed)			.005	.
		N			35	35
		Bootstrap[c]	Bias		-.012	.000
			Std. Error		.143	.000
			95% Confidence Interval	Lower	.151	1.000
				Upper	.704	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-29. SPSS output for engineering manager OE and training manager OE using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.468 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of OE. Because there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of OE, the most important variables for Training Manager and Engineering Manager interviewees in terms of OE are similar. This result confirms that there is a relationship between Training Manager and Engineering Manager interviewees in terms of OE and that the two groups of interest share similar variables. Hence, EQ20d will list the variables that are common to both of the constructs across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.468 indicates a relatively weak positive relationship between Training Manager and Engineering Manager interviewees in terms of OE. Hence, the most important variables relating to OE mentioned by both the engineering managers and training managers do not have a strong relationship between the groups of interest.

sub-*EQ20d. What are the most important variables relating to **OE** mentioned by both the **engineering managers** and **training managers**?*

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. In this case, there were no variables that fit the ranking criteria because the highest co-occurrence value was less than ten; therefore, all of the variables were omitted from being considered as the most important variables for the two groups of interest.

sub-*EQ21a. What are the most important variables for the* **engineering managers** *relating to* ***TI****?*

Table 4F-41. Summary of the most important variables for engineering managers relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Schedule	13	1
Research	10	2
Training	9	3
Indicator	9	4
Audience	8	5
Management	6	6
Decision Making	5	8.5
Success	5	8.5
Relationship	5	8.5
Customer	5	8.5
Guideline	4	11.5
Organizational Effectiveness	4	11.5
Measurement	3	13
Market Need	2	14.5
Staffing	2	14.5
Value	1	16
Technology	0	26
Cost	0	26
Benefit	0	26
Capacity	0	26
Competency	0	26
Knowledge Transfer	0	26
Teaching	0	26
Adopting	0	26
Challenge	0	26
Expectation	0	26
Failure	0	26
Mentoring	0	26
Outsourcing	0	26
Performance	0	26
Risk	0	26
Safety	0	26
SME	0	26
TRL	0	26
Weight	0	26

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering Managers in relation to TI are Schedule, Research, Training, Indicator, and Audience.

sub-*EQ21b. What are the most important variables for the* ***training managers*** *relating to* ***TI****?*

Table 4F-42. Summary of the most important variables for training managers relating to TI

Variable	Technology Innovation Co-Occurrence	Technology Innovation Co-Occurrence Ranking
Training	7	1.5
Organizational Effectivene	7	1.5
Schedule	6	3
Success	4	4.5
Guideline	4	4.5
Management	3	8
Indicator	3	8
Market Need	3	8
Staffing	3	8
Audience	3	8
Measurement	1	12
Cost	1	12
Research	1	12
Performance	0	24.5
Technology	0	24.5
Challenge	0	24.5
Competency	0	24.5
Decision Making	0	24.5
Knowledge Transfer	0	24.5
Teaching	0	24.5
Value	0	24.5
Safety	0	24.5
Mentoring	0	24.5
SME	0	24.5
Benefit	0	24.5
Failure	0	24.5
Customer	0	24.5
Expectation	0	24.5
Outsourcing	0	24.5
Adopting	0	24.5
Capacity	0	24.5
Relationship	0	24.5
Risk	0	24.5
TRL	0	24.5
Weight	0	24.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Training Managers in relation to TI are Training, Organizational Effectiveness, Schedule, Success, and Guideline.

sub-*EQ21c. Are the most important variables relating to* ***TI*** *for the* ***engineering managers*** *different than* ***training managers****?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering Managers and Training Managers in relation to TI.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers in relation to TI.

						Training Manager TI Co-Occurrence	Engineering Manager TI Co-Occurrence
Spearman's rho	Training Manager TI Co-Occurrence	Correlation Coefficient				1.000	.742**
		Sig. (2-tailed)				.	.000
		N				35	35
		Bootstrap[c]	Bias			.000	-.007
			Std. Error			.000	.103
			95% Confidence Interval	Lower		1.000	.503
				Upper		1.000	.909
	Engineering Manager TI Co-Occurrence	Correlation Coefficient				.742**	1.000
		Sig. (2-tailed)				.000	.
		N				35	35
		Bootstrap[c]	Bias			-.007	.000
			Std. Error			.103	.000
			95% Confidence Interval	Lower		.503	1.000
				Upper		.909	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-30. SPSS output for engineering manager TI and training manager TI using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.742 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of TI. Because there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of TI, the most important variables for Training Manager and Engineering Manager interviewees in terms of TI are similar. This result confirms that there is a relationship between Training Manager and Engineering Manager interviewees in terms of TI and that the two groups of interest share similar variables. Hence, EQ21d will list the variables that are common to both of the groups of interest across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.742 indicates a relatively strong positive relationship between Training Manager and Engineering Manager interviewees in terms of TI. Hence, the most important variables relating to OE mentioned by both the engineering managers and training managers have a strong relationship between the groups of interest.

sub-*EQ21d. What are the most important variables relating to* ***TI*** *mentioned by both the* ***engineering managers*** *and* ***training managers****?*

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. In this case, there were no variables that fit the ranking criteria because the highest co-occurrence value was less than ten; therefore, all of the variables were omitted from being considered as the most important variables for the two groups of interest.

sub-*EQ22a. What are the most important variables for the* **engineering managers** *relating to* **TR**?

Table 4F-43. Summary of the most important variables for engineering managers relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Schedule	11	1.5
Audience	11	1.5
Guideline	10	3
Technology	9	4
Management	8	5
Organizational Effectiveness	7	6
Decision Making	6	7.5
Measurement	6	7.5
Relationship	4	9
Indicator	3	11.5
Success	3	11.5
Customer	3	11.5
Cost	3	11.5
Research	2	15
Competency	2	15
Knowledge Transfer	2	15
Market Need	1	20
Value	1	20
Benefit	1	20
Capacity	1	20
Teaching	1	20
Challenge	1	20
SME	1	20
Training	0	29.5
Staffing	0	29.5
Adopting	0	29.5
Expectation	0	29.5
Failure	0	29.5
Mentoring	0	29.5
Outsourcing	0	29.5
Performance	0	29.5
Risk	0	29.5
Safety	0	29.5
TRL	0	29.5
Weight	0	29.5

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Engineering Managers in relation to TR are Schedule, Audience, Guideline, Technology, and Management.

sub-*EQ22b. What are the most important variables for the* **training managers** *relating to* ***TR****?*

Table 4F-44. Summary of the most important variables for training managers relating to TR

Variable	Training Co-Occurrence	Training Co-Occurrence Ranking
Organizational Effectiveness	34	1
Schedule	28	2
Success	25	3
Guideline	24	4
Management	23	5
Indicator	14	7
Market Need	14	7
Measurement	14	7
Audience	11	9.5
Performance	11	9.5
Staffing	10	12
Cost	10	12
Knowledge Transfer	10	12
Technology	7	15.5
Challenge	7	15.5
Competency	7	15.5
Decision Making	7	15.5
Teaching	6	18
Mentoring	5	19
SME	3	20
Value	2	22
Benefit	2	22
Customer	2	22
Research	1	26
Safety	1	26
Failure	1	26
Expectation	1	26
Outsourcing	1	26
Training	0	32
Adopting	0	32
Capacity	0	32
Relationship	0	32
Risk	0	32
TRL	0	32
Weight	0	32

Following the ranking criteria described earlier in the chapter, where when analyzing one group of interest, the top five (ranking 1 to 5) will be considered as the most important variables. The most important variables mentioned by the Training Managers in relation to TR are Organizational Effectiveness, Schedule, Success, Guideline, and Management.

sub-*EQ22c. Are the most important variables relating to* ***TR*** *for the* **engineering managers** *different than* **training managers***?*

H0:The variables do not have a rank-order relationship in the population represented by Engineering Managers and Training Managers in relation to TR.

To reject H0: is to say that there is a rank-order relationship between the variables relationship in the population represented by Engineering Managers and Training Managers in relation to TR.

					Training Manager TR Co-Occurrence	Engineering Manager TR Co-Occurrence
Spearman's rho	Training Manager TR Co-Occurrence	Correlation Coefficient			1.000	.654**
		Sig. (2-tailed)			.	.000
		N			35	35
		Bootstrap[c]	Bias		.000	-.012
			Std. Error		.000	.112
			95% Confidence Interval	Lower	1.000	.376
				Upper	1.000	.828
	Engineering Manager TR Co-Occurrence	Correlation Coefficient			.654**	1.000
		Sig. (2-tailed)			.000	.
		N			35	35
		Bootstrap[c]	Bias		-.012	.000
			Std. Error		.112	.000
			95% Confidence Interval	Lower	.376	1.000
				Upper	.828	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 4F-31. SPSS output for engineering manager TR and training manager TR using Spearman's rho

The obtained value for Spearman's correlation for this case is 0.654 ($p<0.01$) and the critical value for Spearman's correlation for N=35 (df=33) is 0.430 ($p<0.01$). Since the obtained value for Spearman's correlation is greater than the critical value for Spearman's correlation, the null hypothesis is rejected. Hence, there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of TR. Because there is a rank order relationship between the variables in the population represented by Training Manager and Engineering Manager interviewees in terms of TR, the most important variables for Training Manager and Engineering Manager interviewees in terms of TR are similar. This result confirms that there is a relationship between Training Manager and Engineering Manager interviewees in terms of TR and that the two groups of interest share similar variables. Hence, EQ22d will list the variables that are common to both of the groups of interest across all interviewees.

Although the obtained value for Spearman's correlation for this case is greater than the critical value for Spearman's correlation, the obtained correlation value of 0.654 indicates a relatively moderate positive relationship between Training Manager and Engineering Manager interviewees in terms of TR. Hence, the most important variables relating to TR mentioned by both the engineering managers and training managers have neither a strong relationship nor a weak relationship between the groups of interest.

sub-*EQ22d. What are the most important variables relating to **TR** mentioned by both the **engineering managers** and **training managers**?*

Table 4F-45. Summary of the most important variables for engineering managers and training managers relating to TR

Variable	Training Manager TR Co-Occurrence	Engineering Manager TR Co-Occurrence	Training Manager TR Co-Occurrence Ranking	Engineering Manager TR Co-Occurrence Ranking	Difference between Ranking
Audience	11	11	9.5	1.5	8
Schedule	28	11	2	1.5	0.5

Following the ranking criteria described earlier in the chapter, where when analyzing two groups of interest, the variables colored in green and yellow will be considered as the most important variables. The most important variable mentioned by both Engineering Managers and Training Managers in relation to TR is Schedule.

APPENDIX 6A

CORRELATION LAG ANALYSIS FOR CASE 1 – COMPOSITES

Appendix 6A describes the detailed correlation lag analysis for case study 1 – Composites. The results listed in this Appendix 6A are described further in Chapter 6.

The lagged correlation coefficient matrix for both the conservative and un-conservative case is shown in Table 6A-1 and Table 6A-2, respectively. In Figure 6A-1 through Figure 6A-28, the comparisons of using leading zeroes versus not using leading zeroes are shown. For each bivariate, observations are stated in addition to two plots representing the normalized data comparisons, and lead and lag time correlation comparisons. The most significant lead and lag time years within the lead and lag time correlation comparison plots are represented by triangles and dots. The triangles represent p value < 0.01 and the dots represent p value < 0.05.

TIOE[Schedule] and TIOE[Guideline]

The results for TIOE[Schedule] and TIOE[Guideline] are shown in Figure 6A-1a and Figure 6A-1b. TIOE[Guideline] leads TIOE[Schedule] by about 10 years in the conservative case. The guidelines for composites that are being developed takes some time as trade studies, testing, analysis, and approval process is involved for the composite materials planning to be used on the airplane.

TIOE[Guideline] inversely leads TIOE[Schedule] by about 3 years in the unconservative case, as shown in Figure 6A-1a. Although there may be some statistical significance shown in this case, it is unrealistic for guidelines at a large company to be fully developed in 3 years. Hence, using the statistical significance from the conservative case is recommended. If the result in the unconservative case is considered, then the explanation may be that as the deliveries are being made for an airplane program containing the new technology innovation, the memos should already be in place. It would be expected that as another airplane program begins again, especially investing in a new technology innovation, the number of memos would be expected to rise.

However, the operationalized variable of TIOE[Schedule] contains data for two airplane models that had orders at different timeframes. This may be one of the possible reasons why there is statistical significance showing TIOE[Guideline] possibly leading by 10 years or possibly lagging by 10 years. Moreover, the initial deliveries between the two airplane models were approximately 10 years apart.

Table 6A-1. Conservative cross correlation coefficient matrix for case study 1

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.668* (TIOE[Guideline], x-10)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.978** (TIOE[Schedule], x+10)	-0.904** (TIOE[Guideline], x+8)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.806** (TI[Schedule], x+7)	-0.420* (TIOE[Guideline], x+1)	0.870* (TI[Schedule], x-6)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.852** (TIOE[Schedule], x+9)	-0.433* (TI[Guideline], x-8)	0.902** (TI[Guideline), x=0)	*no significant correlation*	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.908** (TIOE[Schedule], x-10)	-0.906** (TIOE[Guideline], x-5)	-0.892** (TI/TR[Audience], x+5)	*no significant correlation*	-0.706** (TI[Guideline], x-3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	*no significant correlation*	*no significant correlation*	0.998* (TIOE[Cost], x=0)	*no significant correlation*	*no significant correlation*	*no significant correlation*	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation - too little data points*	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

Table 6A-2. Un-conservative cross correlation coefficient matrix for case study 1

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.726** (TIOE[Guideline], x-3)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.978** (TIOE[Schedule], x+10)	-0.677** (TIOE[Guideline], x+5)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.806** (TI[Schedule], x+7)	0.417* (TIOE[Guideline], x+5)	0.645** (TI[Schedule], x+1)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.667** (TIOE[Schedule], x-4)	0.598** (TI[Guideline], x=0)	0.548** (TI[Guideline], x-1)	0.483** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.775** (TIOE[Schedule], x-9)	0.900** (TIOE(Guideline), x+3)	0.908** (TI/TR[Audience], x-9)	no significant correlation	-0.706** (TI[Guideline], x-3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.905** (TIOE[Schedule], x-4)	-0.689** (TIOE[Guideline], x+9)	0.891** (TIOE[Cost], x+1)	0.698** (TI[Schedule], x+5)	0.655** (TI[Guideline], x+2)	-0.843** (TI/TR[Audience], x+6)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.770** (TIOE[Schedule], x-1)	-0.656** (TIOE[Guideline], x+9)	0.715* (TIOE[Cost], x+1)	0.585** (TI[Schedule], x+5)	0.602** (TI[Guideline], x+1)	-0.783** (TI/TR[Audience], x+6)	*no significant correlation - too little data points*	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

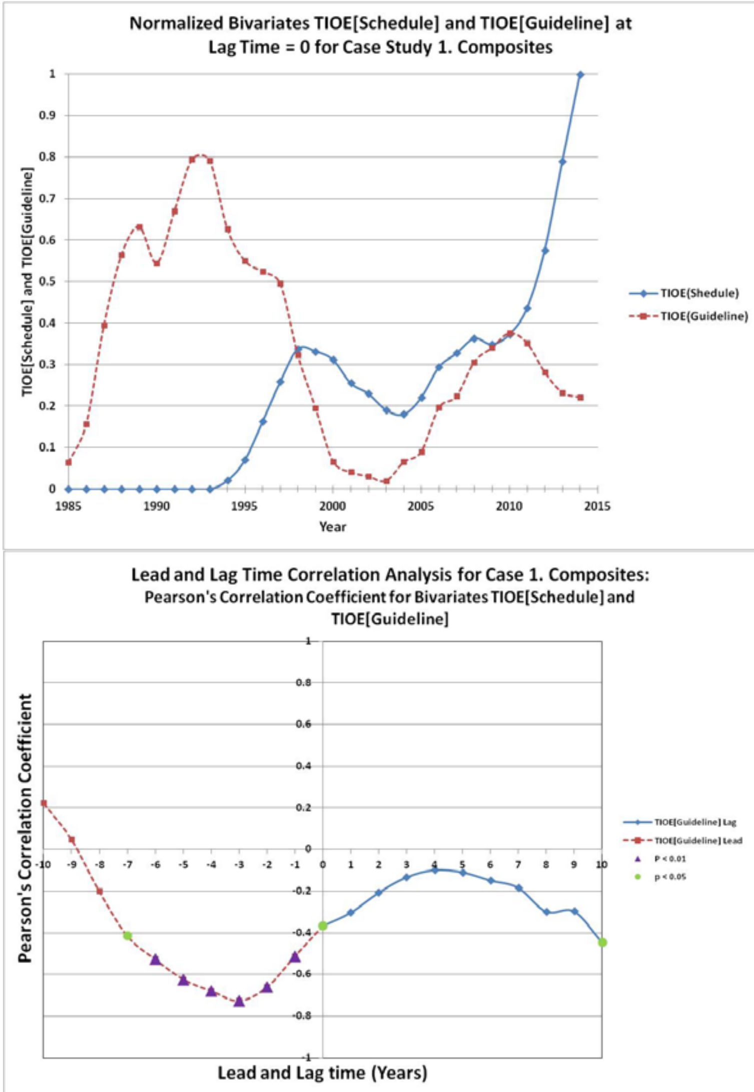


Figure 6A-1a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TIOE[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TIOE[Guideline]

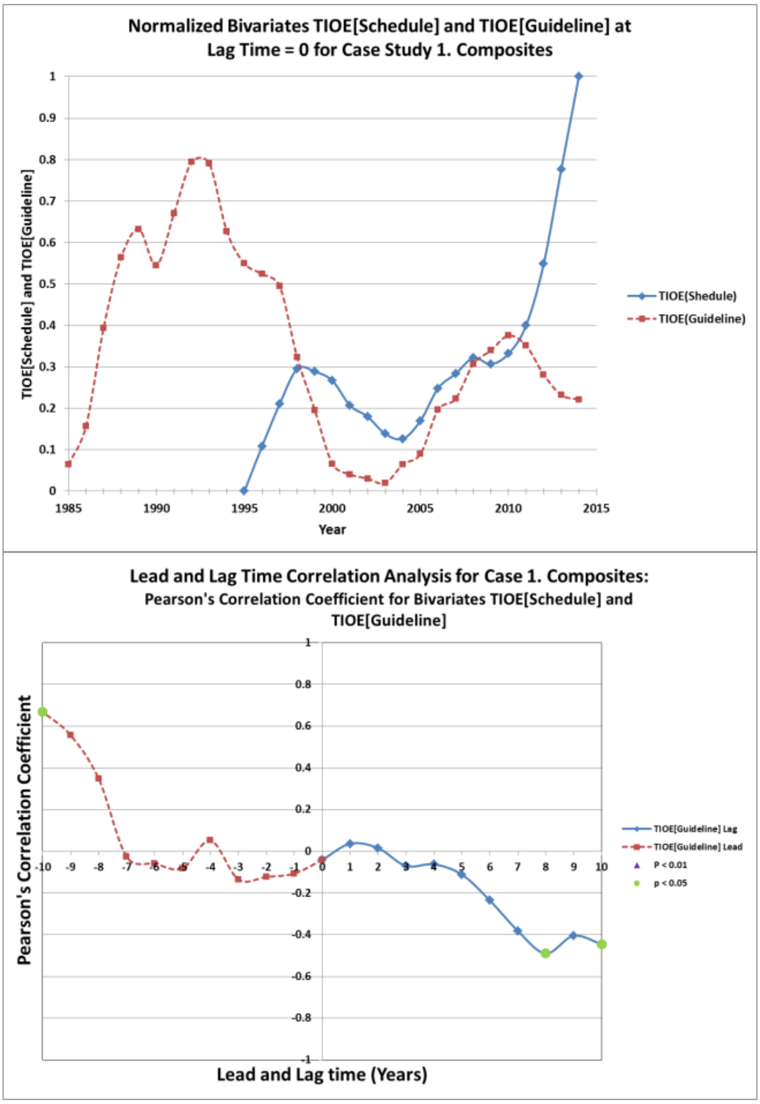


Figure 6A-1b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TIOE[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TIOE[Guideline]

TIOE[Schedule] and TIOE[Cost]

The results for this bivariate, as shown in Figure 6A-2a and Figure 6A-2b, are inconclusive as the investment in product per technology innovation per year may not be a complete data set. Therefore, the results shown in both the conservative and un-conservative cases using TIOE[Cost] will not be heavily considered in the final conclusions of this research. As shown in both cases, TIOE[Cost] is statistically significant and may be useful for companies to use as an indicator if a complete data set was available.

However, the operationalized variable of TIOE[Schedule] contains data for two airplane models that had orders at different timeframes. This may be one of the possible reasons why there is statistical significance showing TIOE[Schedule] possibly lagging TIOE[Cost] by 10 years, inversely lagging TIOE[Cost] by 5 years, and leading TIOE[Cost] by 5 years.

In addition, the data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

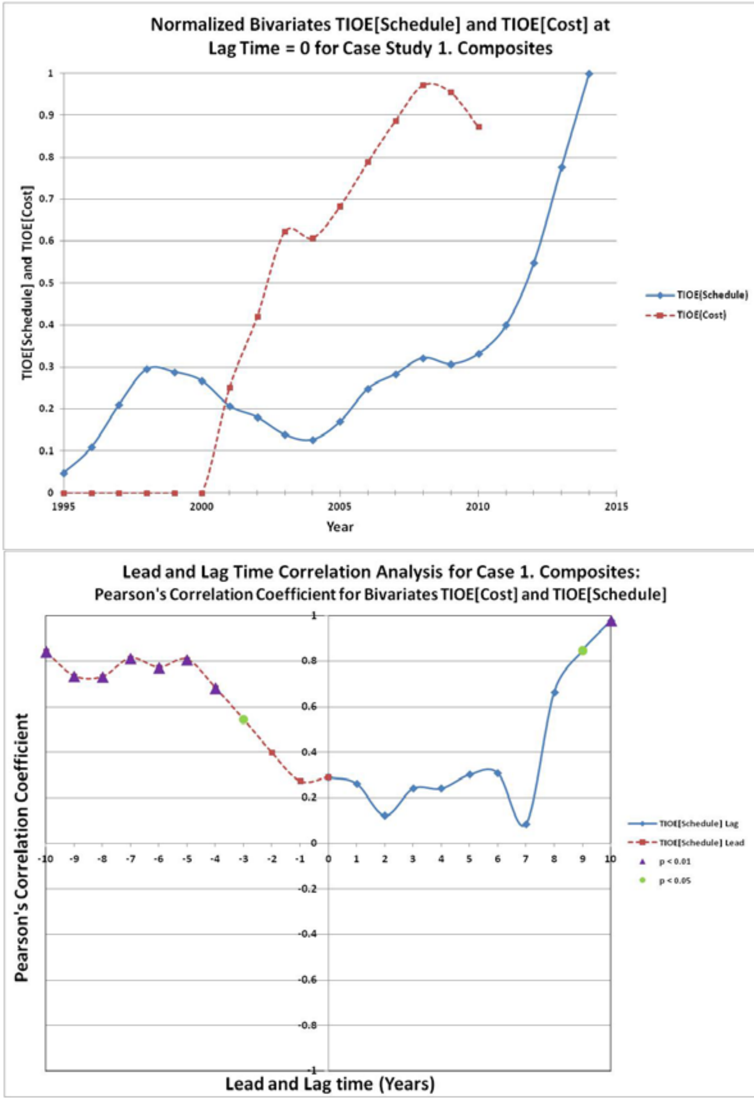


Figure 6A-2a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TIOE[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TIOE[Cost]

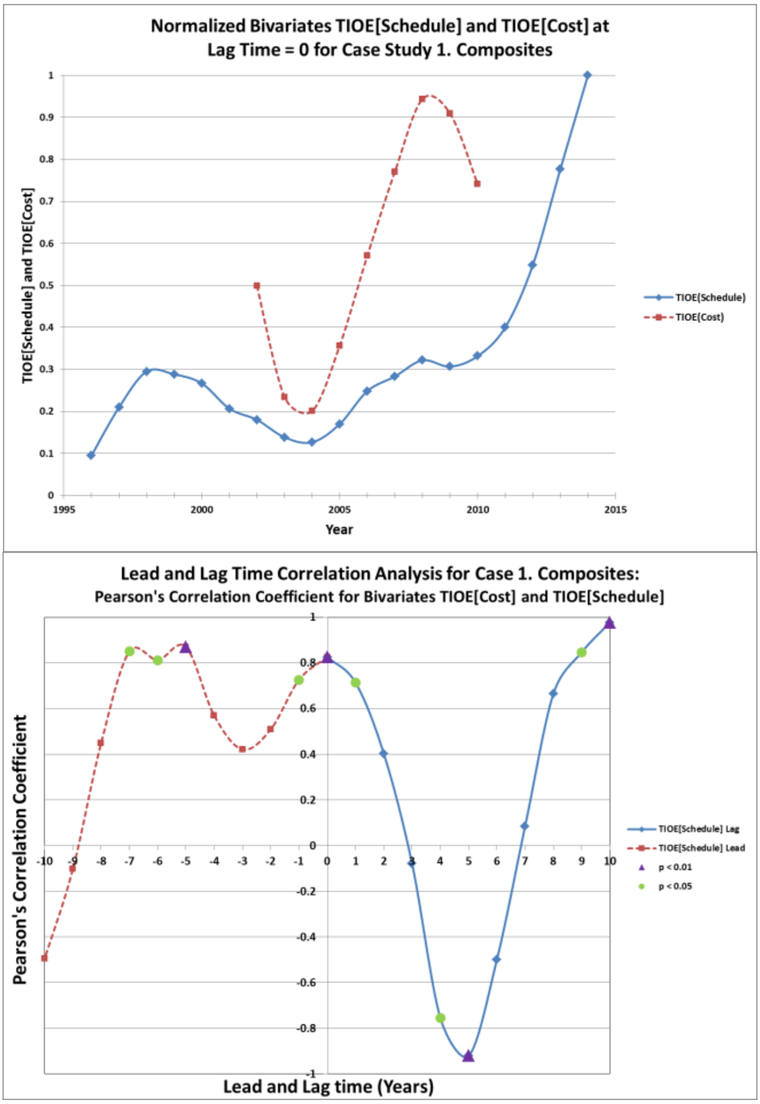


Figure 6A-2b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TIOE[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TIOE[Cost]

TIOE[Schedule] and TI[Schedule]

The results for TIOE[Schedule] and TI[Schedule] are shown in Figure 6A-3a and Figure 6A-3b. The most realistic is TI[Schedule] occurs about 7 years before TIOE[Schedule]. The plot shows a cyclic nature to this bivariate because of the nature of the airplane programs being considered in this data set. There are several different airplane derivatives of the same airplane model that are being ordered and delivered over a period of the observed ten years. Hence, as orders are being made with respect to a new airplane program containing new technology innovations such as composites, it is expected that about 7 years later, the airplane will be delivered.

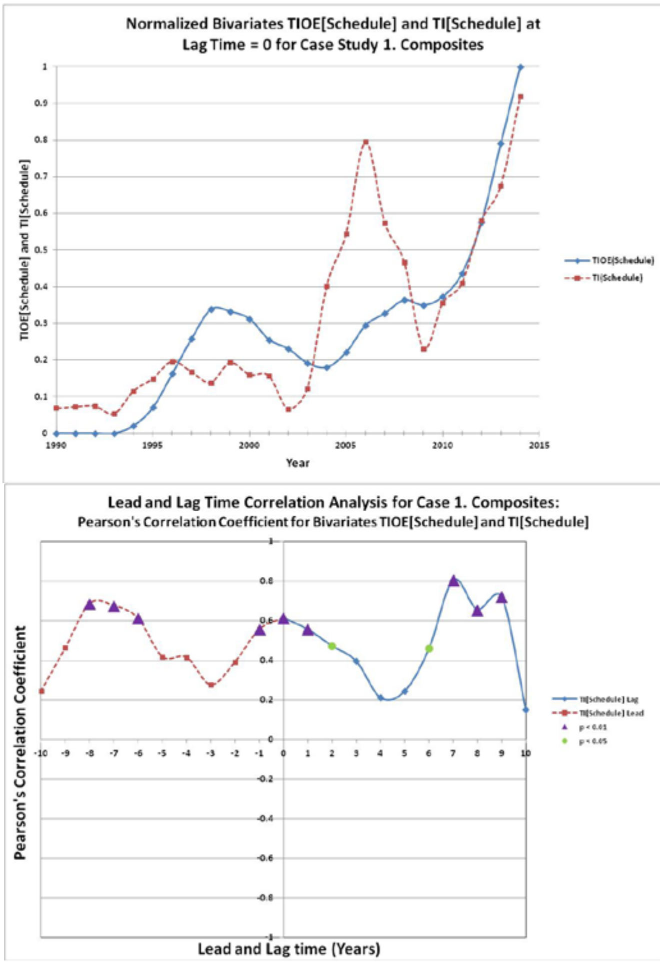


Figure 6A-3a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI[Schedule]

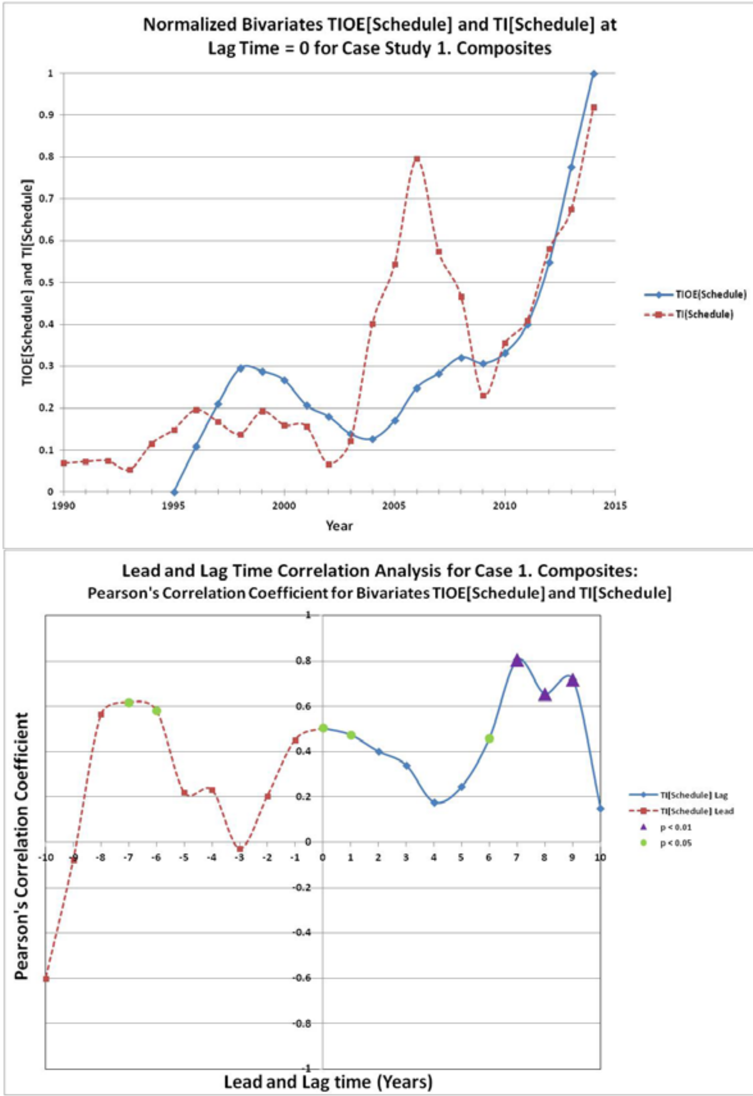


Figure 6A-3b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI[Schedule]

TIOE[Schedule] and TI[Guideline]

The results for TIOE[Schedule] and TI[Guideline] are shown in Figure 6A-4a and Figure 6A-4b. TIOE[Schedule] lags TI[Guideline] by 9 years. The variable TIOE[Schedule] contains data from two different airplane models. Hence, the uptake of deliveries for each airplane model may increase at different periods of time depending on the market need.

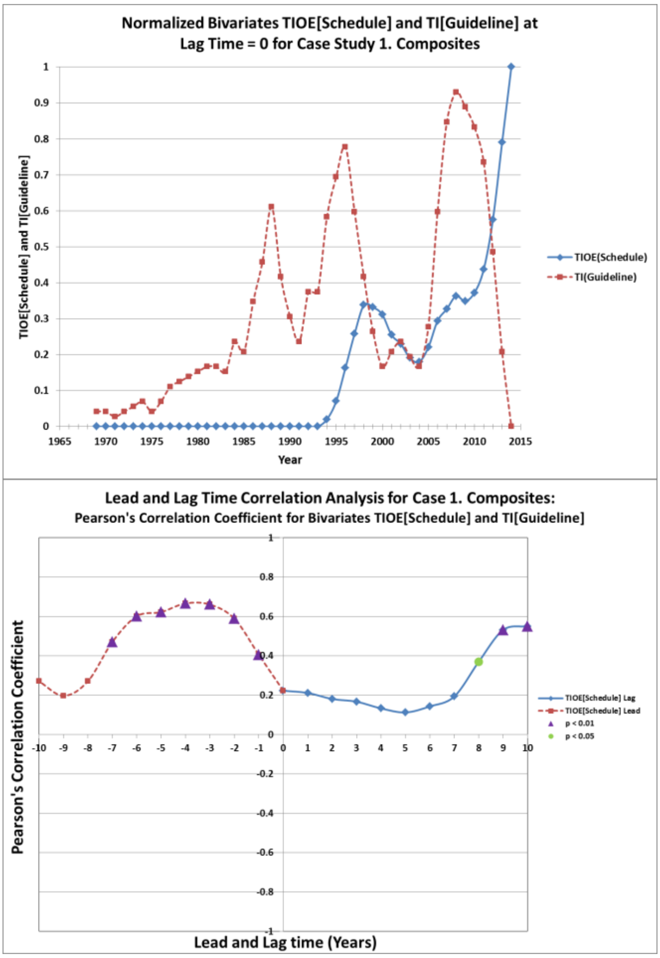


Figure 6A-4a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI[Guideline]

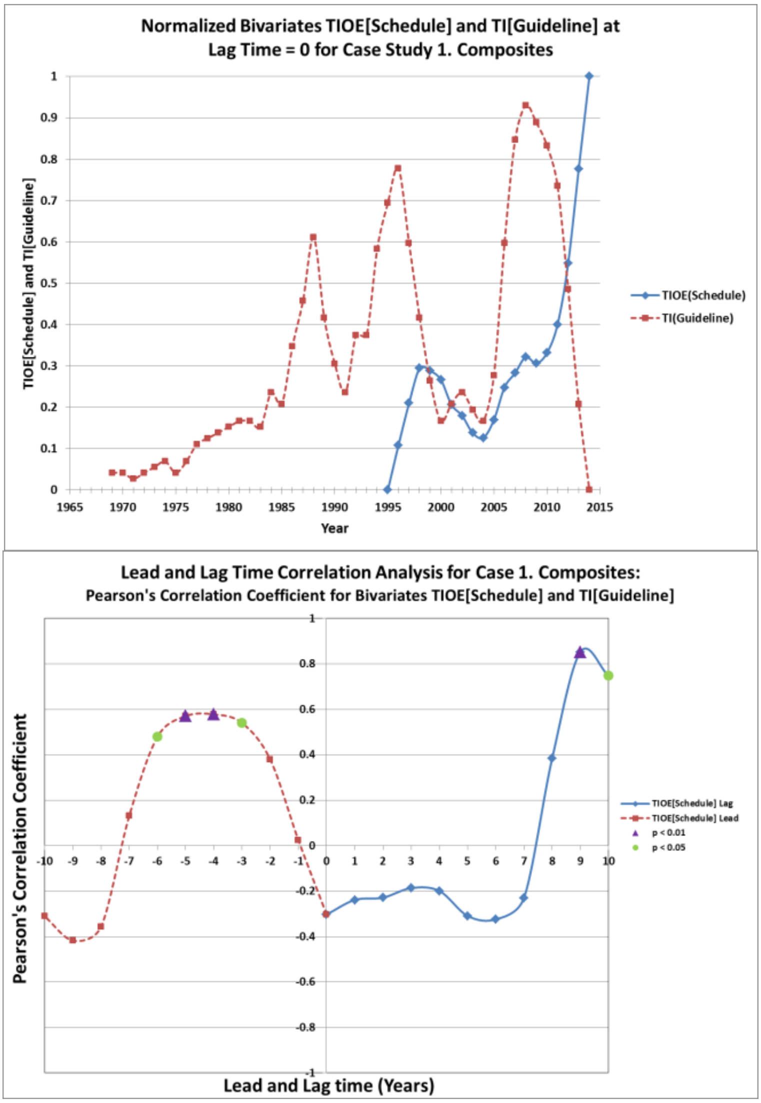


Figure 6A-4b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI[Guideline]

TIOE[Schedule] and TI/TR[Audience]

The results for TIOE[Schedule] and TI/TR[Audience] are shown in Figure 6A-5a and Figure 6A-5b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all of the audience included in this data set needed to take the training that is described in this research. In addition, the variable TIOE[Schedule] contains data from two different airplane models. Hence, the uptake of orders for each airplane model may increase at different periods of time depending on the market need.

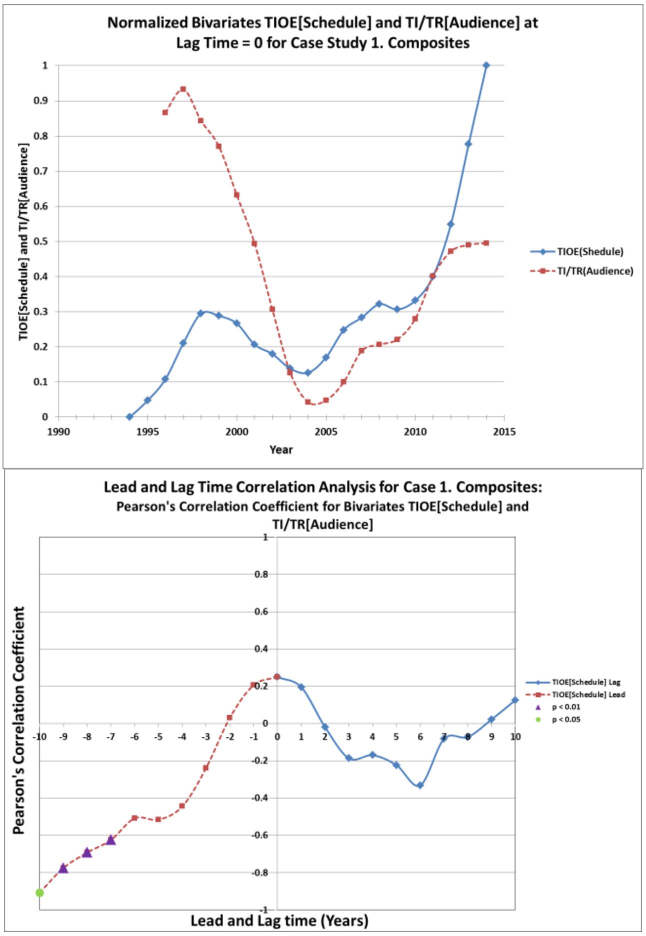


Figure 6A-5a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI/TR[Audience]

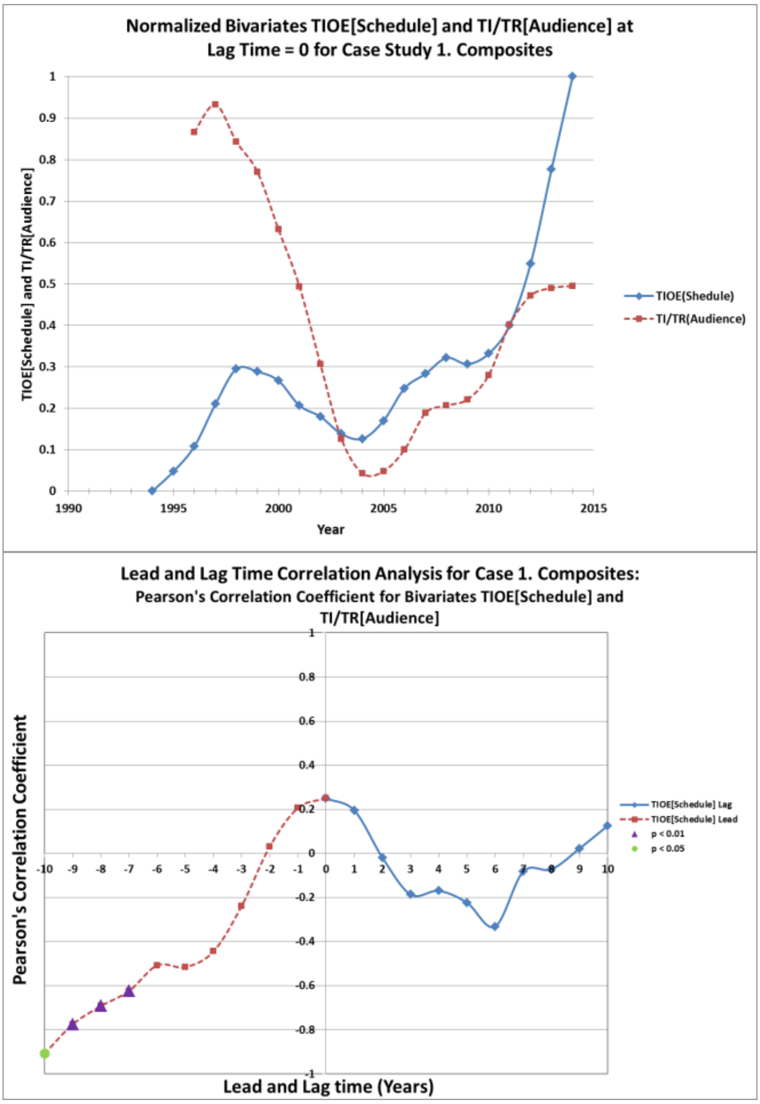


Figure 6A-5b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TI/TR[Audience]

TIOE[Schedule] and TR[Schedule]

The results for TIOE[Schedule] and TR[Cost] are shown in Figure 6A-6a and Figure 6A-6b. TIOE[Schedule] and TR[Schedule] show no significant correlation in the conservative. This may be due to the limited data set that was available at the time of this research. It is possible that there may be more data within the company that was not obtainable due to restrictions from organization to organization. In the un-conservative case, there is significant correlation when TIOE[Schedule] leads TR[Schedule] by 4 years. In the ideal world, the number of courses delivered per technology innovation per year should come before the number of deliveries per technology innovation per airplane per year. A company would want to have a trained workforce to work on the product. It is also possible that TR[Schedule] lags TIOE[Schedule] by 4 years due to funding challenges. For this case study, the company obtains money when an airplane is delivered.

What is shown in the un-conservative case tends to agree with what was mentioned in the interviews in Chapter 4. There have been mention of courses with composites could have been offered earlier.

The variable TIOE[Schedule] also contains data from two different airplane models. Hence, the uptake of deliveries for each airplane model may increase at different periods of time depending on the market need.

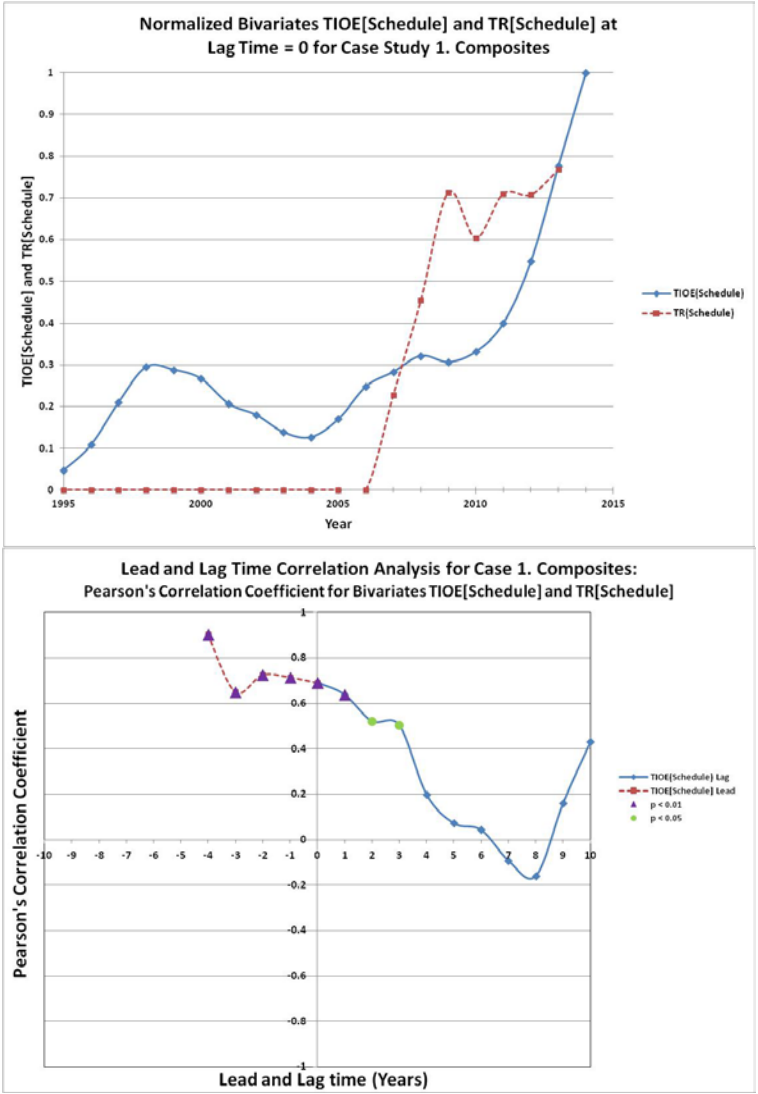


Figure 6A-6a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TR[Schedule]

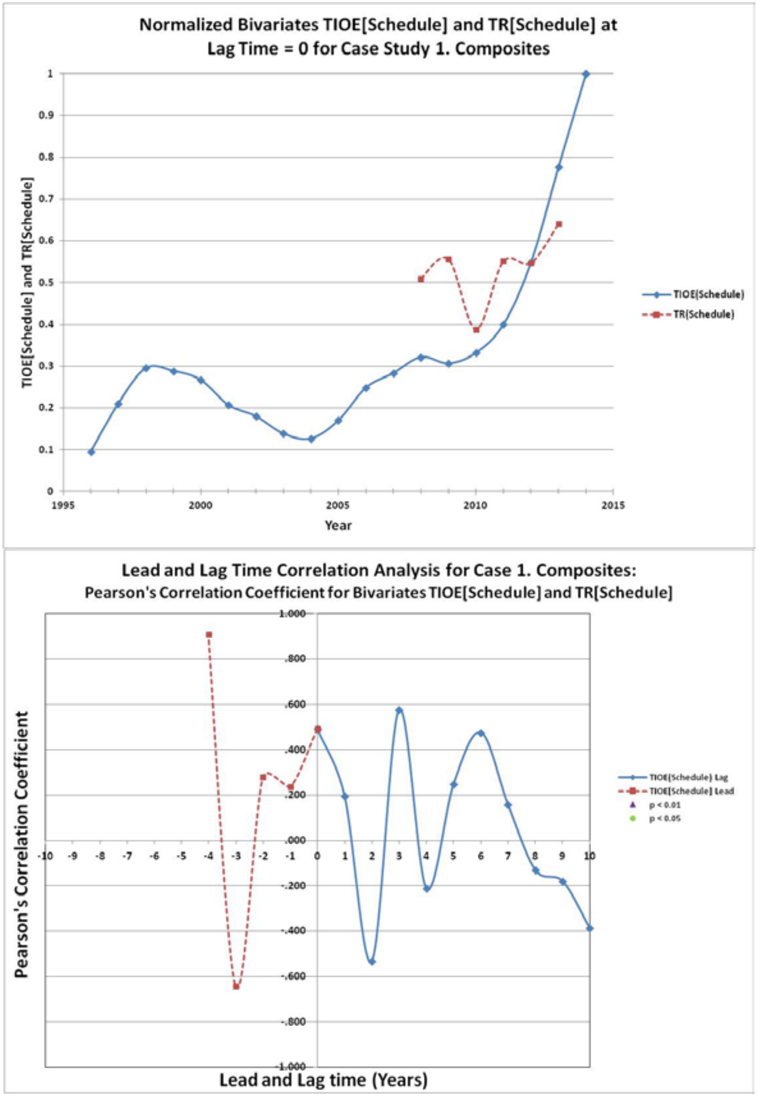


Figure 6A-6b. Comparison removing leading zeroes between normalized bivariates TIOE[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TR[Schedule]

TIOE[Schedule] and TR[Cost]

The results for TIOE[Schedule] and TR[Cost] are shown in Figure 6A-7a and Figure 6A-7b. TIOE[Schedule] and TR[Cost] show no significant correlation in the conservative case. This may be due to the limited data set that was available at the time of this research. It is possible that there may be more data within the company that was not obtainable due to restrictions from organization to organization. In the un-conservative case, there is significant correlation when TIOE[Schedule] leads TR[Cost] by 1-4 years. In the ideal world, the number of student hours completing courses per technology innovation per year should come before the number of deliveries per technology innovation per airplane per year. A company would want to have a trained workforce to work on the product. It is also possible that TR[Cost] lags TIOE[Schedule] by 4 years due to funding challenges. For this case study, the company obtains money when an airplane is delivered.

What is shown in the un-conservative case tends to agree with what was mentioned in the interviews in Chapter 4. There have been mention of courses with composites could have been offered earlier.

The variable TIOE[Schedule] contains data from two different airplane models. Hence, the uptake of orders for each airplane model may increase at different periods of time depending on the market need.

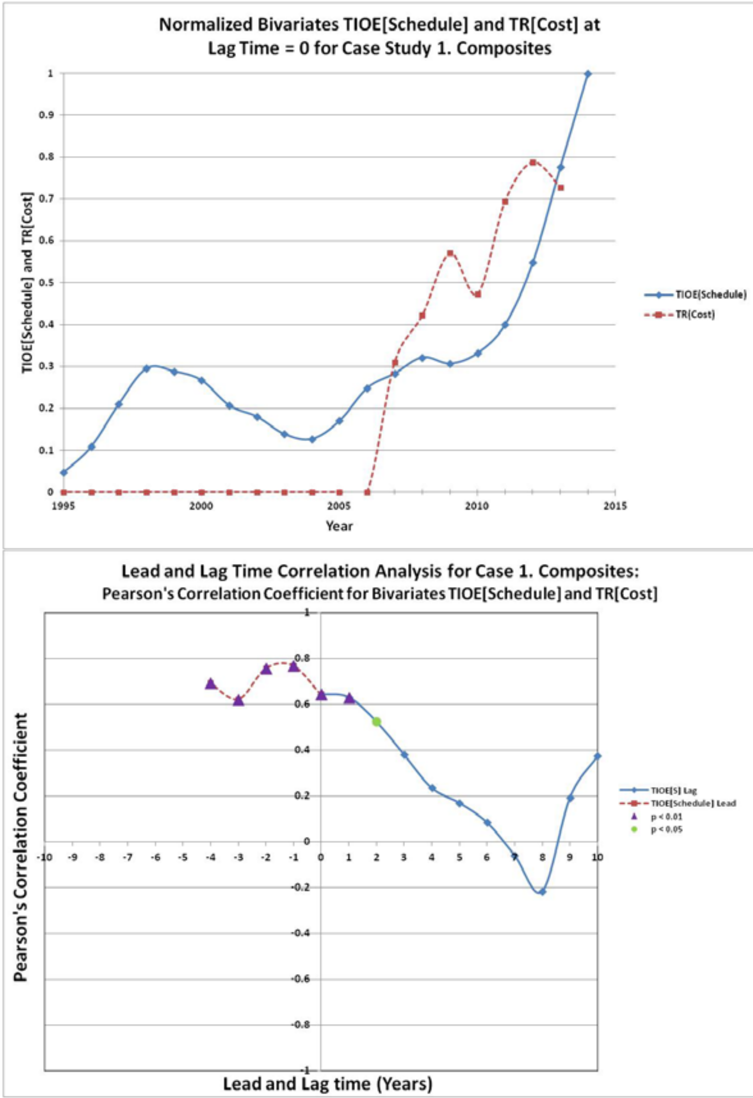
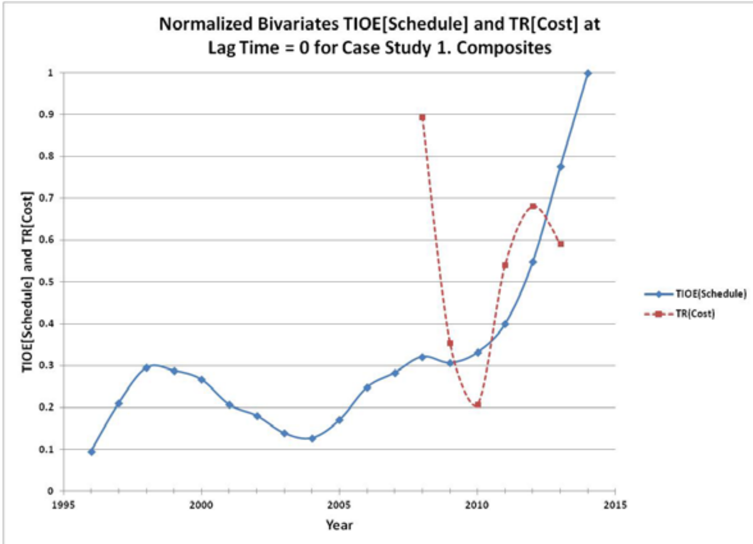


Figure 6A-7a. Comparison using leading zeroes between normalized bivariates TIOE[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Schedule] and TR[Cost]



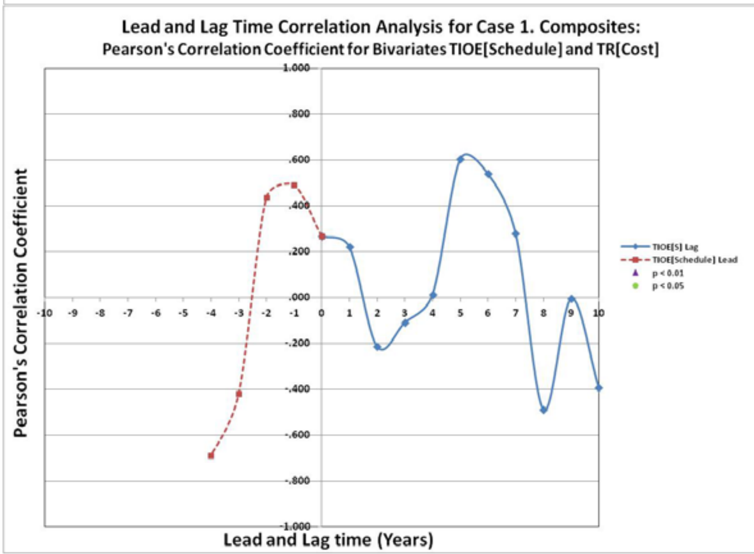


Figure 6A-7b. Comparison removing leading zeroes between normalized bivariates TIOE*[Schedule] and* TR*[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates* TIOE*[Schedule] and* TR*[Cost]*

TIOE[Guideline] and TIOE[Cost]

The results for TIOE[Guideline] and TIOE[Cost] are shown in Figure 6A-8a and Figure 6A-8b. The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

It is common sense that the uptake of TIOE[Guideline] and TIOE[Cost] do not have a lag. As a technology innovation is being heavily invested in, the organizations have funds to direct towards the resources necessary to develop the memo documents per technology innovation per year. As the funding becomes less, the number of resources to develop memos should decline as well. This can be seen in Figure 6A-8b when observing the trends for the normalized data values between the bivariate.

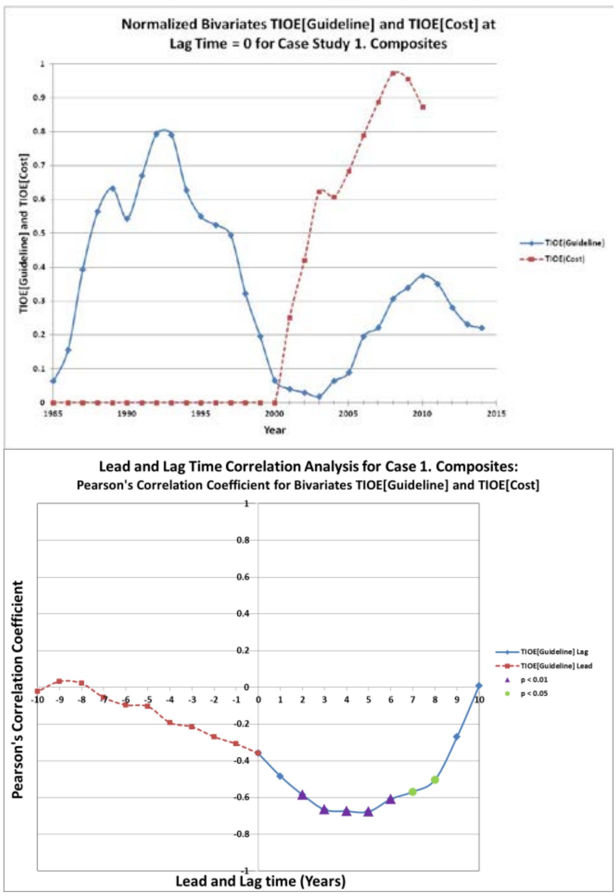


Figure 6A-8a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TIOE[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TIOE[Cost]

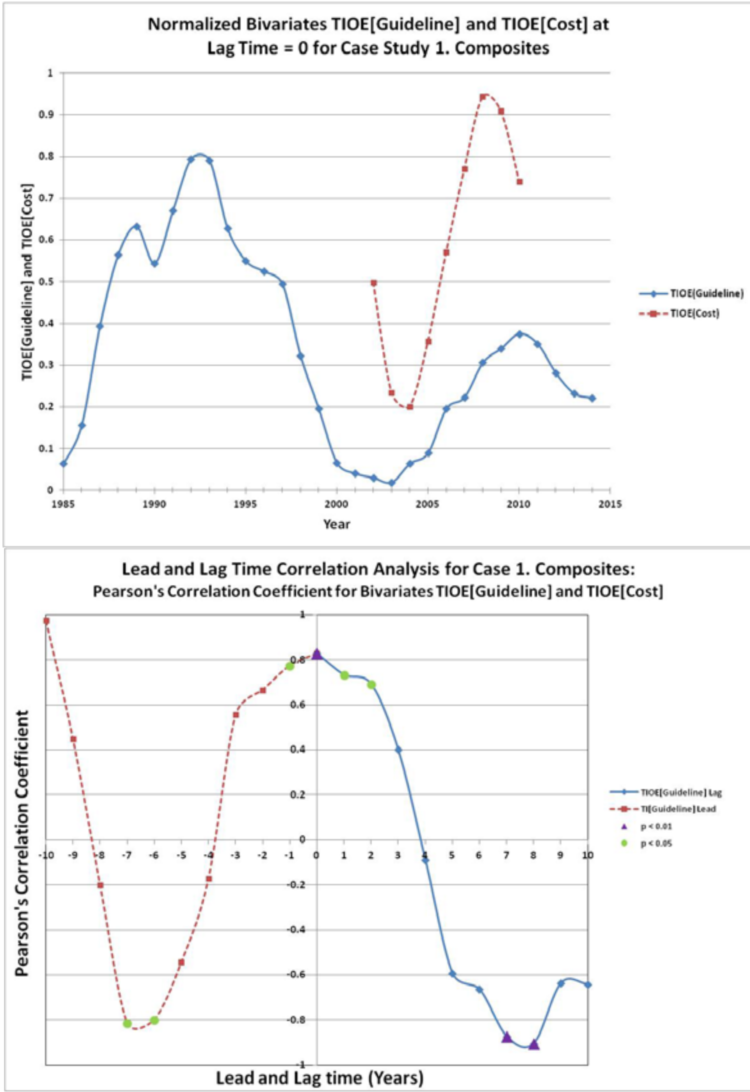


Figure 6A-8b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TIOE[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TIOE[Cost]

TIOE[Guideline] and TI[Schedule]

The results for TIOE[Guideline] and TI[Schedule] are shown in Figure 6A-9a and Figure 6A-9b. TIOE[Guideline] lags TI[Schedule] between 1-5 years inversely. As there is an uptake in the number of orders, the number of memos being developed for the technology innovation decreases. This is unexpected because as the orders are being made for an airplane program containing the new technology innovation, the memos should be developed shortly thereafter. It would be expected that as another airplane program begins again, especially investing in a new technology innovation, the number of memos would be expected to rise. The discrepancy may be due to the data used for TI[Schedule] and TIOE[Guideline] contains both airplane programs.

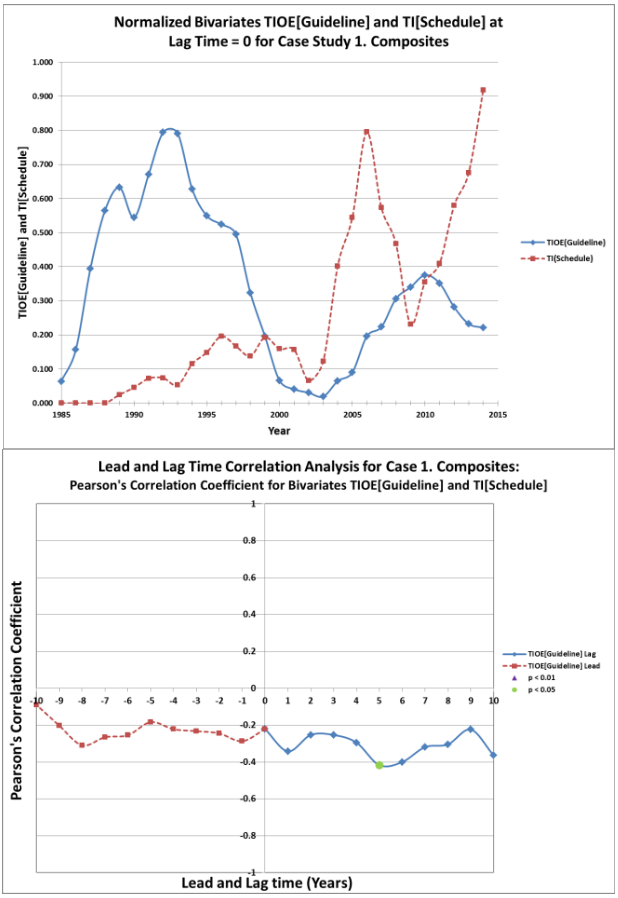


Figure 6A-9a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI[Schedule]

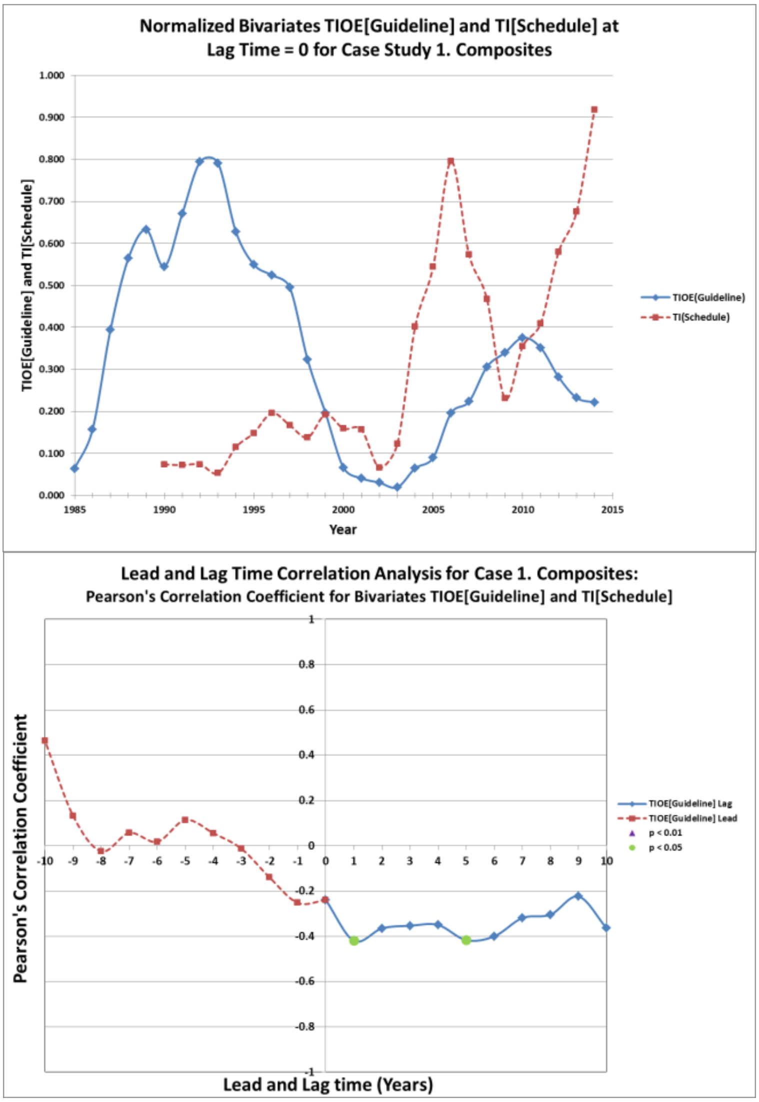


Figure 6A-9b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI[Schedule]

TIOE[Guideline] and TI[Guideline]

The results for TIOE[Guideline] and TI[Guideline] are shown in Figure 6A-10a and Figure 6A-10b. TI[Guideline] leads TIOE[Guideline] inversely by about 8 years in the conservative case, as shown in Figure 6A-10b. It is expected that as the SMEs supporting the development of patents increases, the number of memo documents decreases because the resource is not available to develop the memos. It is also expected that the development of patents occurs prior to memos being developed, as patents can be developed while the technology innovation is still not mature. Memos are only developed when the technology innovation is fully mature.

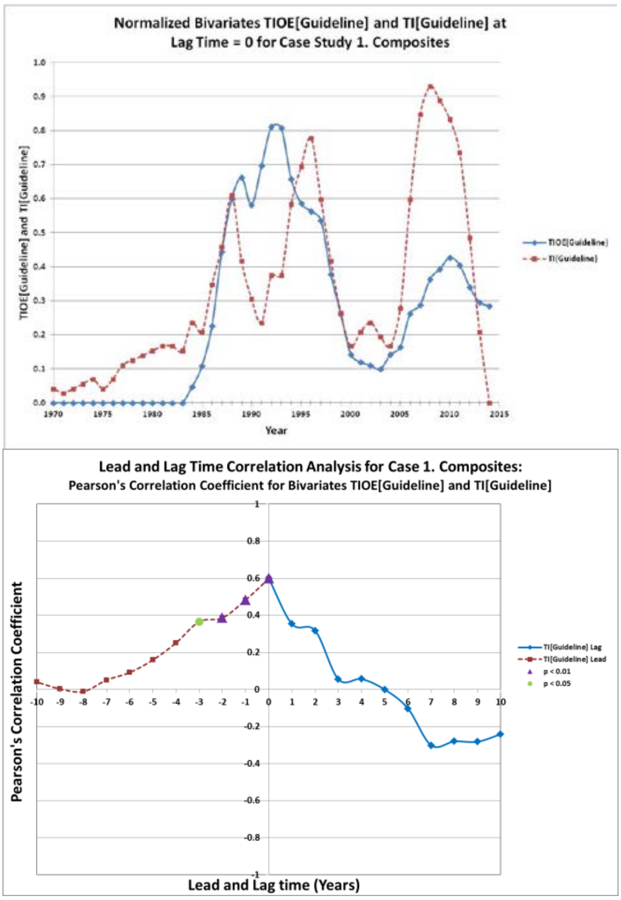


Figure 6A-10a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI[Guideline]

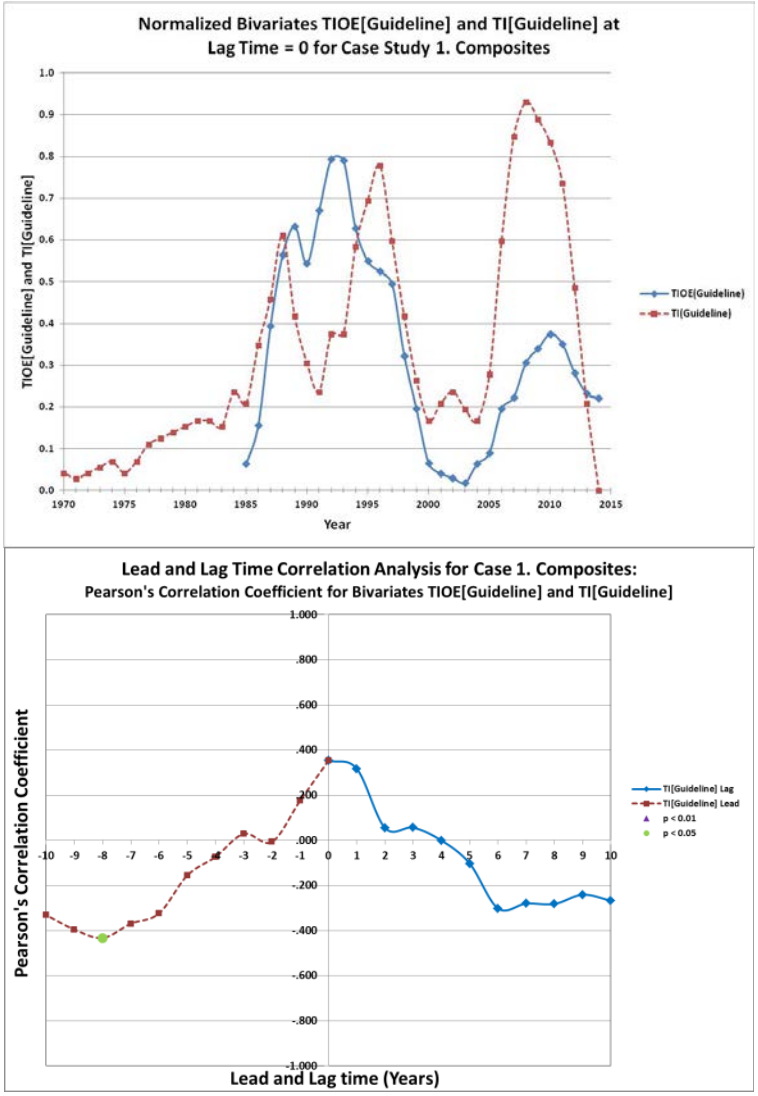


Figure 6A-10b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI[Guideline]

TIOE[Guideline] and TI/TR[Audience]

The results for TIOE[Guideline] and TI/TR[Audience] are shown in Figure 6A-11a and Figure 6A-11b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. However, if the data set were complete, it would be expected that as the number of memos are completed, that the number of engineers would decrease as resources are reassigned to other projects. It is also expected that the employment numbers increase before the number of memos are published as the development of memos need resources to be developed.

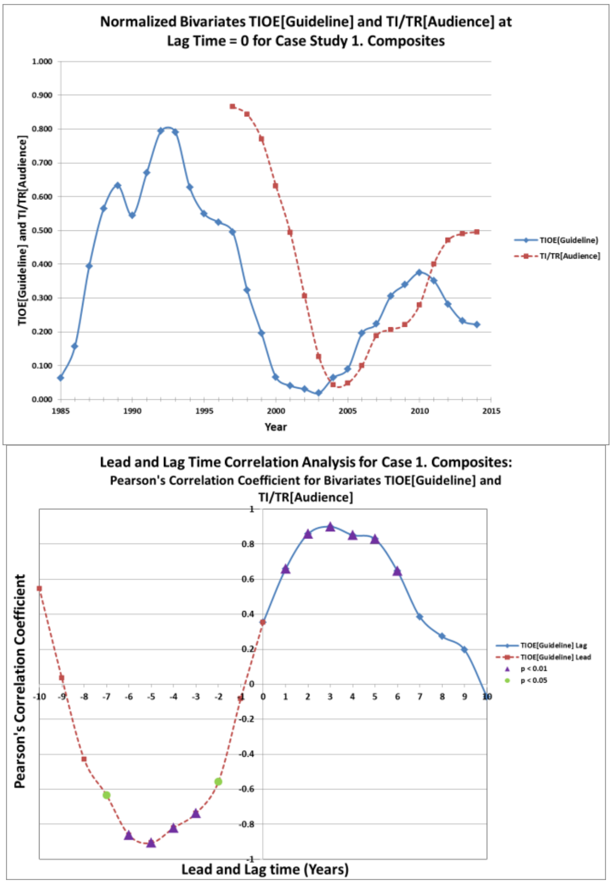


Figure 6A-11a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI/TR[Audience]

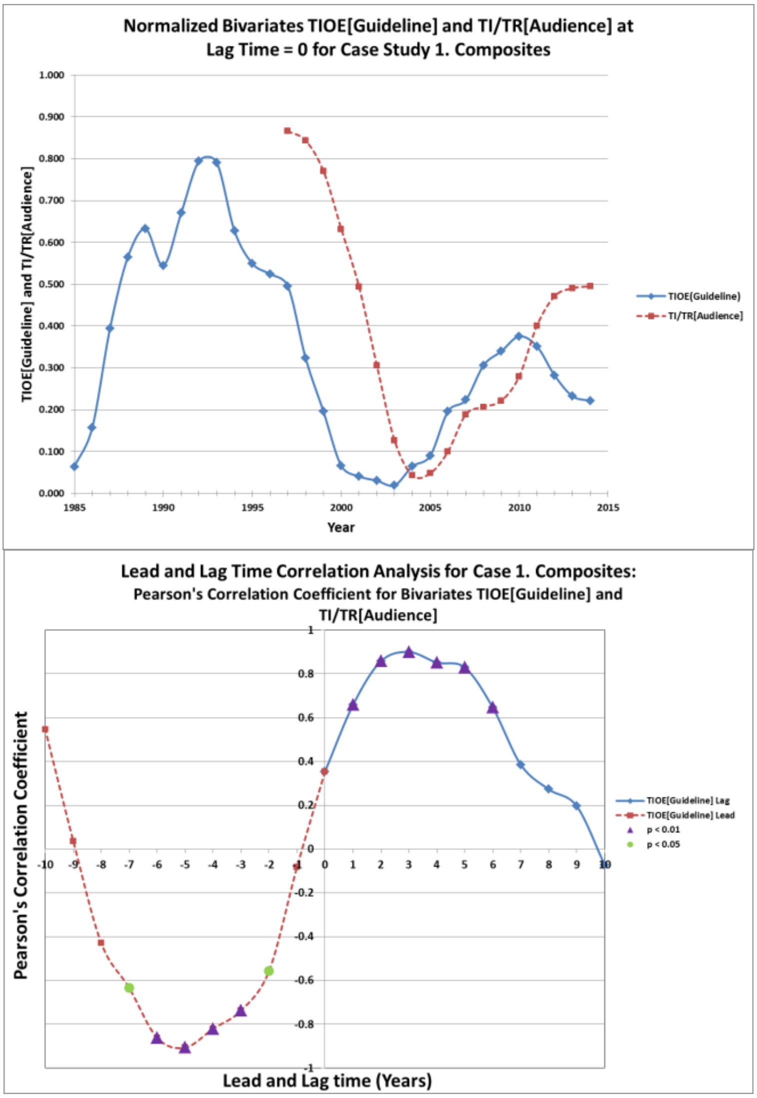


Figure 6A-11b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TI/TR[Audience]

TIOE[Guideline] and TR[Schedule]

The results for TIOE[Guideline] and TR[Schedule] is shown in Figure 6A-12a and Figure 6A-12b. From a conservative point, there are no significant correlation between these two variables. This may be due to the limited number of data available for TR[Schedule].

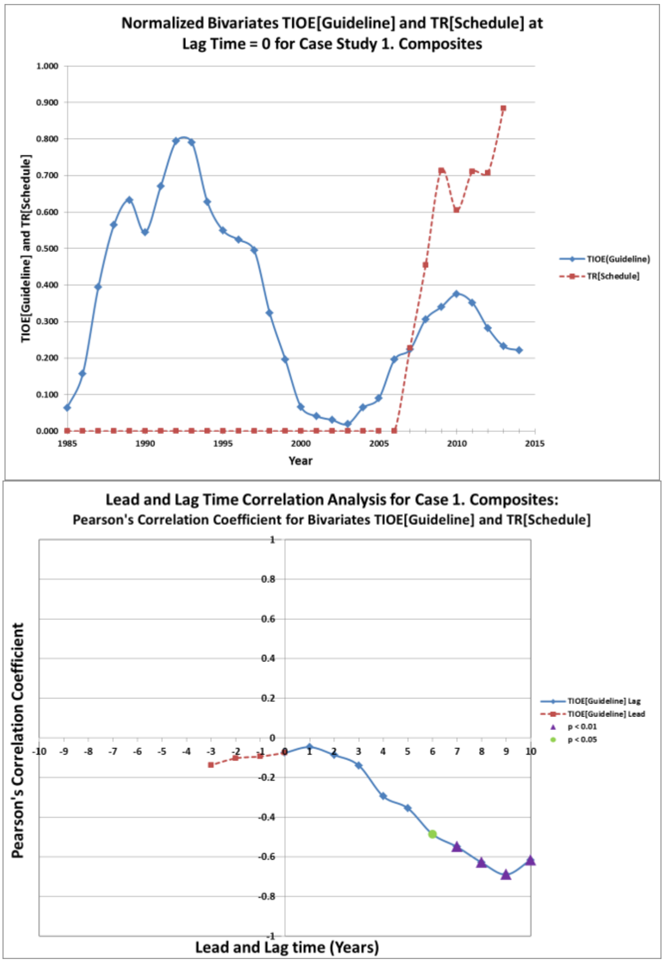


Figure 6A-12a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TR[Schedule]

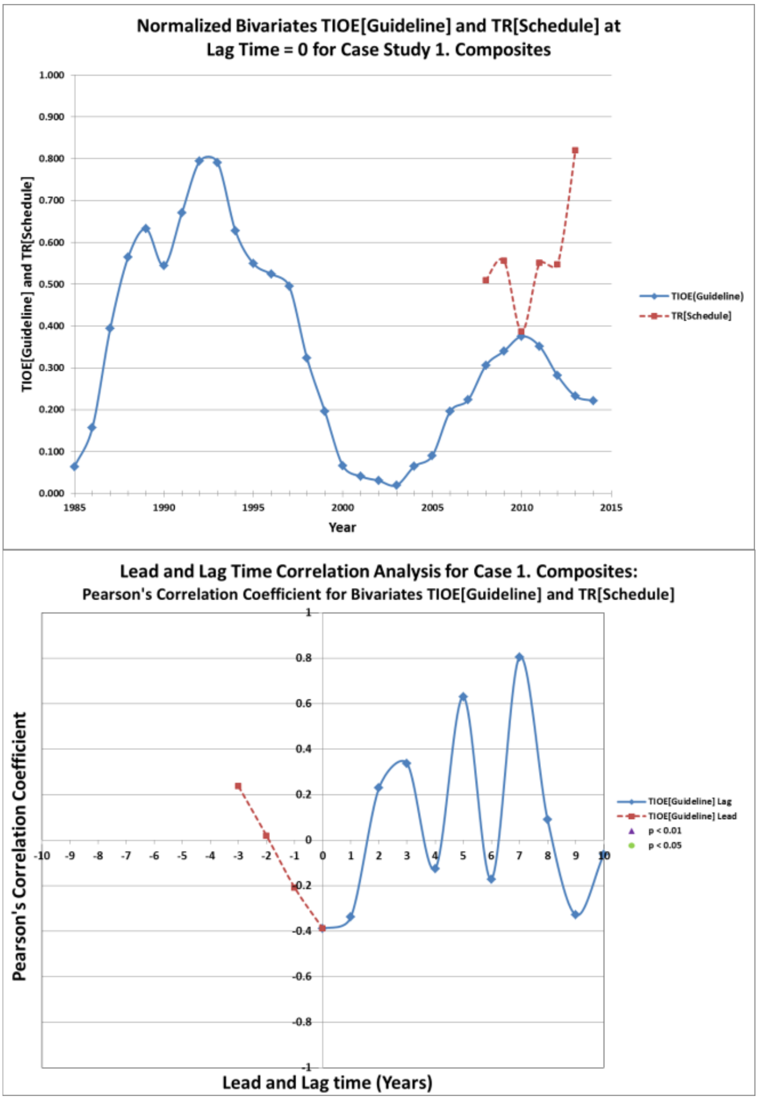


Figure 6A-12b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TR[Schedule]

TIOE[Guideline] and TR[Cost]

The results for TIOE[Guideline] and TR[Cost] is shown in Figure 6A-13a and Figure 6A-13b. From a conservative point, there are no significant correlation between these two variables. This may be due to the limited number of data available for TR[Cost].

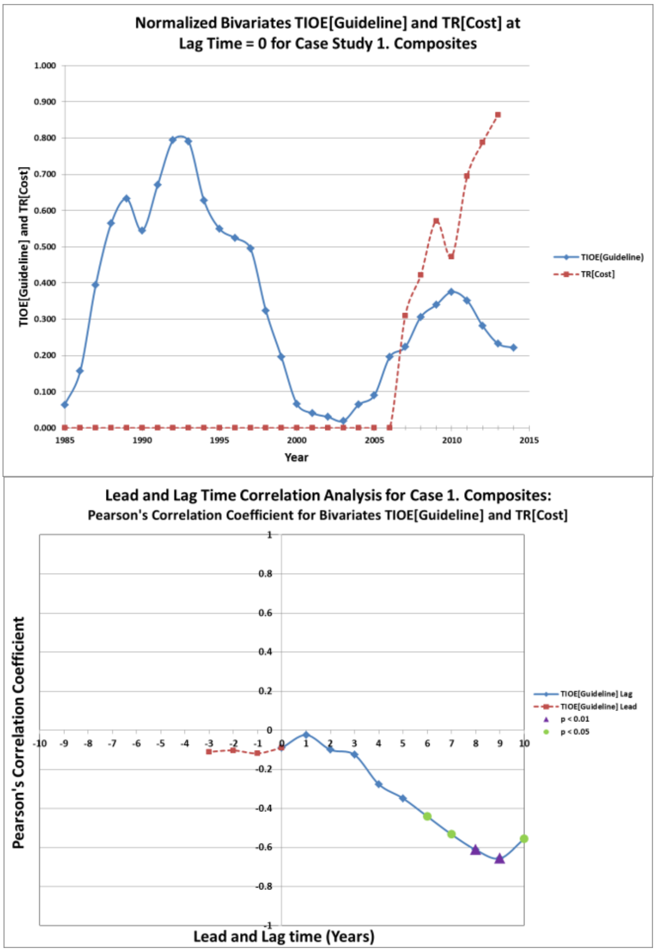


Figure 6A-13a. Comparison using leading zeroes between normalized bivariates TIOE[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TR[Cost]

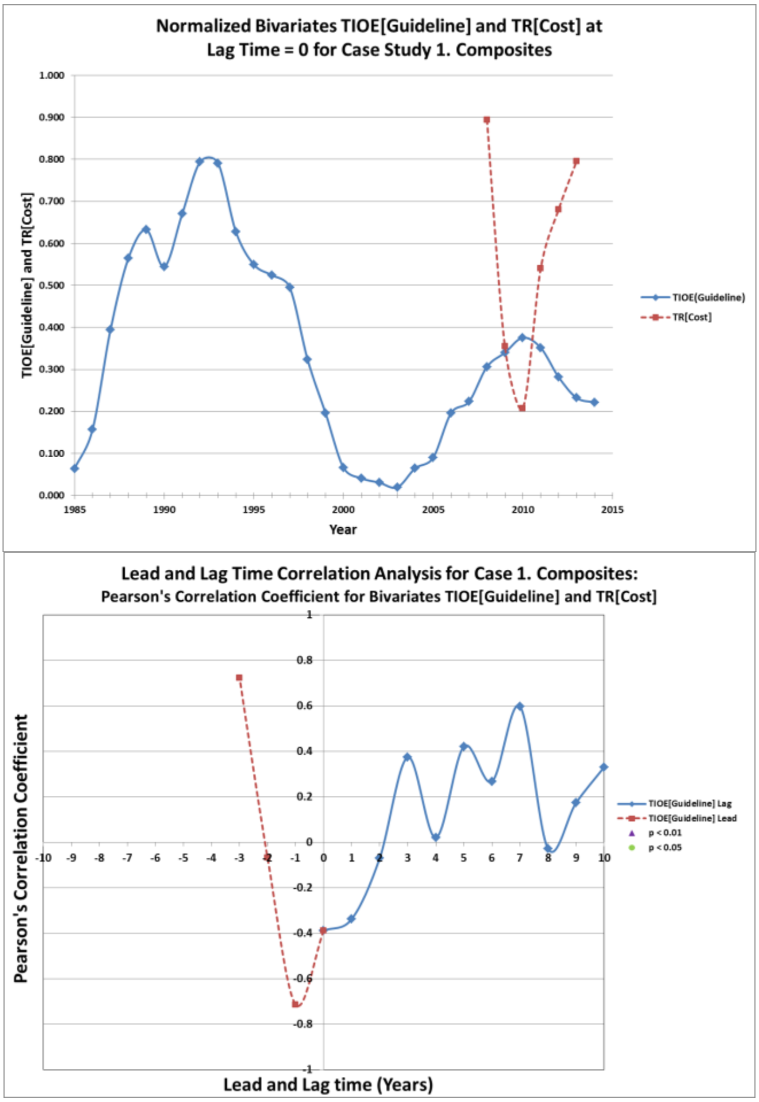


Figure 6A-13b. Comparison removing leading zeroes between normalized bivariates TIOE[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Guideline] and TR[Cost]

TIOE[Cost] and TI[Schedule]

The results for TIOE[Cost] and TI[Schedule] are shown in Figure 6A-14a and Figure 6A-14b in Appendix A. TIOE[Cost] leads TI[Schedule] by about 2 years. It is expected that investments in the product occurs before the number of orders are made, as the technology innovation often times are used as a selling point for the airplane. In reality, a company tends to invest in the next new technology innovation to be competitive with competing companies. Once there is some promise shown in a technology innovation, the company will then begin selling the possibilities and competitive advantage that the new technology innovation brings to the customers. The company will then aim to gain orders from customers.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

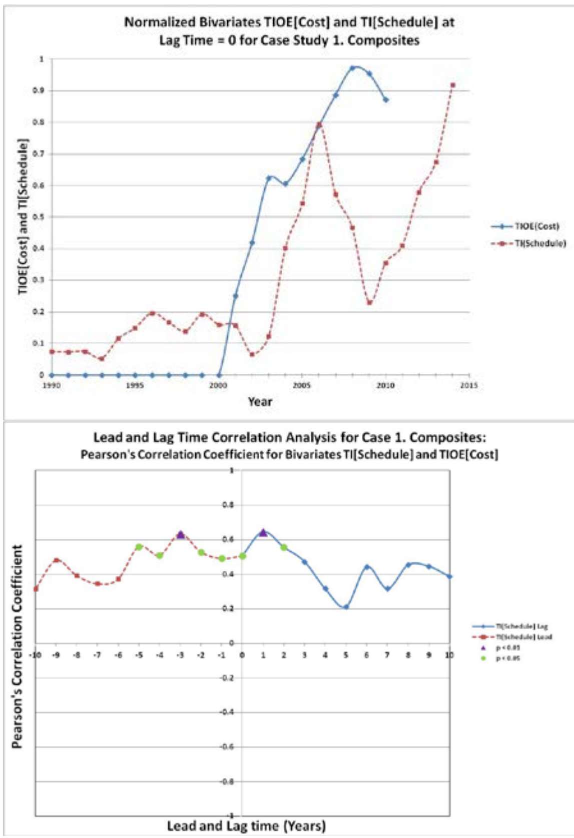


Figure 6A-14a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Schedule]

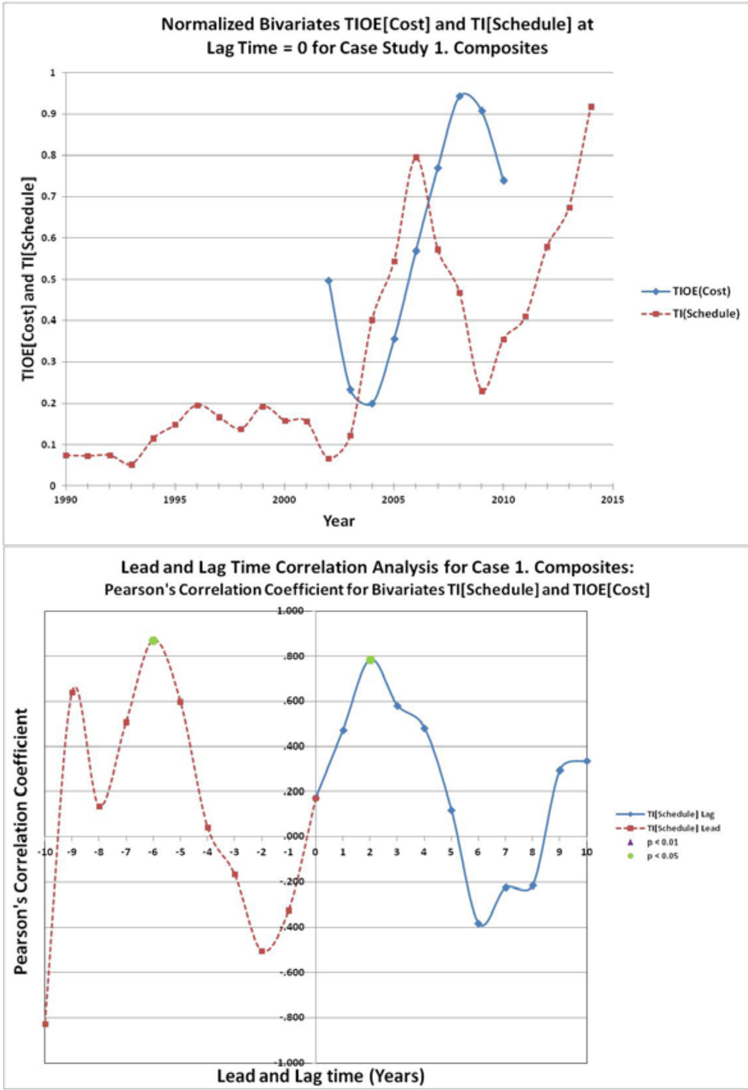


Figure 6A-14b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Schedule]

TI[Guideline] and TIOE[Cost]

The results for TI[Guideline] and TIOE[Cost] are shown in Figure 6A-15a and Figure 6A-15b. It is expected that there be no lag between these two variables. As there is an uptake in investment in a technology innovation, the funding would be available for resources to research, develop and file for patents for a technology innovation. Hence, an uptake in TI[Guideline] would be expected at the same time as during an uptake for TIOE[Cost].

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

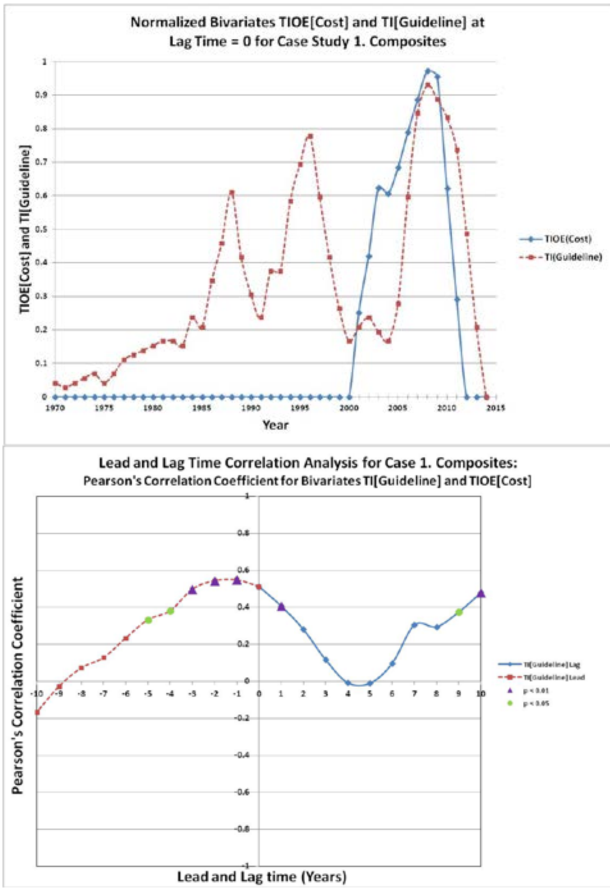


Figure 6A-15a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Guideline]

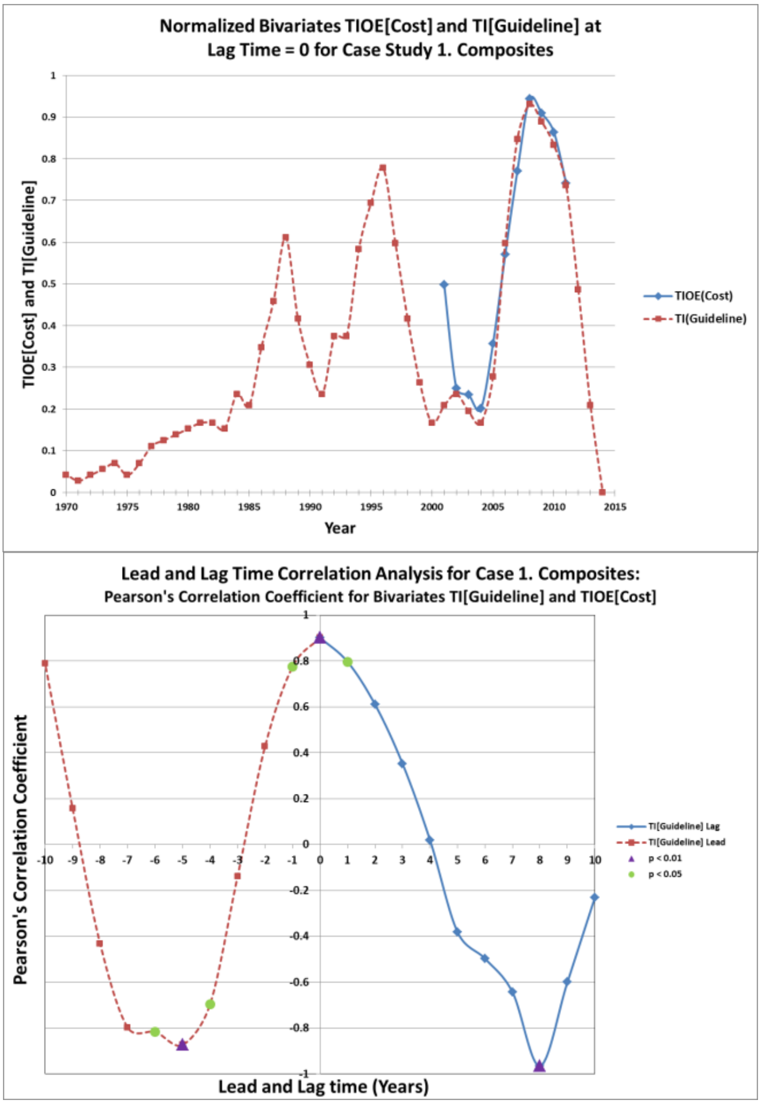


Figure 6A-15b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Guideline]

TIOE[Cost] and TI/TR[Audience]

The results for TIOE[Cost] and TI/TR[Audience] are shown in Figure 6A-16a and Figure 6A-16b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. If the exact data needed for TI/TR[Audience] was available, the expected result would be for the number of employees to uptake around the same time as the investment in product per technology innovation. Once there is funding for the technology innovation, the funding is allocated to however many resources as needed to work with the technology innovation. In the conservative case, there is a significant correlation that supports this expectation.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

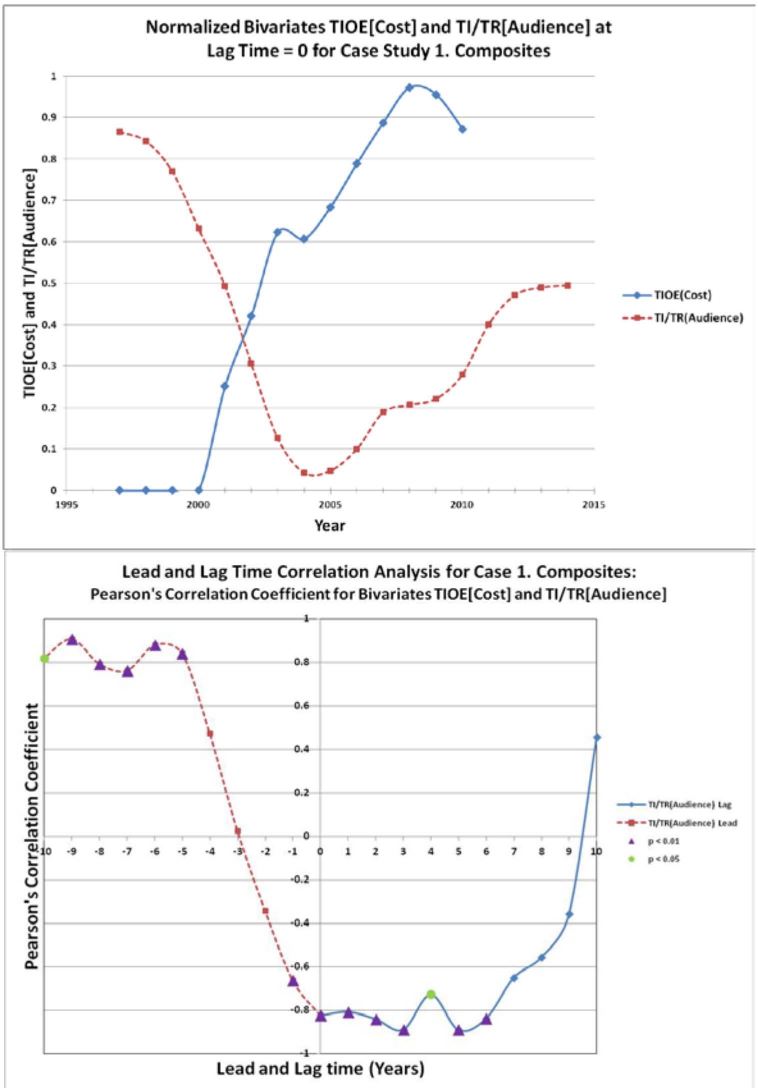


Figure 6A-16a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI/TR[Audience]

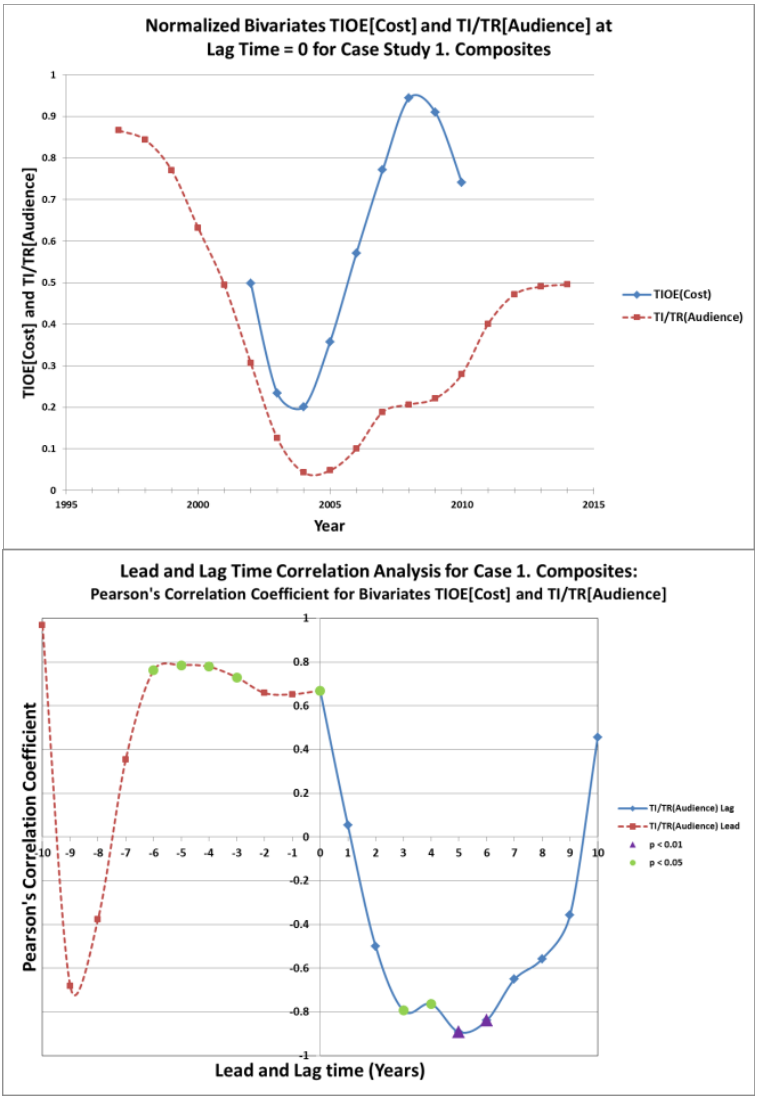


Figure 6A-16b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI/TR[Audience]

TIOE[Cost] and TR[Schedule]

The results for TIOE[Cost] and TR[Schedule] are shown in Figure 6A-17a and Figure 6A-17b. There is almost a perfect correlation between these two variables.

As the data set for TR[Schedule] was limited between each organization, the interpretation of these results may not provide an accurate account for the rest of the company. It may also be that what is seen here may suggest an improvement in when to offer training that is needed to be considered for this organization. It would be expected that as investment in the technology innovation has an uptake, there should be a positive uptake in the number of course hours corresponding to the technology innovation shortly thereafter.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.

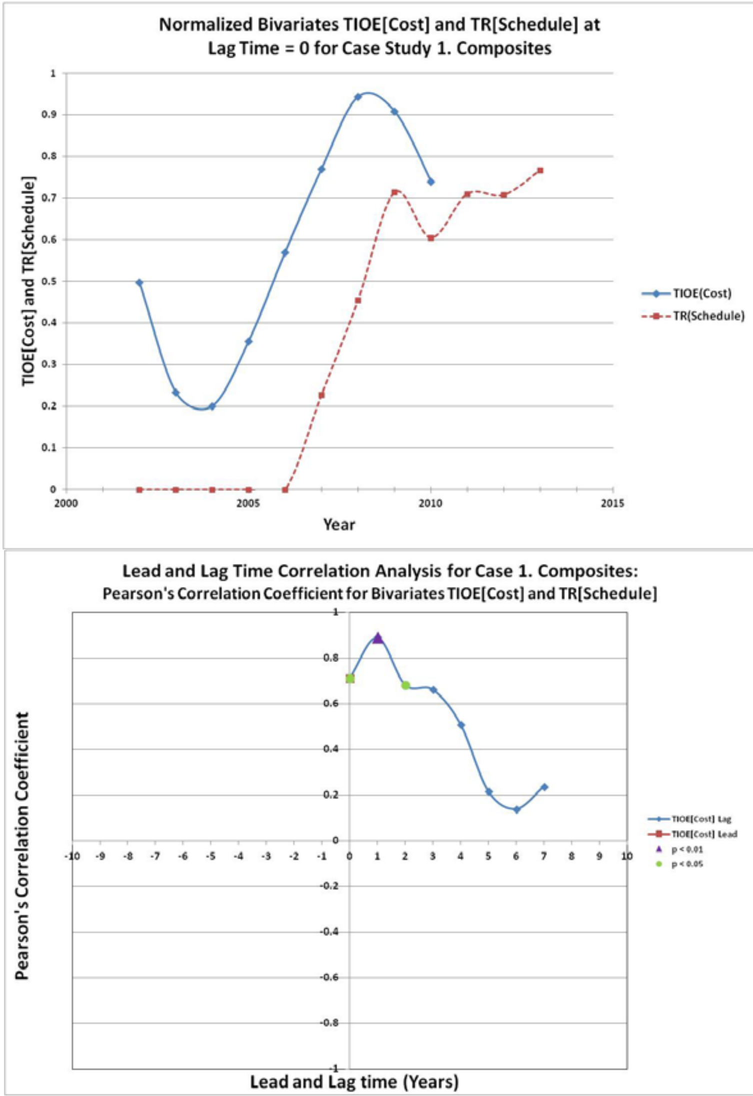


Figure 6A-17a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Schedule]

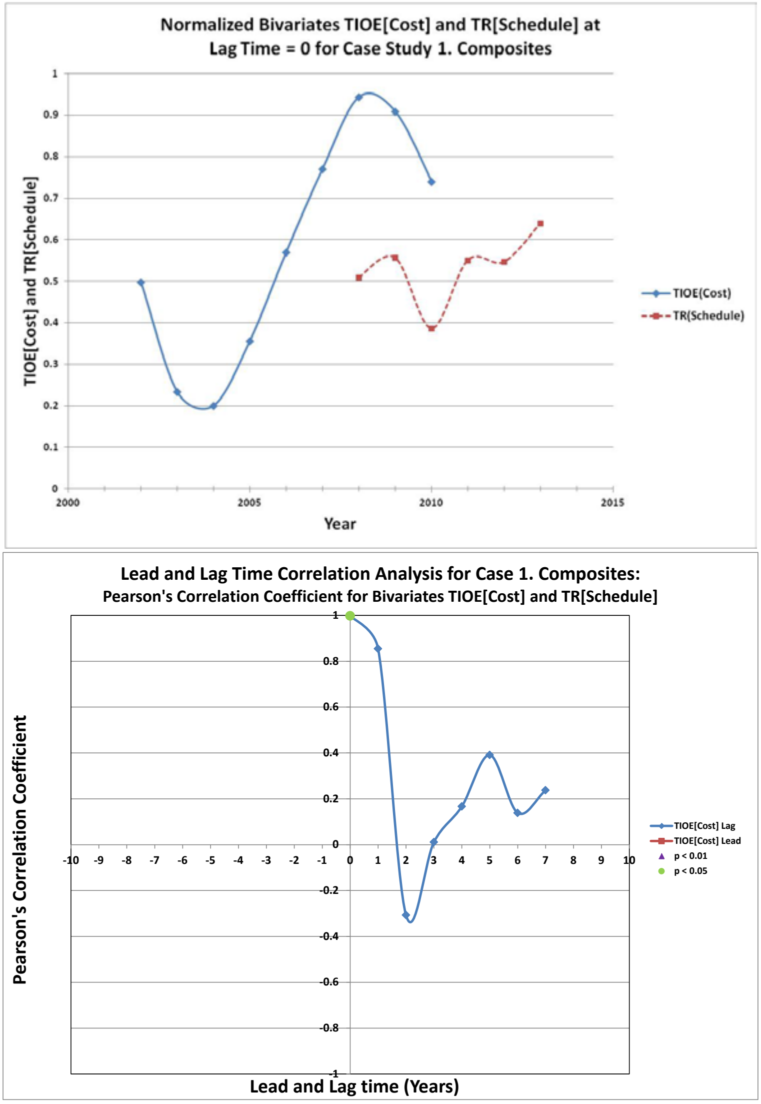


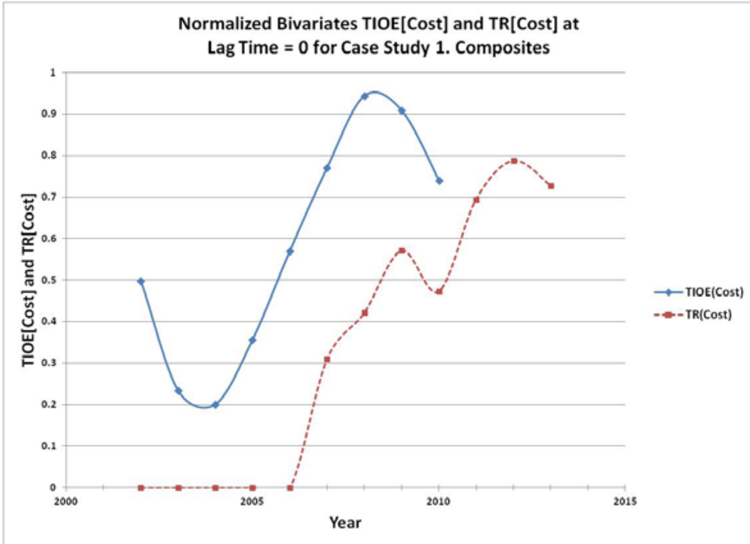
Figure 6A-17b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Schedule]

TIOE[Cost] and TR[Cost]

The results for TIOE[Cost] and TR[Cost] are shown in Figure 6A-18a and Figure 6A-18b in Appendix A. There are no significant correlations for this bivariate.

As the data set for TR[Cost] was limited between each organization, the interpretation of these results may not provide an accurate account for the rest of the company. It may also be that what is seen here may suggest an improvement in when to offer training that is needed to be considered for this organization. It would be expected that as investment in the technology innovation has an uptake, there should be a positive uptake in the number of course hours corresponding to the technology innovation shortly thereafter. A negative correlation is not expected in this case.

The data obtained for TIOE[Cost] was limited by the organization as this information is sensitive within each organization. Therefore, the results using TIOE[Cost] within the scope of this research is considered carefully.



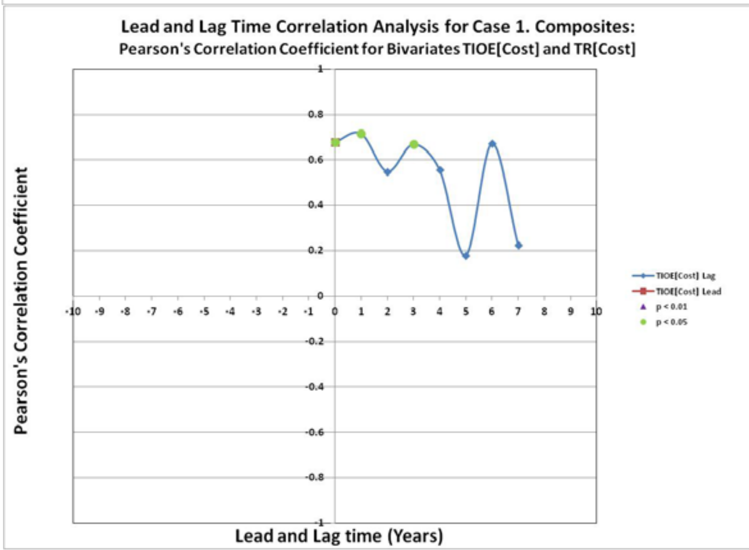


Figure 6A-18a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Cost]

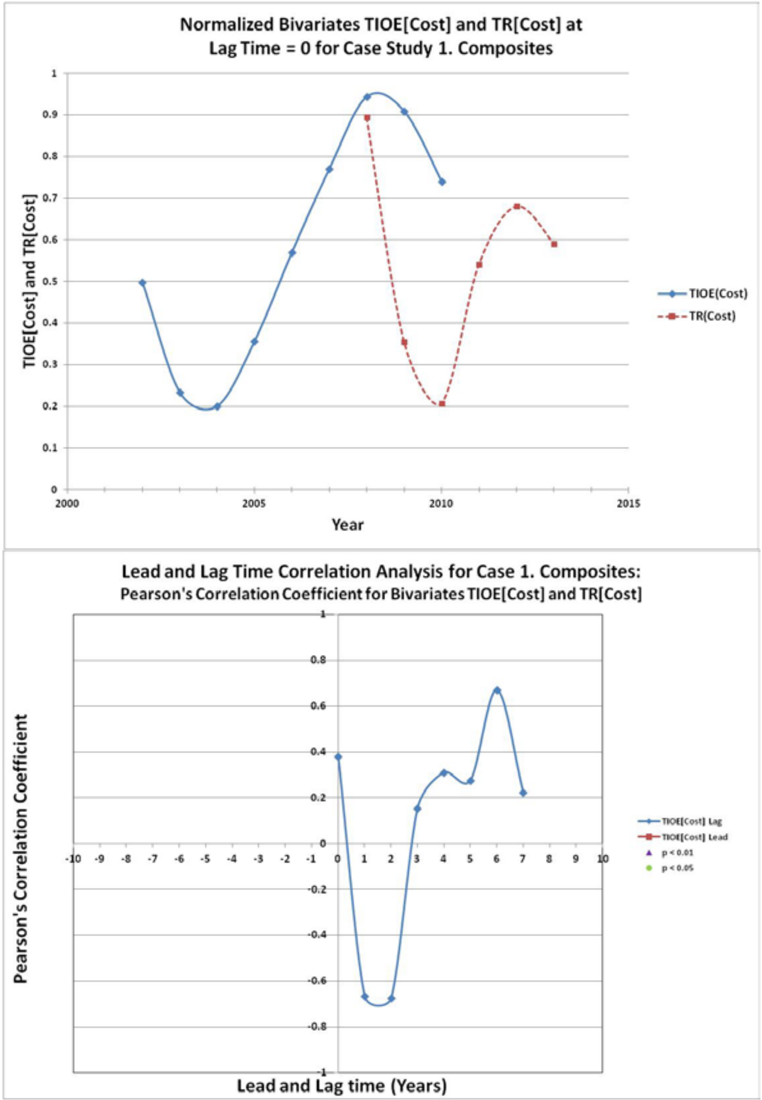


Figure 6A-18b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Cost]

TI[Schedule] and TI[Guideline]

The results for TI[Schedule] and TI[Guideline] are shown in Figure 6A-19a and Figure 6A-19b. TI[Guideline] leads TI[Schedule] by 2 years in the un-conservative case. It is concurrent with industry that the number of patents filed occurs before the airplane is ordered initially. Then patents continue to be filed after the airplane is being ordered, which helps explain why it may appear later that TI[Guideline] lags TI[Schedule]. It may also be possible that because TI[Schedule] contains data for two airplane programs, the timeline for the patents filed may reflect the type of airplane depending on how much the technology innovation is being used. This variability may be a reason for the lower correlation values. In the conservative case, there is no significant correlation between these two variables.

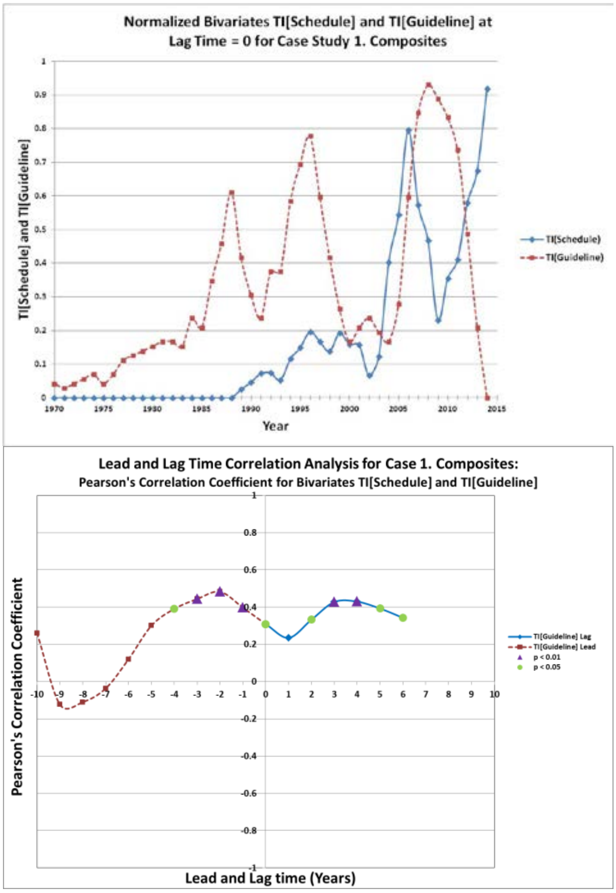


Figure 6A-19a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI[Guideline]

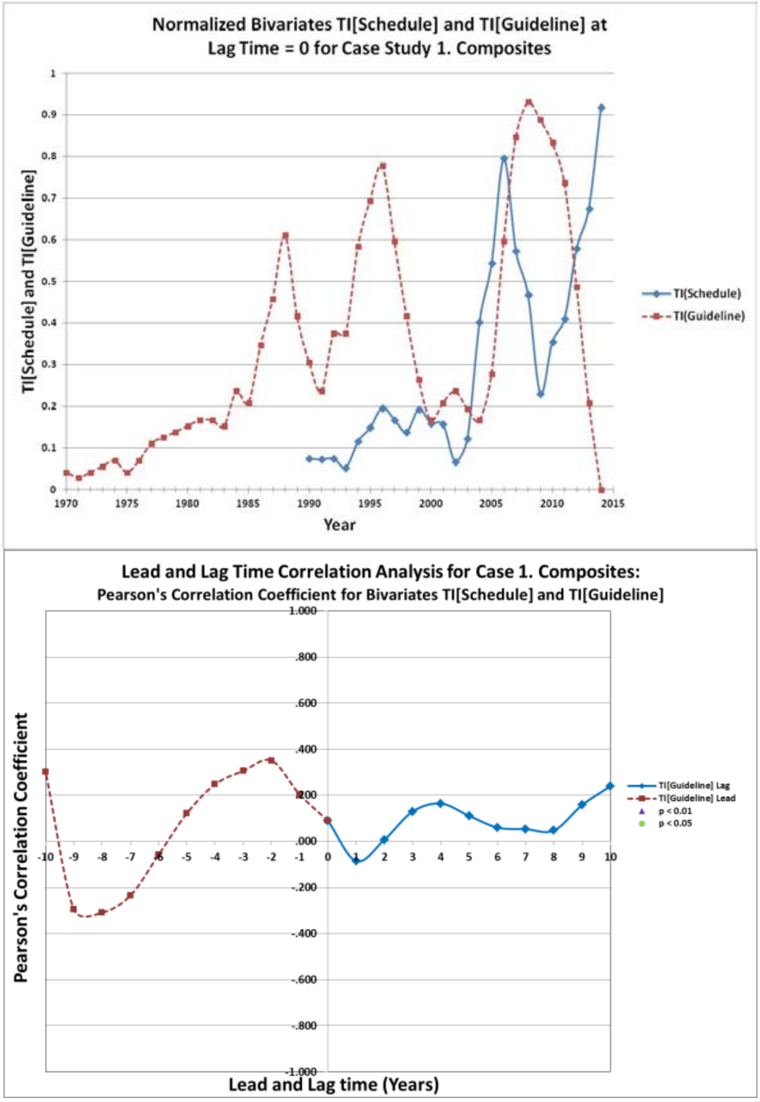


Figure 6A-19b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI[Guideline]

TI[Schedule] and TI/TR[Audience]

The results for TI[Schedule] and TI/TR[Audience] are shown in Figure 6A-20a and Figure 6A-20b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. For this bivariate set, the results indicate no significant correlations between the two variables.

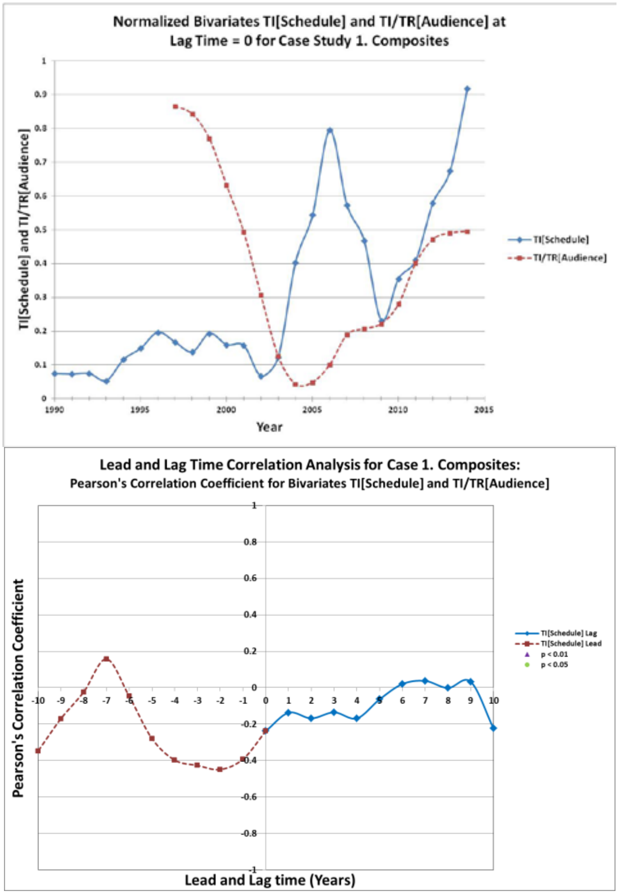


Figure 6A-20a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI/TR[Audience]

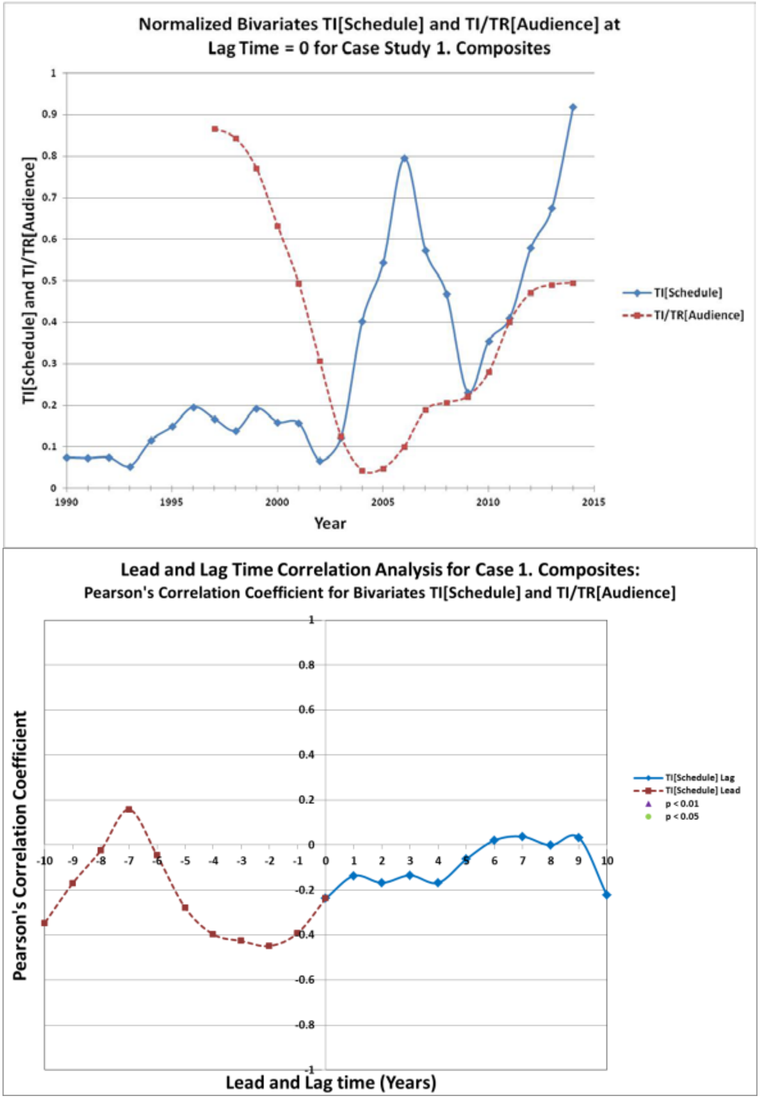


Figure 6A-20b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI/TR[Audience]

TI[Schedule] and TR[Schedule]

The results for TI[Schedule] and TR[Schedule] are shown in Figure 6A-21a and Figure 6A-21b. In the conservative case, there are no significant correlation shown between the two variables. In the un-conservative case, the results suggest that there is about a 3-5 year lag for TI[Schedule]. In the ideal world, this lead time in training would be effective for the organization for composites because it is a mature technology. As orders are placed, more focus will be on meeting the delivery date, where engineers need to be ready to perform.

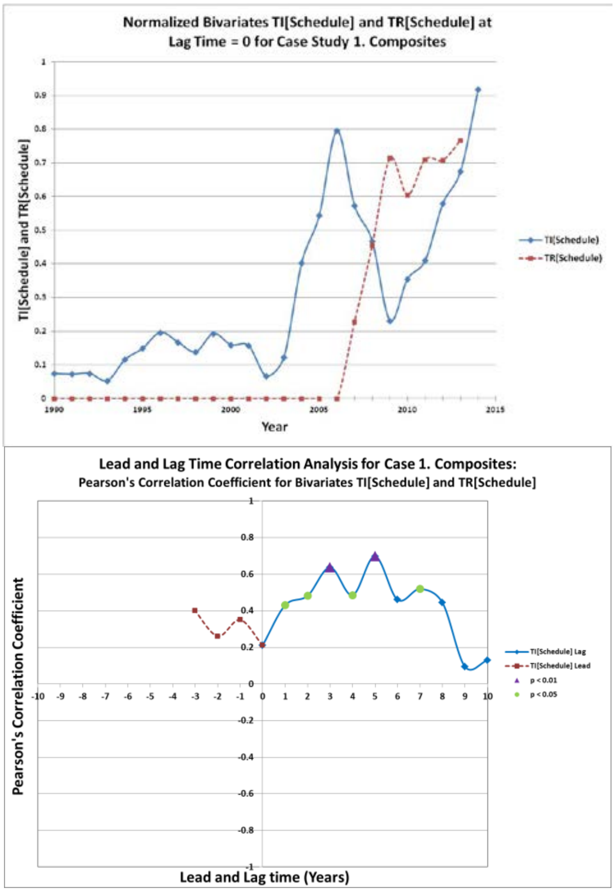
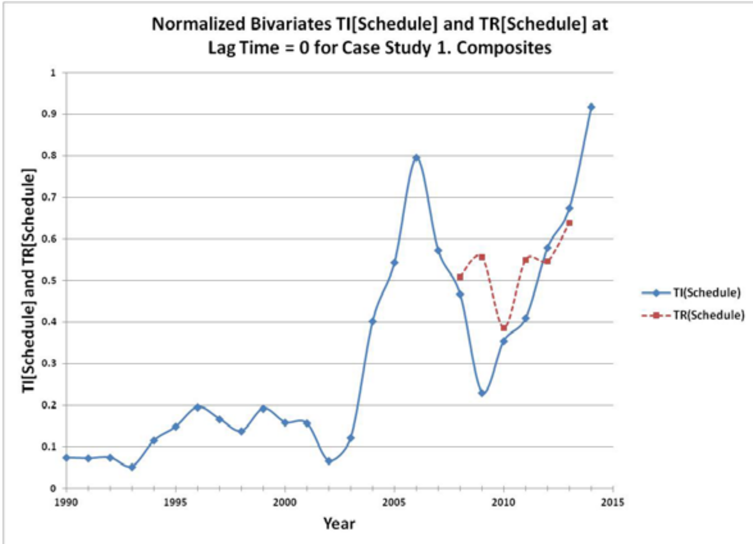


Figure 6A-21a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Schedule]



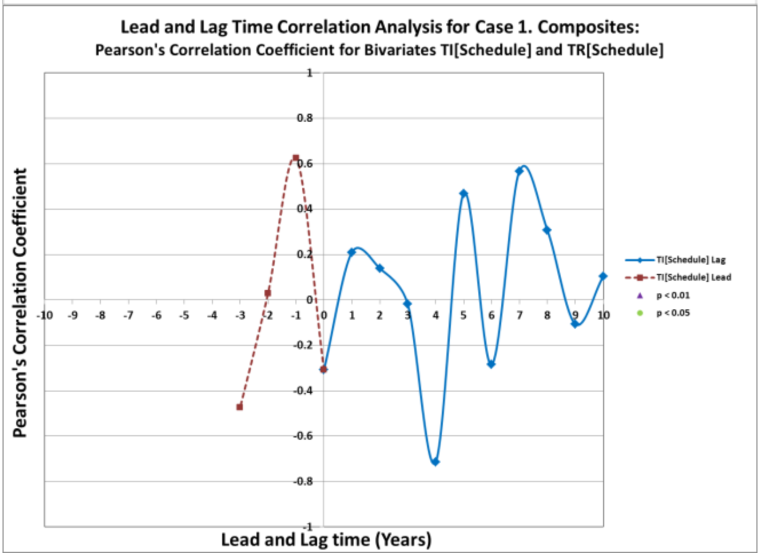


Figure 6A-21b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Schedule]

TI[Schedule] and TR[Cost]

The results for TI[Schedule] and TR[Cost] are shown in Figure 6A-22a and Figure 6A-22b. In the conservative case, there are no significant correlation shown between the two variables. In the un-conservative case, the results suggest that there is about a 1-5 year lag for TI[Schedule]. In the ideal world, this lead time in training would be effective for the organization for composites because it is a mature technology. As orders are placed, more focus will be on meeting the delivery date, where engineers need to be ready to perform.

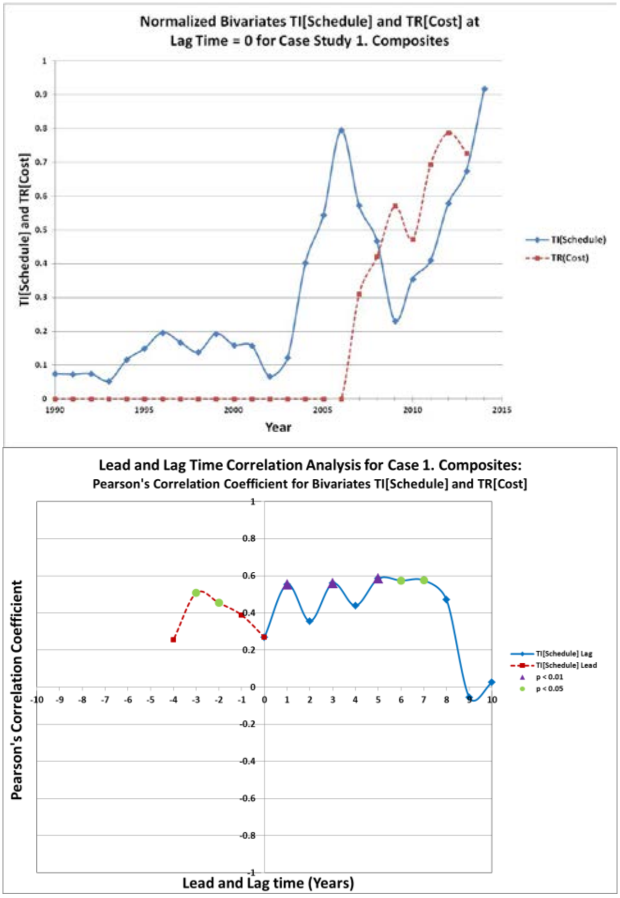


Figure 6A-22a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Cost]

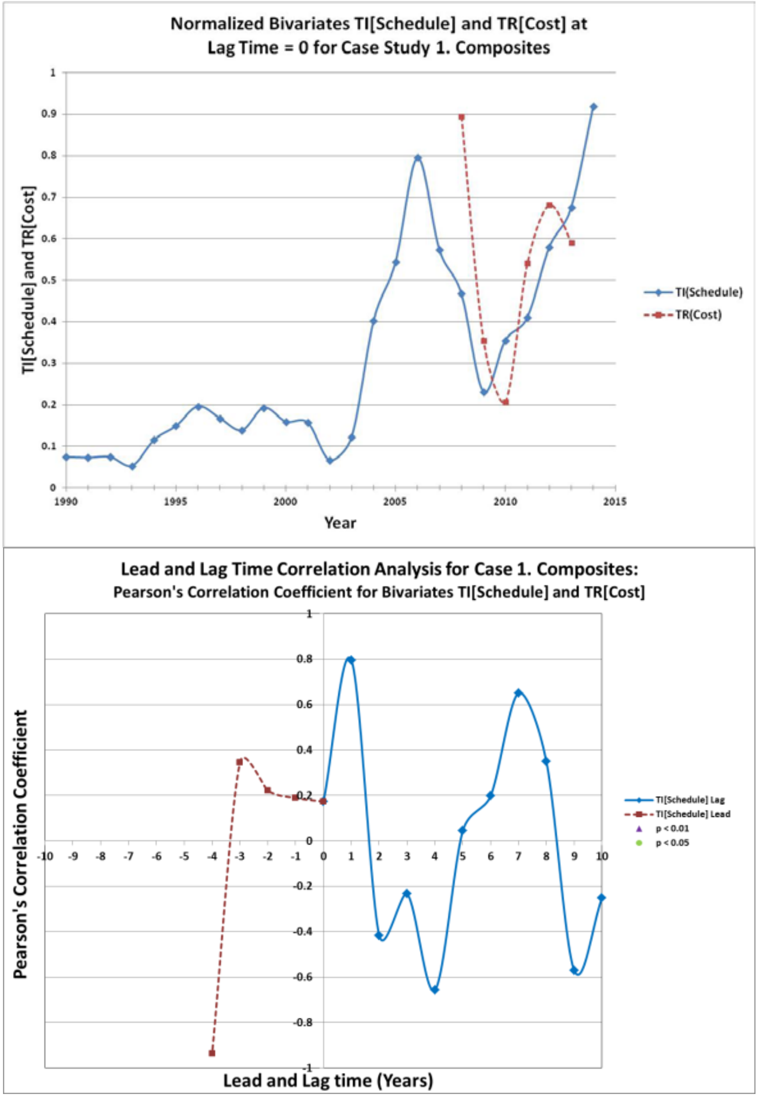


Figure 6A-22b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Cost]

TI[Guideline] and TI/TR[Audience]

The results for TI[Guideline] and TI/TR[Audience] are shown in Figure 6A-23a and Figure 6A-23b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. The results suggest that as TI[Schedule] leads TI/TR[Audience] 2-3 years, there is a negative correlation between these two variables. The results also suggest that as TI[Schedule] lags TI/TR[Audience] by 3-4 years, there is a strong positive correlation.

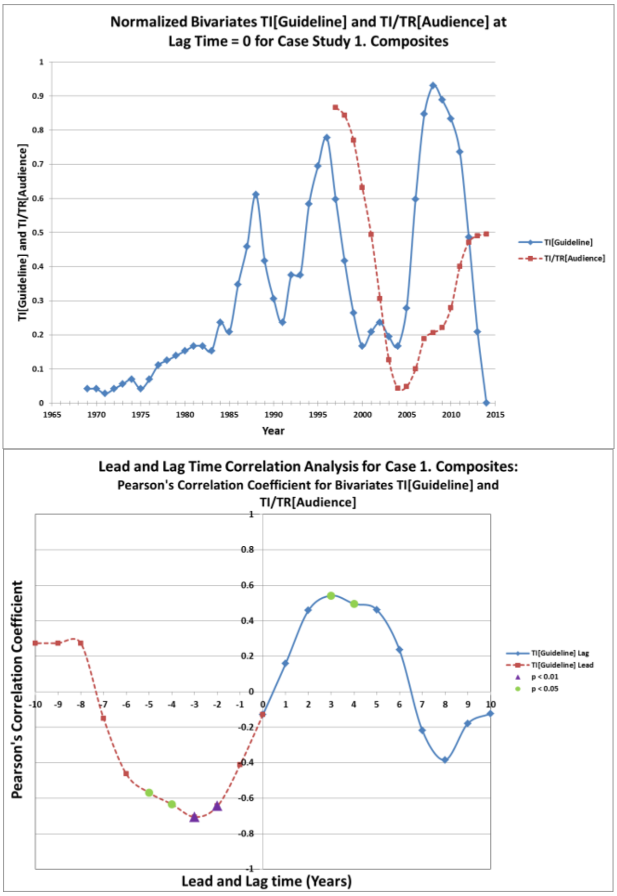


Figure 6A-23a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TI/TR[Audience]

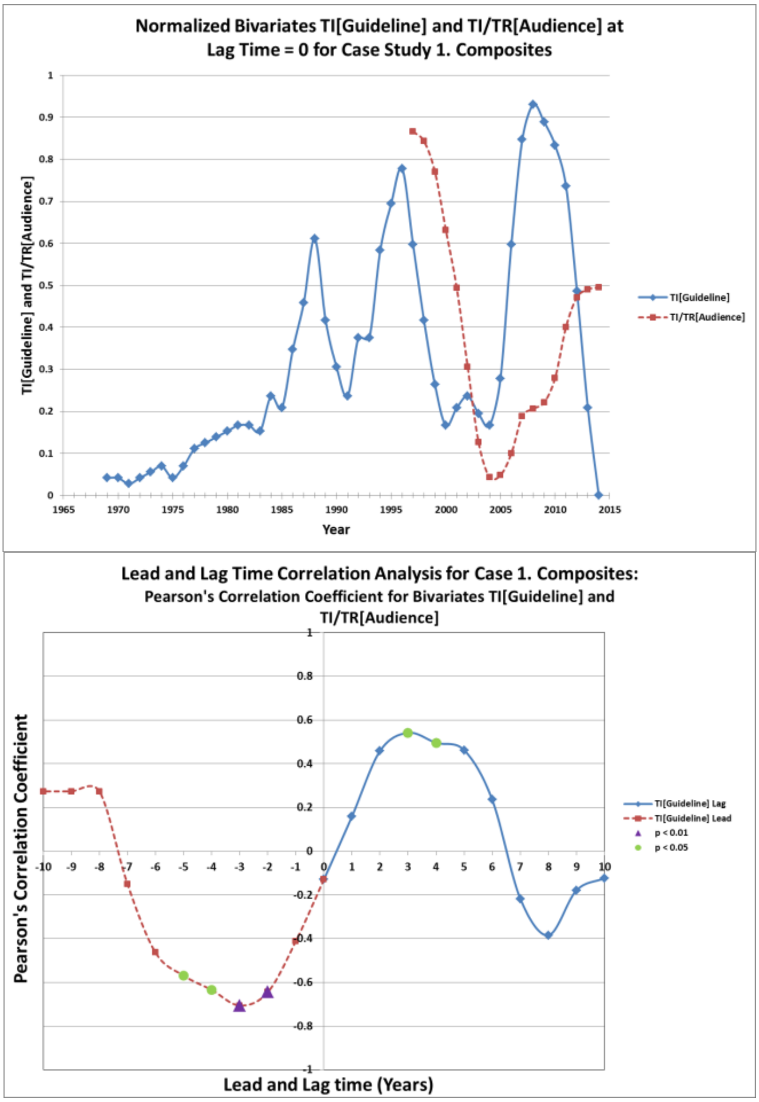


Figure 6A-23b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TI/TR[Audience]

TI[Guideline] and TR[Schedule]

The results for TI[Guideline] and TR[Schedule] are shown in Figure 6A-24a and Figure 6A-24b. In the conservative case, there are no significant correlations shown between these two variables. The results for the conservative case show that the most significant correlation occurs when TI[Guideline] lags TR[Schedule] by 2 years. This suggests that training occurs prior to patents being filed, which would be expected. As more engineers are trained, the knowledge gained from the courses may enable an uptake in patents filed shortly after.

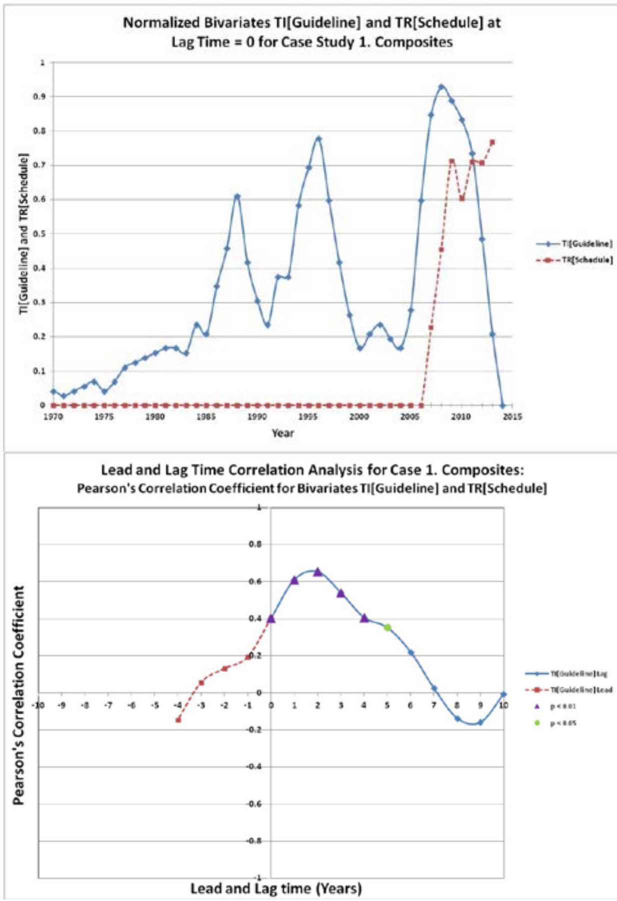


Figure 6A-24a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Schedule]

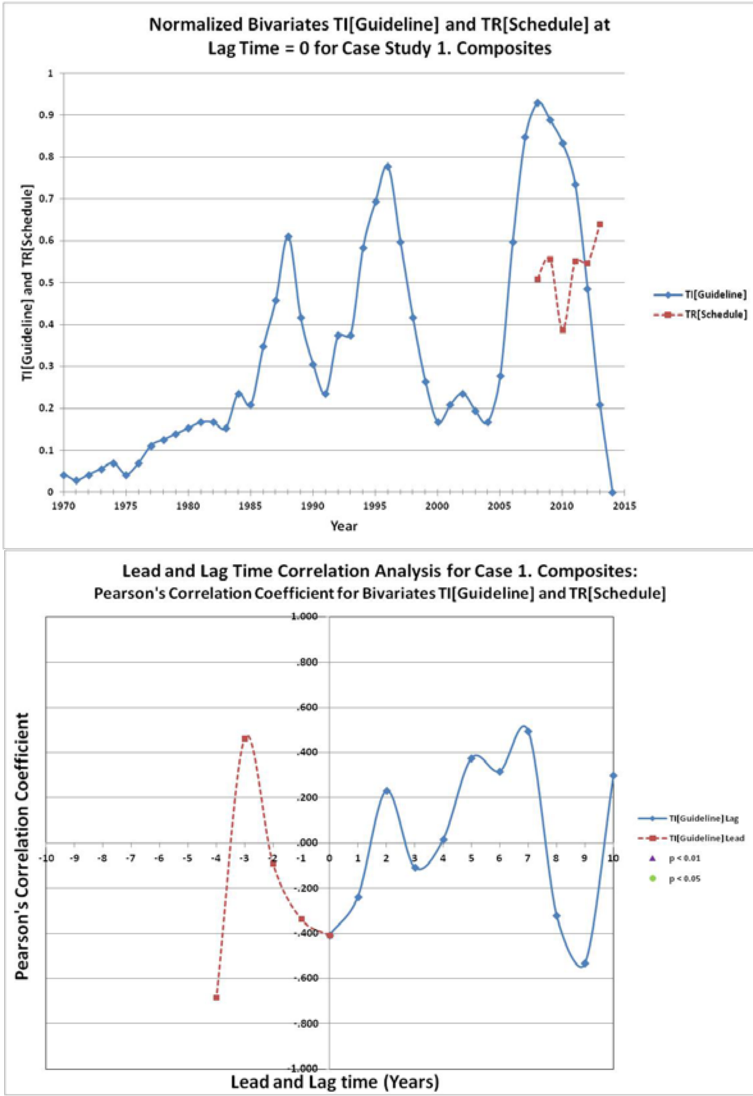


Figure 6A-24b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Schedule]

TI[Guideline] and TR[Cost]

The results for TI[Guideline] and TR[Cost] are shown in Figure 6A-25a and Figure 6A-25b. In the conservative case, there are no significant correlations shown between these two variables. The results for the conservative case show that the most significant correlation occurs when TI[Guideline] lags TR[Cost] by 1-2 years. This suggests that training occurs prior to patents being filed, which would be expected. As more engineers are trained, the knowledge gained from the courses may enable an uptake in patents filed shortly after.

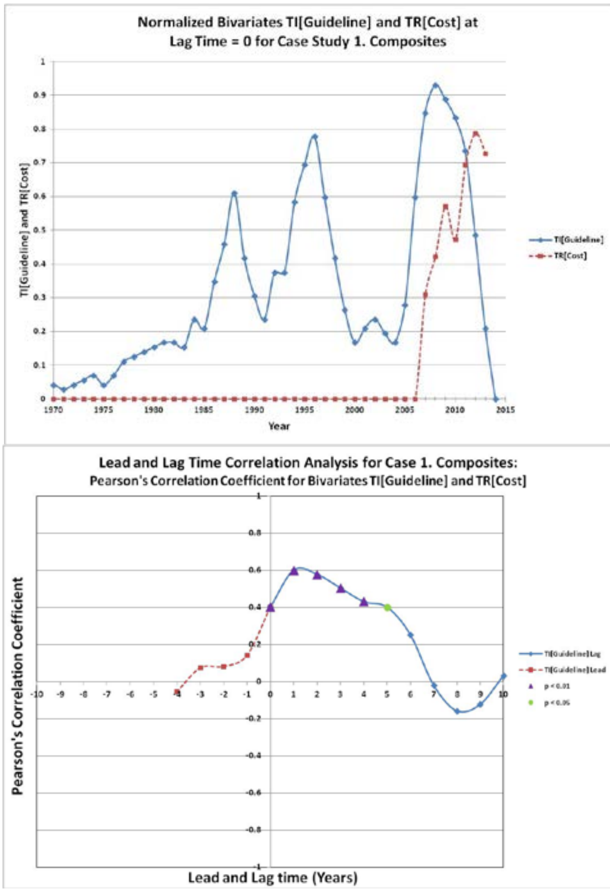


Figure 6A-25a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Cost]

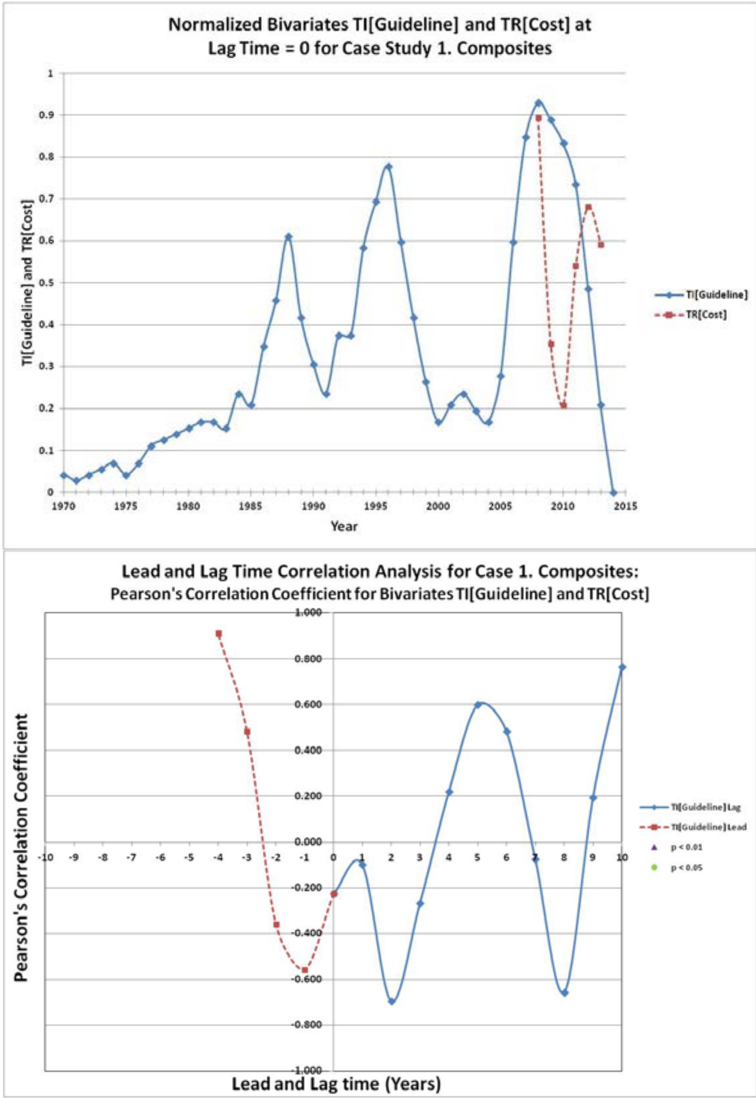


Figure 6A-25b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Cost]

TR[Schedule] and TI/TR[Audience]

The results for TR[Schedule] and TI/TR[Audience] are shown in Figure 6A-26a and Figure 6A-26b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. Because of the limited data obtained for TR[Schedule], the conservative case will be considered instead of the un-conservative case. In the conservative case, the results shown that there are no significant correlations between these two variables.

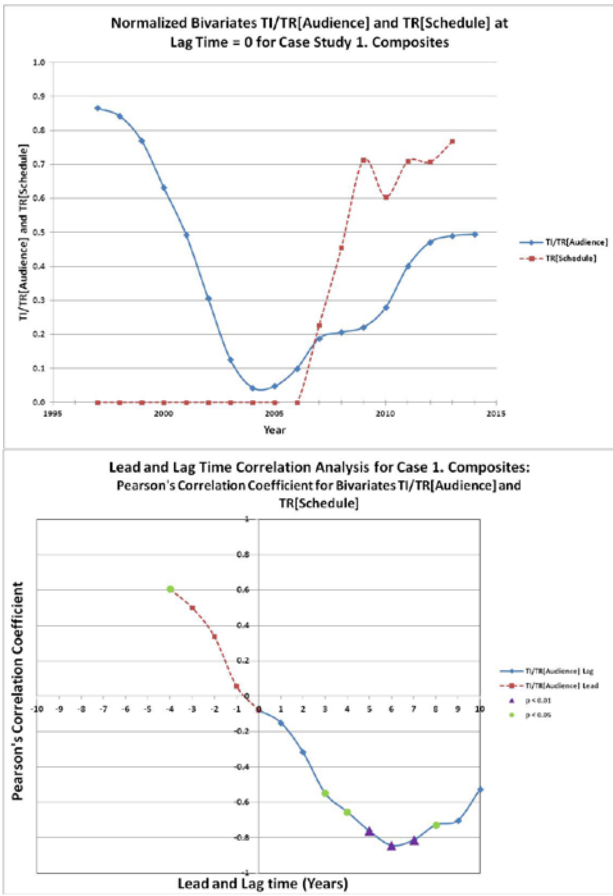


Figure 6A-26a. Comparison using leading zeroes between normalized bivariates TR[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TI/TR[Audience]

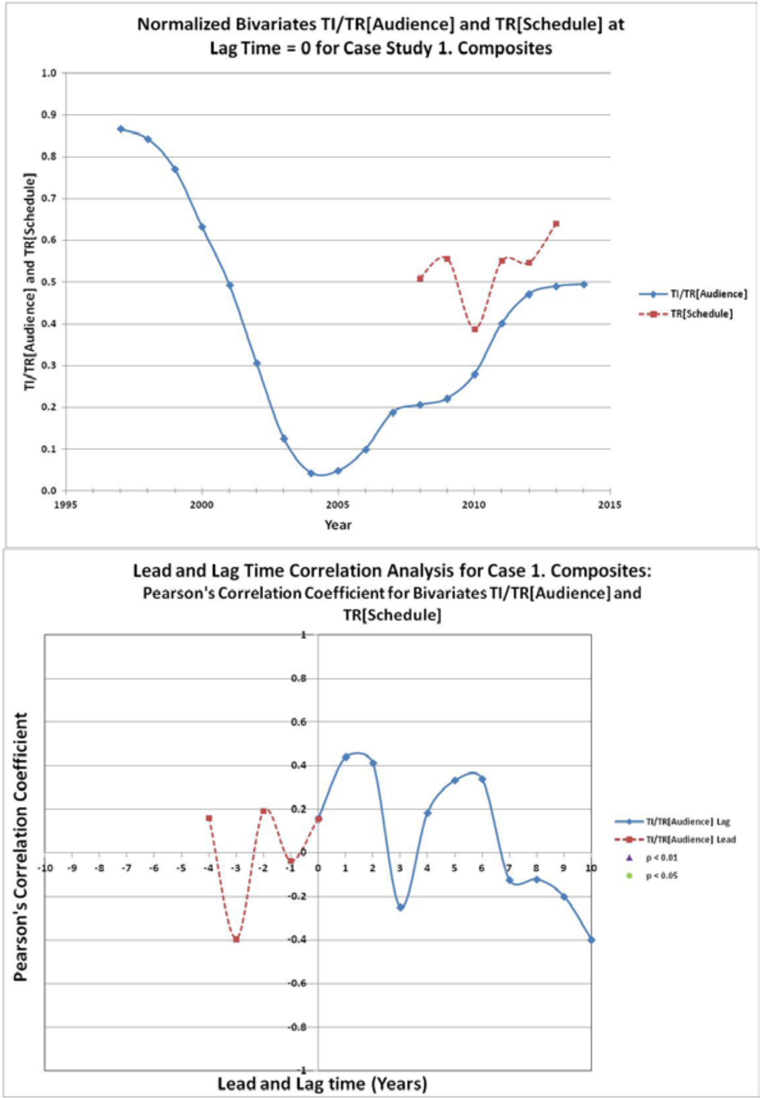


Figure 6A-26b. Comparison removing leading zeroes between normalized bivariates TR[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TI/TR[Audience]

TR[Cost] and TI/TR[Audience]

The results for TR[Cost] and TI/TR[Audience] are shown in Figure 6A-27a and Figure 6A-27b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. Because of the limited data obtained for TR[Cost], the conservative case will be considered instead of the un-conservative case. In the conservative case, the results shown that there are no significant correlations between these two variables.

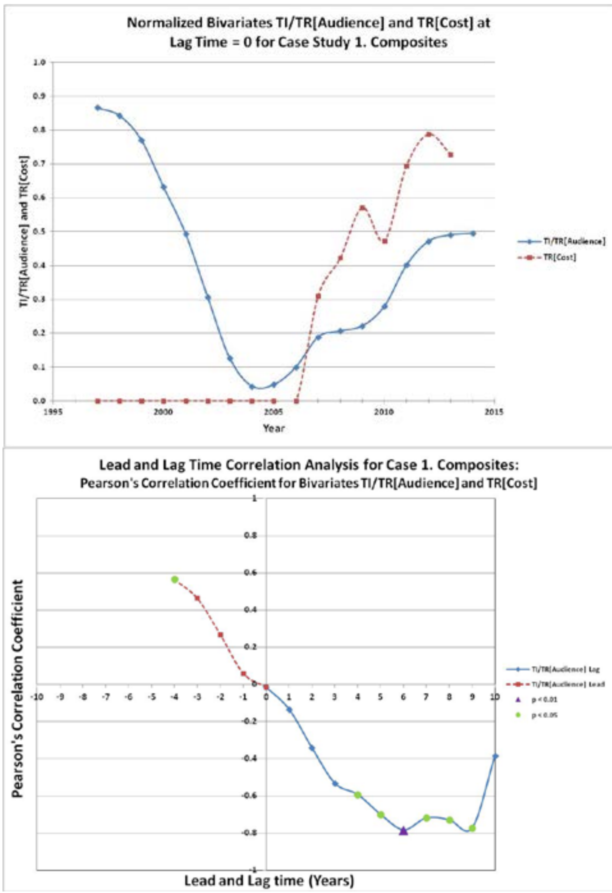


Figure 6A-27a. Comparison using leading zeroes between normalized bivariates TR[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Cost] and TI/TR[Audience]

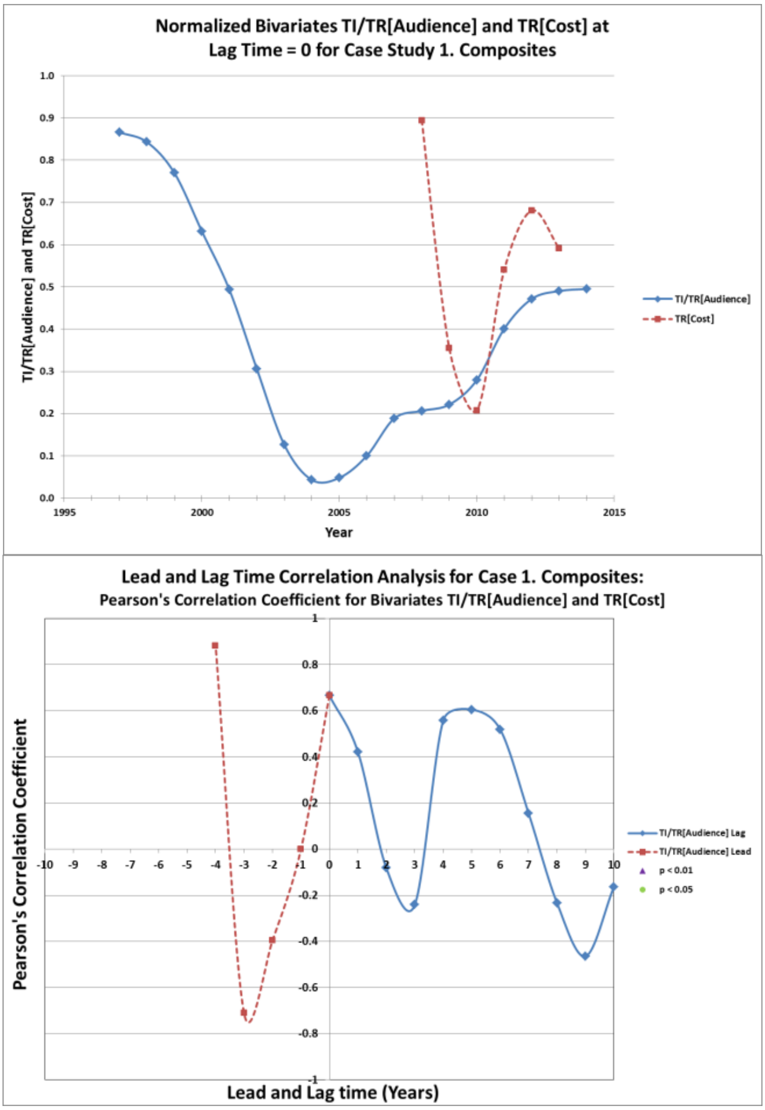


Figure 6A-27b. Comparison removing leading zeroes between normalized bivariates TR[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Cost] and TI/TR[Audience]

TR[Cost] and TR[Schedule]

The results for TR[Cost] and TR[Schedule] are shown in Figure 6A-28a and Figure 6A-28b. The results for this data set are inconclusive, as there are not enough data points to show any significance. However, if there were more data available for this bivariate set, it would be expected that there is a strong positive correlation. The number of student hours completing courses per technology per year is derived from the number of courses delivered per technology innovation per year.

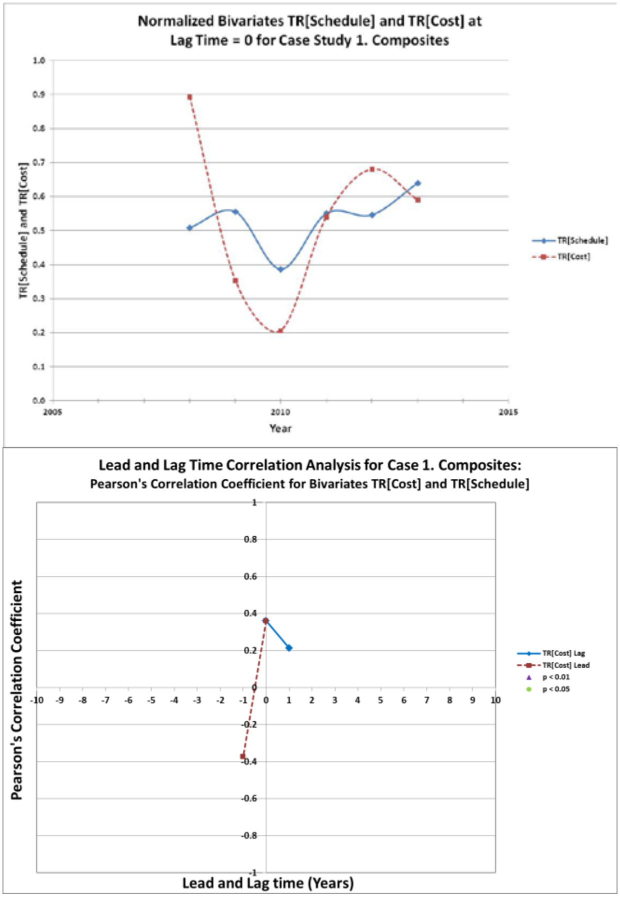


Figure 6A-28a. Comparison using leading zeroes between normalized bivariates TR[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TR[Cost]

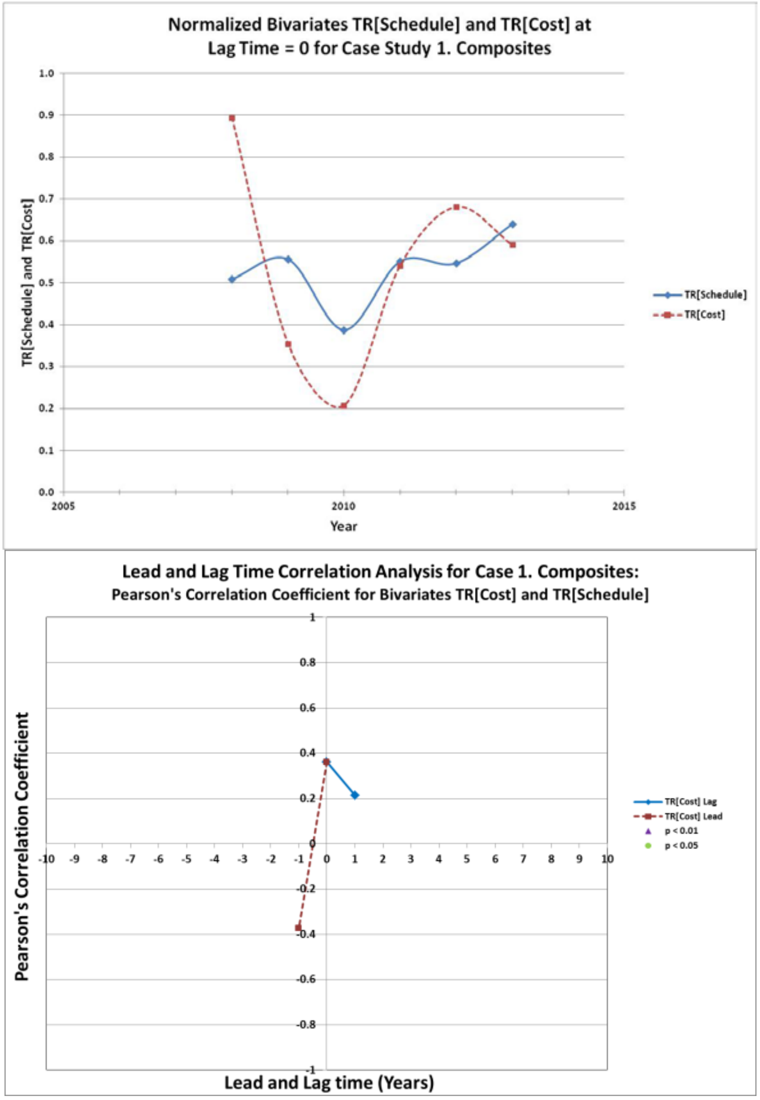


Figure 6A-28b. Comparison removing leading zeroes between normalized bivariates TR[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TR[Cost]

APPENDIX 6B

CORRELATION LAG ANALYSIS FOR CASE 2 – NANOTECHNOLOGY

Appendix 6B describes the detailed correlation lag analysis for case study 2 – Nanotechnology. The results listed in this Appendix 6B are described further in Chapter 6.

The lagged correlation coefficient matrix for both the conservative and un-conservative case is shown in Table 6B-1 and Table 6B-2, respectively. In Figure 6B-1 through Figure 6B-15, the comparisons of using leading zeroes versus not using leading zeroes are shown. For each bivariate, observations are stated in addition to two plots representing the normalized data comparisons, and lead and lag time correlation comparisons. The most significant lead and lag time years within the lead and lag time correlation comparison plots are represented by triangles and dots. The triangles represent p value < 0.01 and the dots represent p value < 0.05.

TI[Schedule] and TIOE[Cost]

The results for TI[Schedule] and TIOE[Cost] are shown in Figure 6B-1a and Figure 6B-1b. In the conservative case, the results show that TI[Schedule] lags TIOE[Cost] by about 9 years. In the un-conservative case, the results show that TI[Schedule] leads TIOE[Cost] by about 1-3 years. Either case could be argued. In the conservative case, the investment in the product per technology innovation per year occurs 9 years before the number of orders per technology innovation per year. The investment may include research and development in the new technology innovation and as the new technology innovation brings promises to higher airplane performance, this would aim to target the market need. This in turns entices the airline customers to order the latest and greatest airplane containing the new technology innovation that promises higher performance. In the un-conservative case, the number of orders per technology innovation per year occurs 1-3 years before the investment in the product per technology innovation per year. This may suggest that after the airplane is ordered, more investment is being made on the new technology innovation to aide in the development with hopes of efficiency to meet the desired delivery date. Because this is a technology that has not matured, it is possible that the two scenarios discussed above are valid.

Table 6B-1. Conservative cross correlation coefficient matrix for case study 2

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	no significant correlation	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	no significant correlation	0.703** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market	no significant correlation	no significant correlation	no significant correlation	1.000		
Total Number of Courses Delivered [TR(Schedule)]	no significant correlation	-0.774* (TI[Schedule], x-3)	0.787** (TI[Guideline], x-3)	0.901** (TI/TR[Audience), x+8)	1.000	
Total Number of Students Completing Course [TR(Cost)]	no significant correlation	-0.792* (TI[Schedule], x+4)	-0.814* (TI[Guideline], x+2)	-0.878** (TI/TR[Audience], x-3)	no significant correlation - too little data points	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

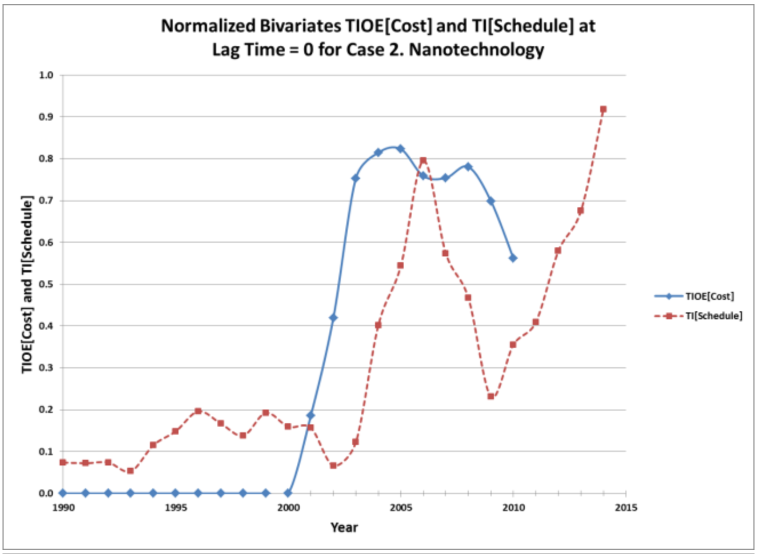
Table 6B-2. Un-conservative cross correlation coefficient matrix for case study 2

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.660** (TI[Schedule], x-3)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.838** (TI[Guideline], x-3)	0.744** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.925** (TI/TR[Audience], x=0)	no significant correlation	0.902** (TI[Guideline], x-10)	1.000		
Total Number of Courses Delivered [TR(Schedule)]	no significant correlation	0.751** (TI[Schedule], x+1)	0.873** (TI[Guideline], x-3)	0.901** (TI/TR[Audience), x+8)	1.000	
Total Number of Students Completing Course [TR(Cost)]	no significant correlation	0.683** (TI[Schedule], x=0)	0.879** (TI[Guideline], x-3)	0.829** (TI/TR[Audience], x-6)	0.939** (TR[Schedule], x=0)	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.



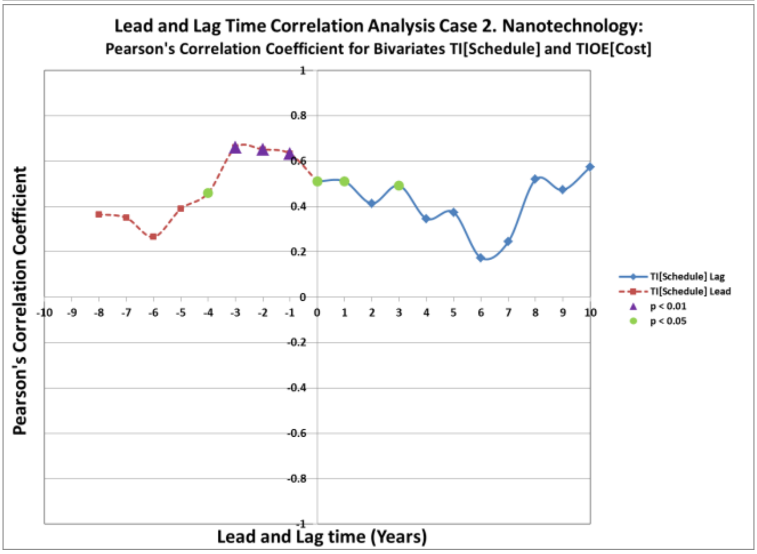


Figure 6B-1a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Schedule]

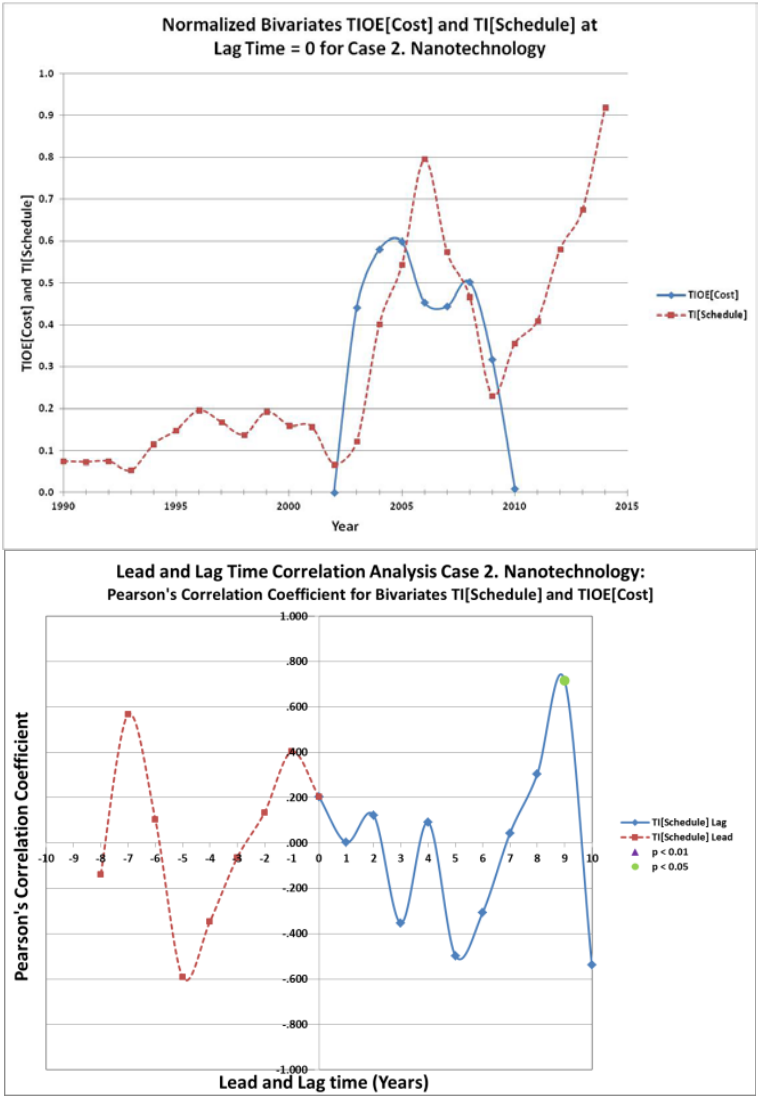


Figure 6B-1b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Schedule]

TIOE[Cost] and TI[Guideline]

The results for TIOE[Cost] and TI[Guideline] are shown in Figure 6B-2a and Figure 6B-2b. In the conservative case, there are no significant correlations between these two variables. Because of the large number of leading zeroes in the un-conservative case, the results may be too skewed to consider for the scope of this research.

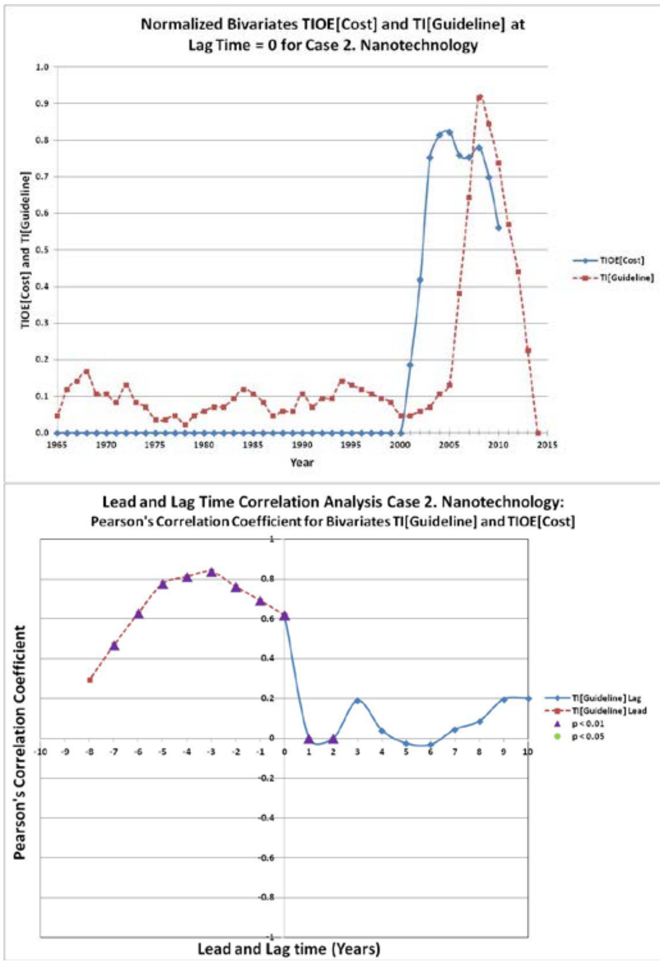


Figure 6B-2a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Guideline]

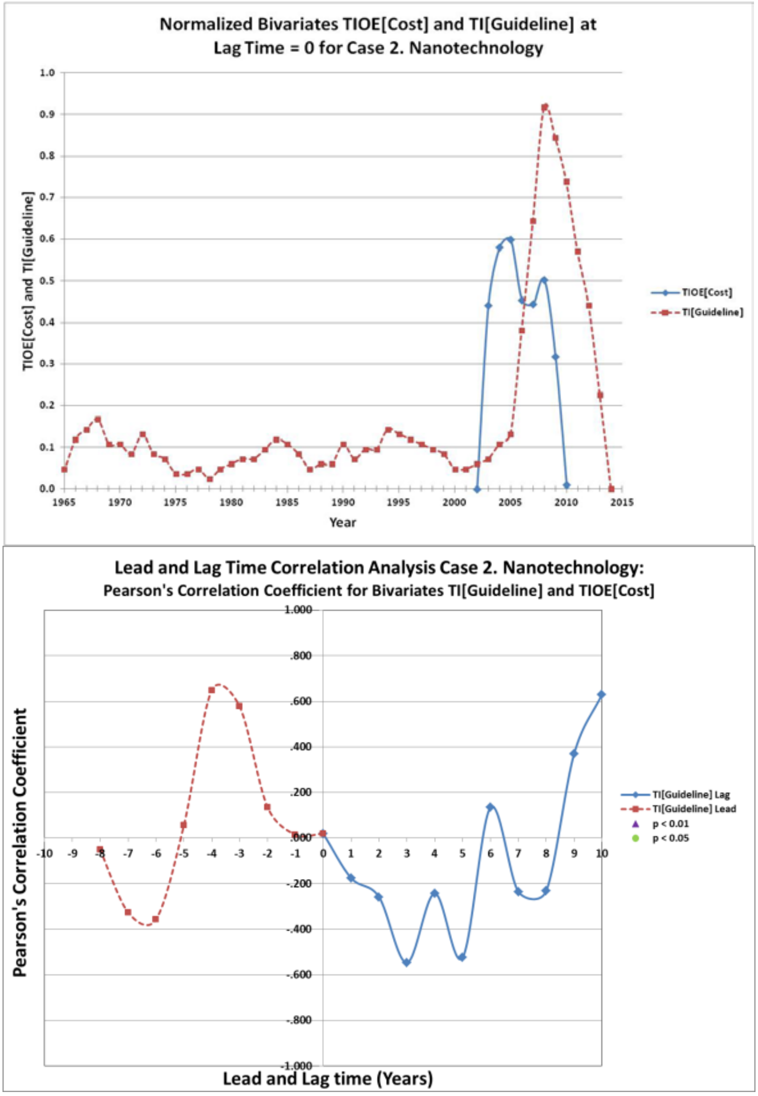


Figure 6B-2b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI[Guideline]

TIOE[Cost] and TI/TR[Audience]

The results for TIOE[Cost] and TI/TR[Audience] are shown in Figure 6B-3a and Figure 6B-3b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. In the conservative case, there are no significant correlations shown for the two variables. In the un-conservative case, the strongest correlation is negative and is shown when there is no lag between TIOE[Cost] and TI/TR[Audience]. It would expected that a the investment in the product per technology innovation per year increases, there would be a need for engineers to work on the technology shortly thereafter. The negative correlation shown in the un-conservative results may be due to the maturity of the technology.

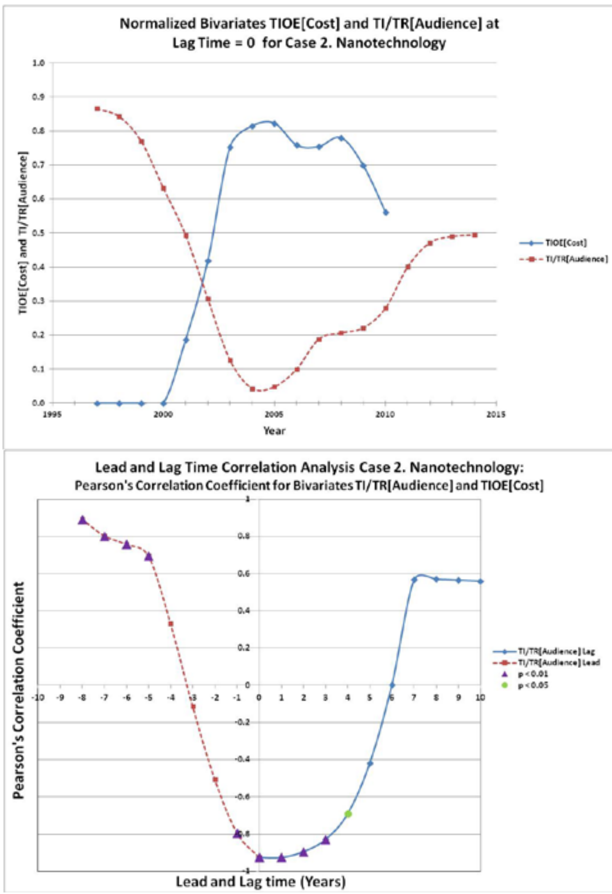


Figure 6B-3a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI/TR[Audience]

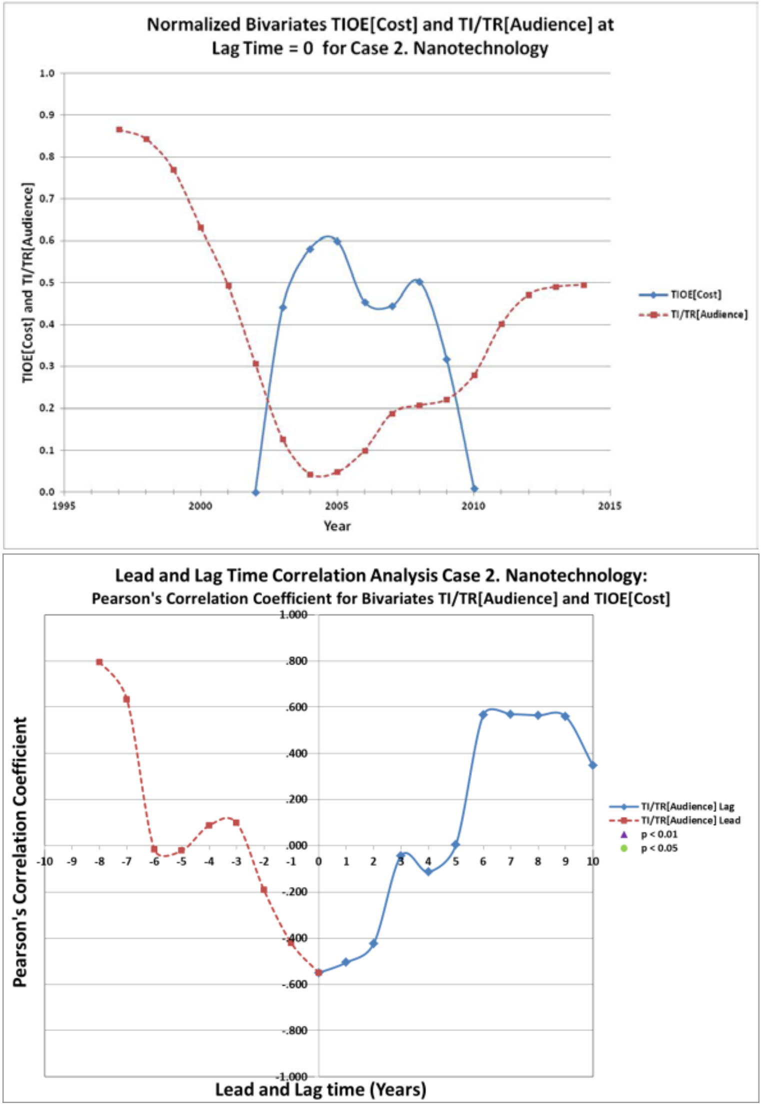


Figure 6B-3b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TI/TR[Audience]

TIOE[Cost] and TR[Schedule]

The results for TIOE[Cost] and TR[Schedule] are shown in Figure 6B-4a and Figure 6B-4b. In both the conservative and un-conservative cases, there are no significant correlations shown between the two variables.

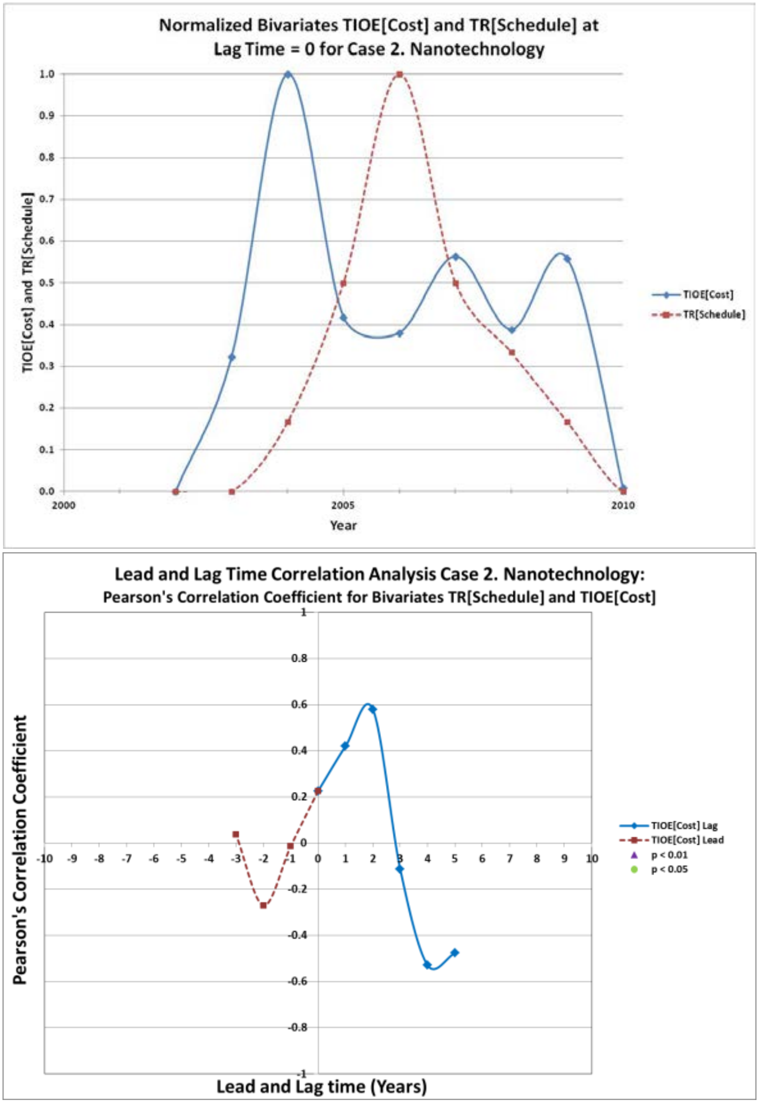
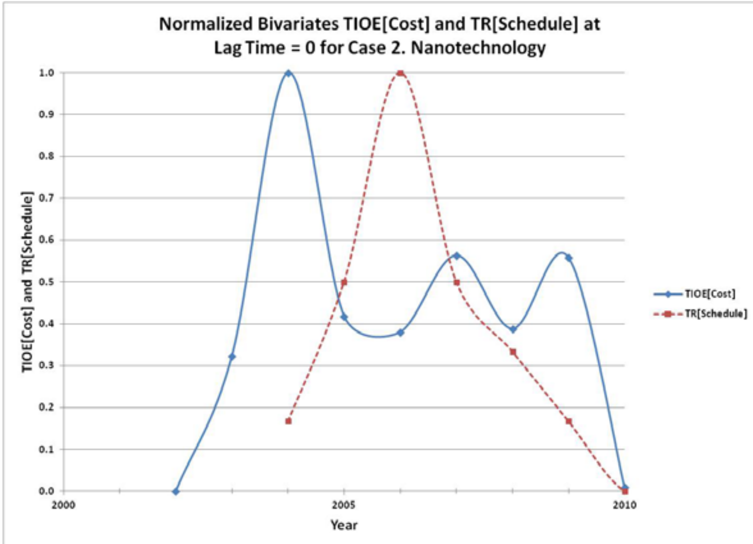


Figure 6B-4a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Schedule]



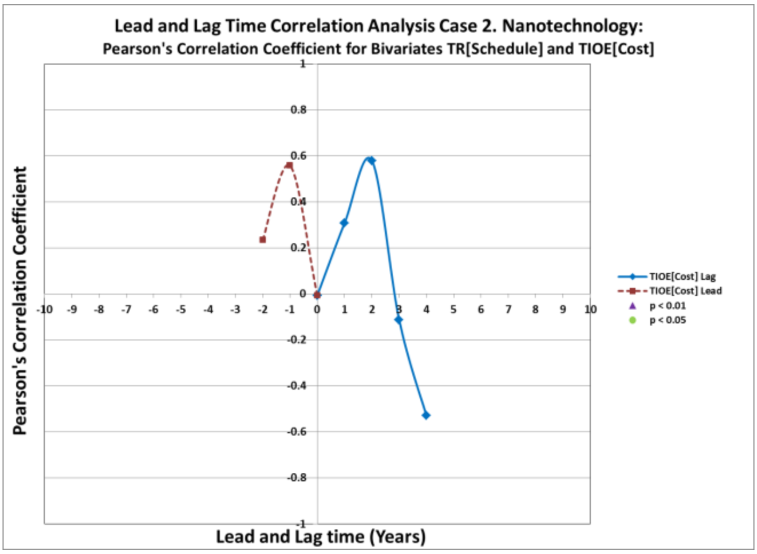


Figure 6B-4b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Schedule]

TIOE[Cost] and TR[Cost]

The results for TIOE[Cost] and TR[Cost] are shown in Figure 6B-5a and Figure 6B-5b. In both the conservative and un-conservative cases, there are no significant correlations shown between the two variables.

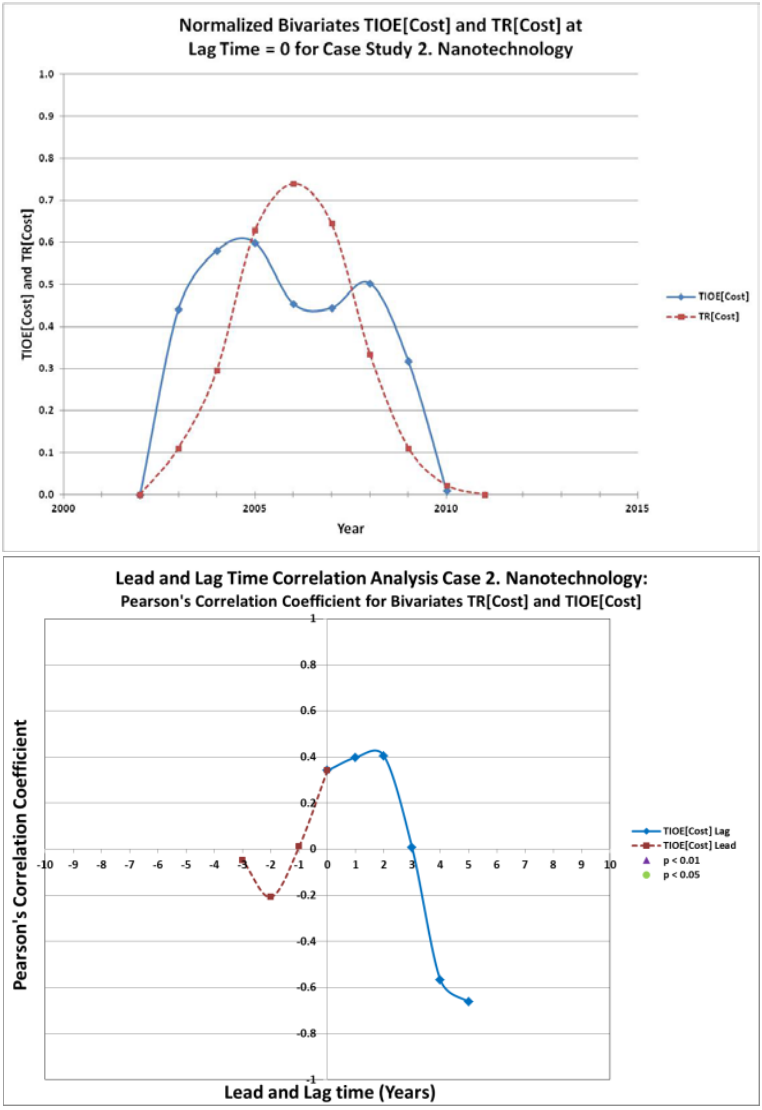


Figure 6B-5a. Comparison using leading zeroes between normalized bivariates TIOE[Cost] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Cost]

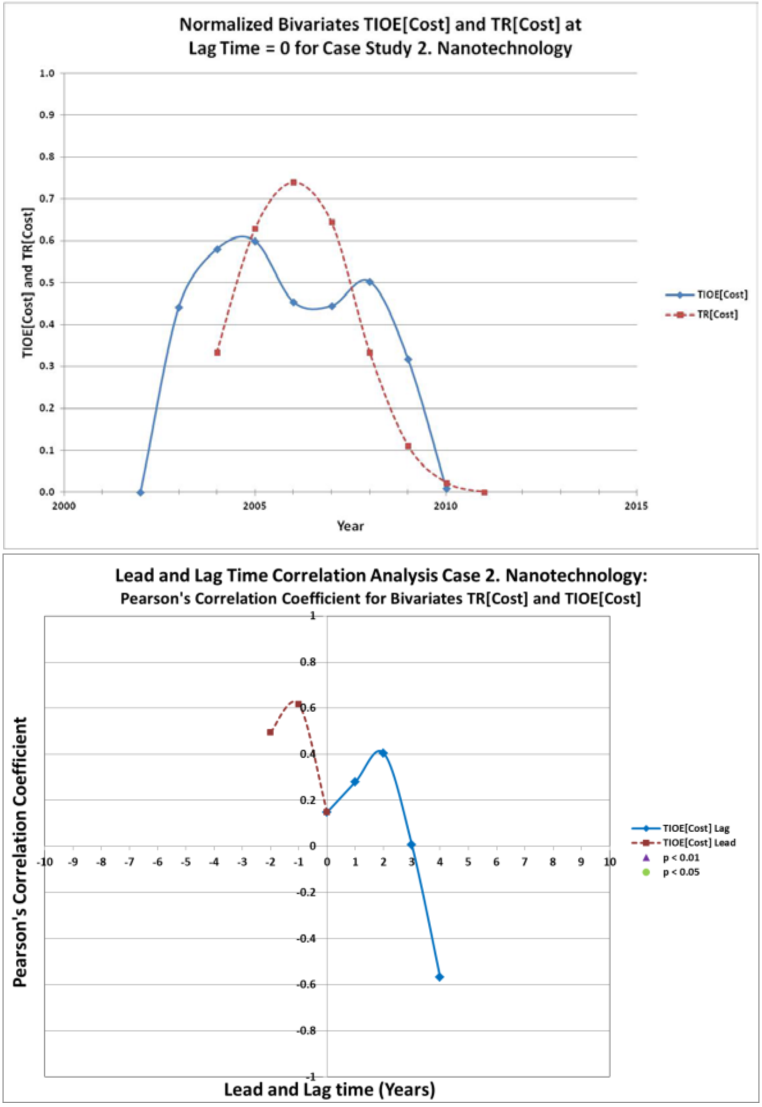


Figure 6B-5b. Comparison removing leading zeroes between normalized bivariates TIOE[Cost] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TIOE[Cost] and TR[Cost]

TI[Schedule] and TI[Guideline]

The results for TI[Schedule] and TI[Guideline] are shown in Figure 6B-6a and Figure 6B-6b. In the conservative case, the results show that the strongest correlation occurs when TI[Guideline] leads 2-4 years before TI[Schedule]. It is expected that TI[Guideline] leads TI[Schedule]. It is also expected that the trends observed for this bivariate be cyclic in nature. TI[Guideline] will always continue even after an airplane product is delivered as the technology innovation still exists. It is common that a technology innovation may be applied to other parts of the airplane in later models. Hence, there are significant correlations at different periods of time between this bivariate.

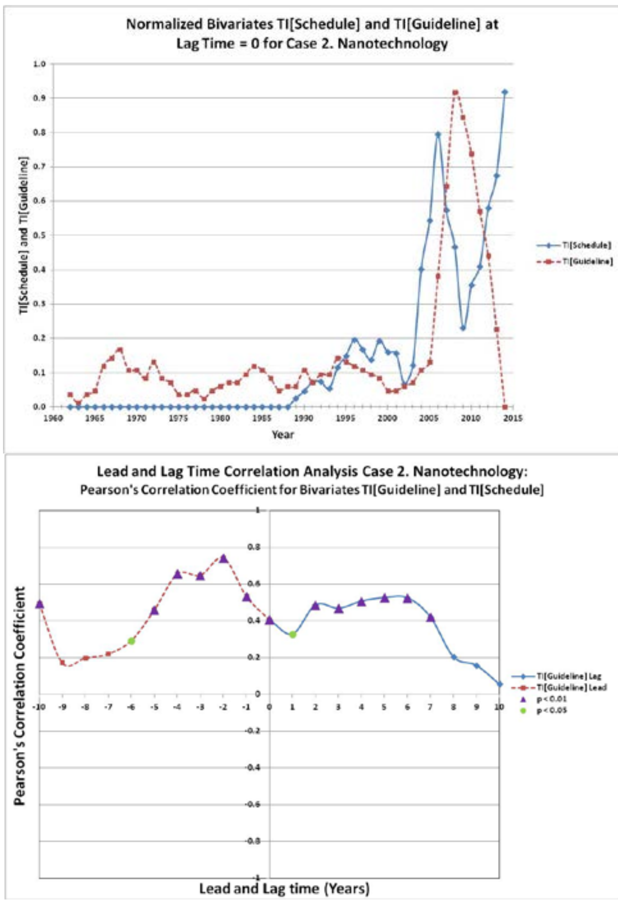


Figure 6B-6a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI[Guideline]

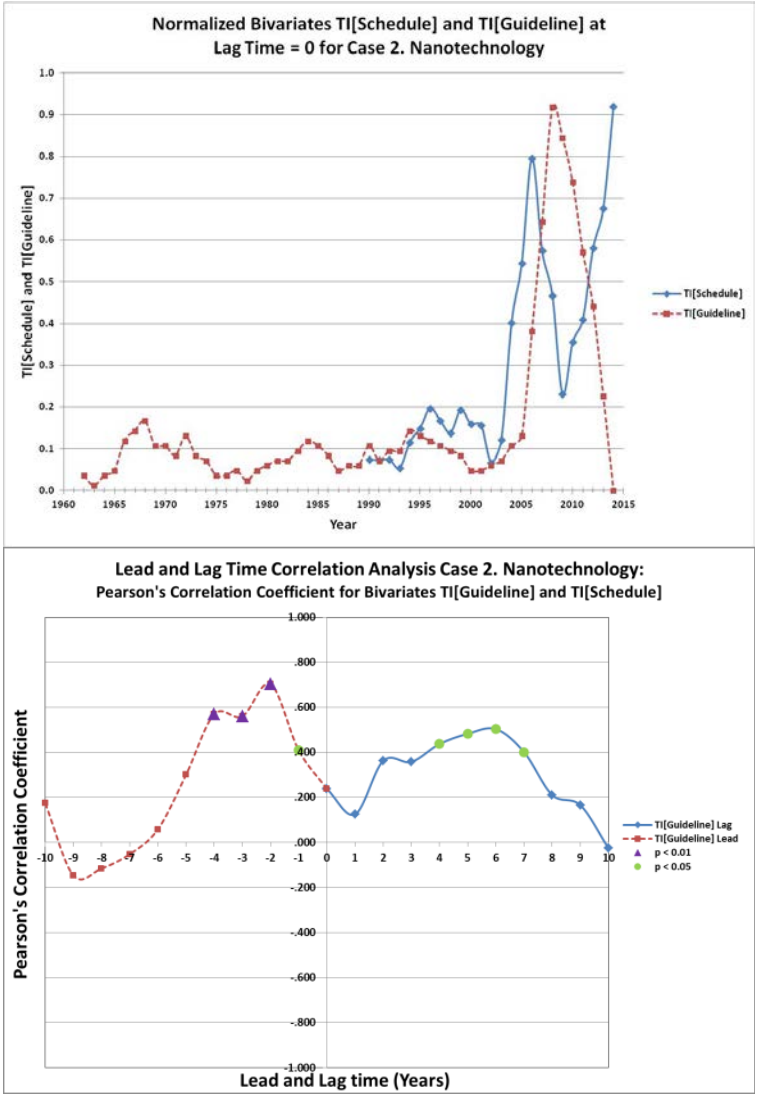


Figure 6B-6b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TI[Guideline] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI[Guideline]

TI[Schedule] and TI/TR/[Audience]

The results for TI[Schedule] and TI/TR[Audience] are shown in Figure 6B-7a and Figure 6B-7b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. For both the conservative and un-conservative cases, the results show that there are no significant correlations between these two variables. If there was a complete data set for TI/TR[Audience], the expectation would be for the number of engineers increase shortly after the number of orders are made to help support the program.

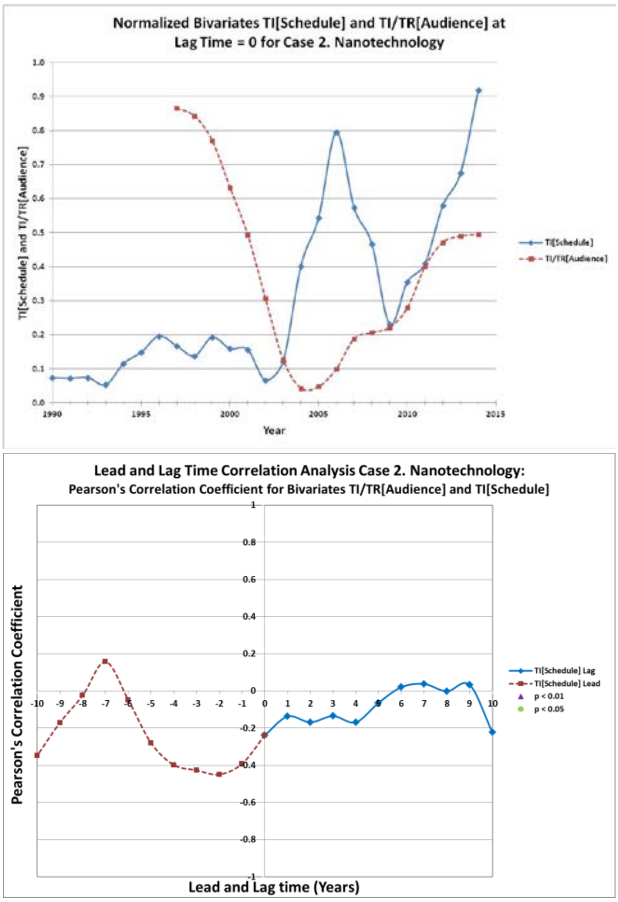


Figure 6B-7a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI/TR[Audience]

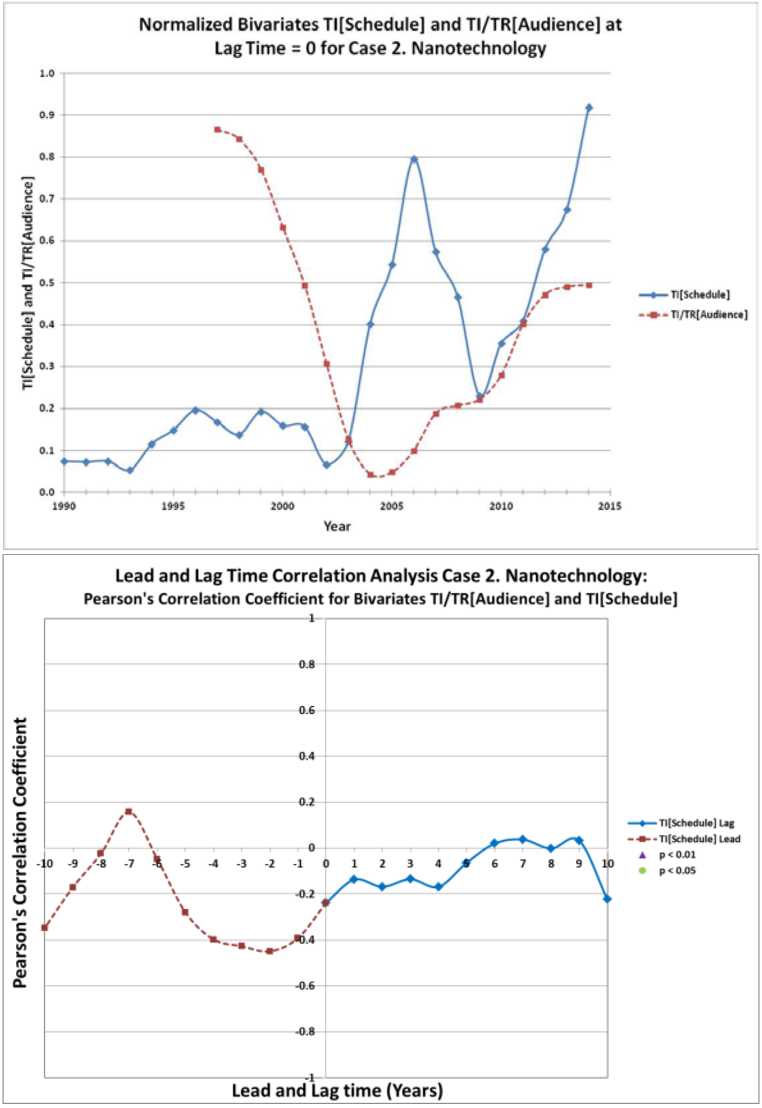


Figure 6B-7b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TI/TR[Audience]

TI[Schedule] and TR[Schedule]

The results for TI[Schedule] and TR[Schedule] are shown in Figure 6B-8a and Figure 6B-8b. In the conservative case, TI[Schedule] leads TR[Schedule] by 3 years. This is depicting what is currently happening right now at the company. This does not suggest that this is the ideal way. It is in the scope of this research to recommend ideal situations for the companies to consider based on what was observed in this chapter, as well as the Chapter 2, 3, and 4.

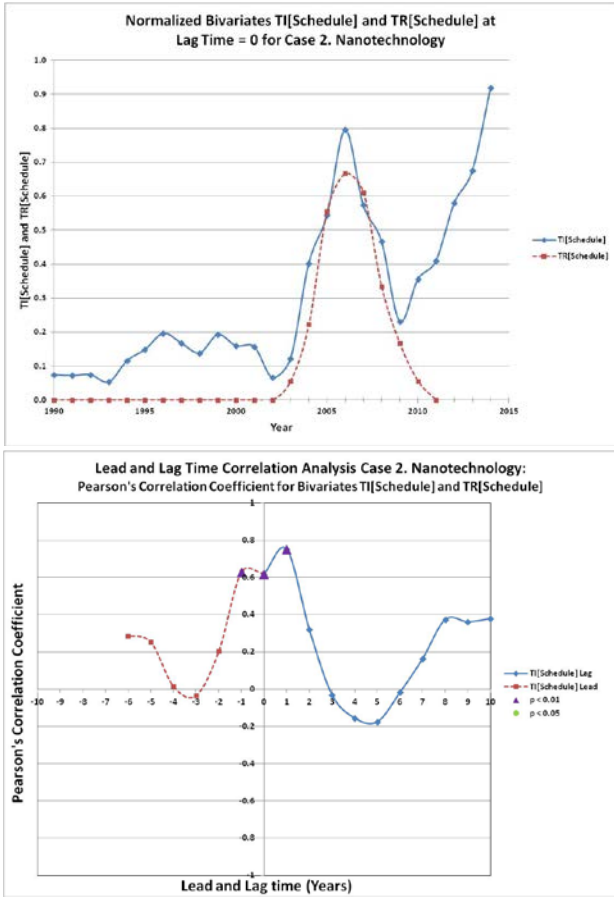


Figure 6B-8a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Schedule]

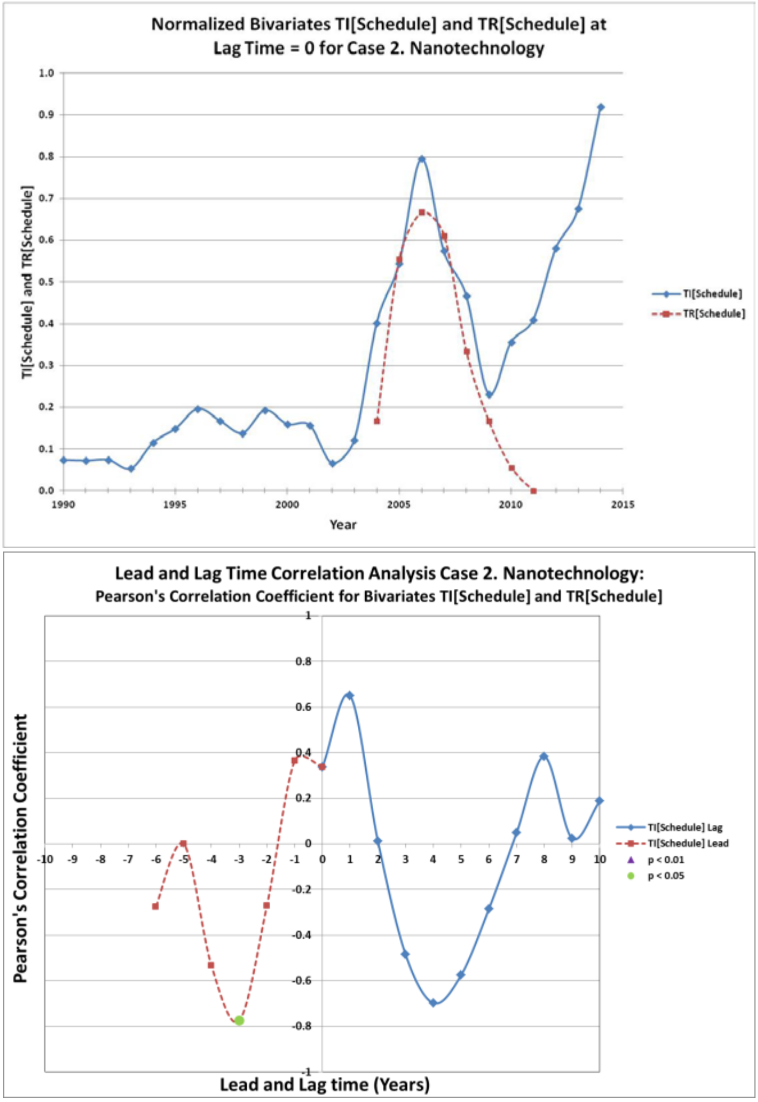
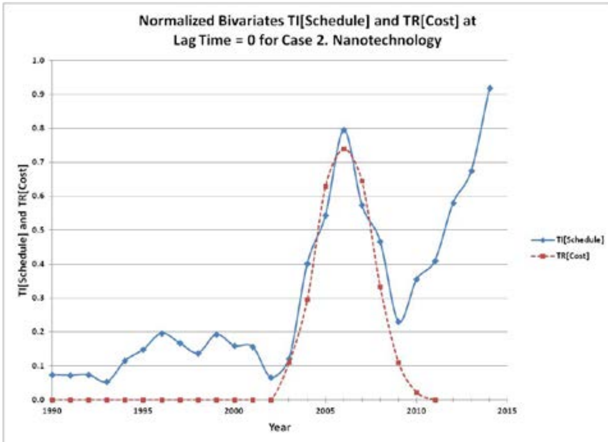


Figure 6B-8b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Schedule]

TI[Schedule] and TR[Cost]

The results for TI[Schedule] and TR[Cost] are shown in Figure 6B-9a and Figure 6B-9b. In the conservative case, TI[Schedule] lags TR[Cost] by 4 years. The variable TI[Schedule] should be omitted from the data set as the technology innovation is too early in the maturity cycle to be placed on the airplane. For this case study, the technology innovation is not production ready. Hence, any results seen here should not be taken into consideration when drawing conclusions for this chapter.



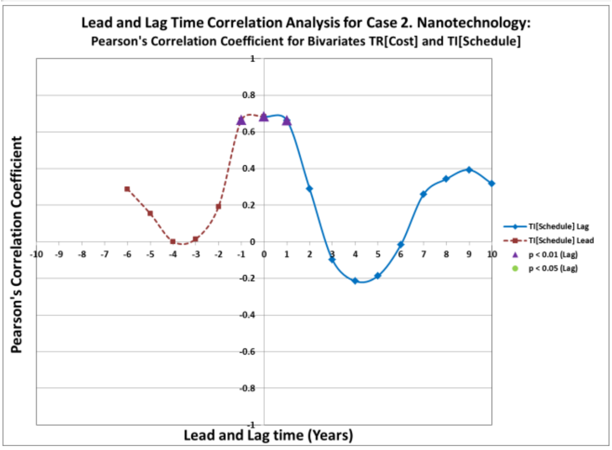


Figure 6B-9a. Comparison using leading zeroes between normalized bivariates TI[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Cost]

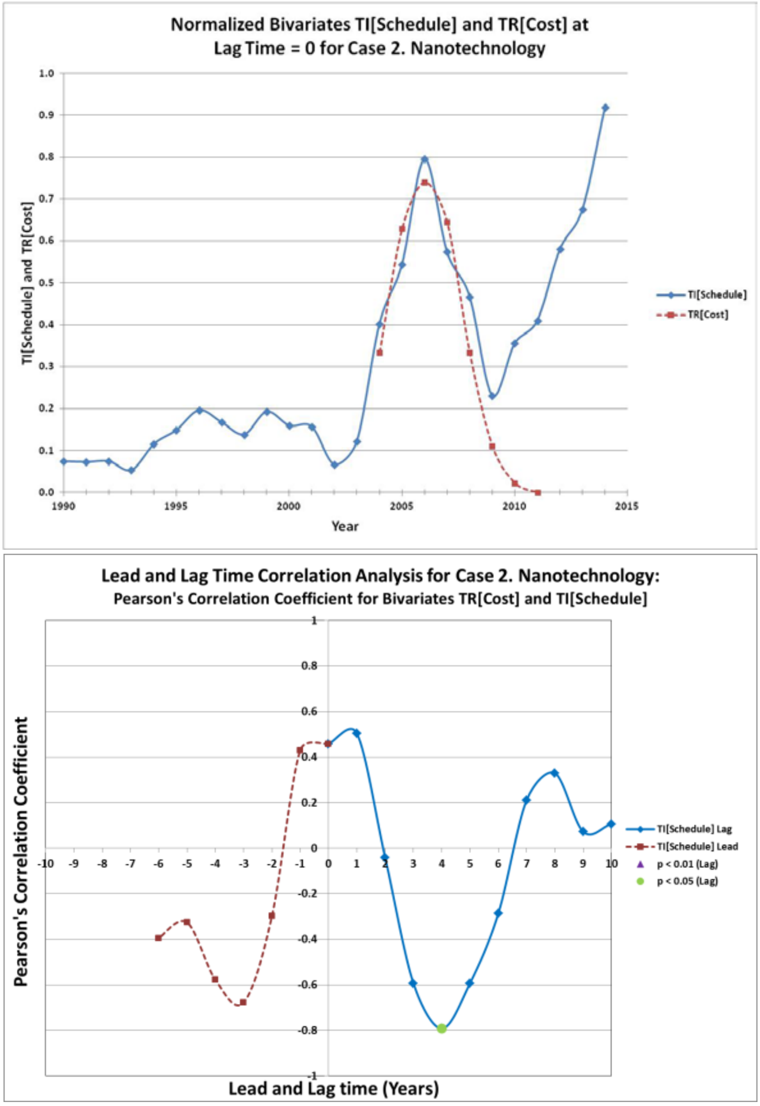


Figure 6B-9b. Comparison removing leading zeroes between normalized bivariates TI[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Schedule] and TR[Cost]

TI[Guideline] and TI/TR[Audience]

The results for TI[Guideline] and TI/TR[Audience] are shown in Figure 6B-10a and Figure 6B-10b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. In both the conservative and un-conservative cases, the strongest positive correlation occurs when TI[Guideline] leads TI/TR[Audience] by 10 years. As this technology is early in the maturity cycle, it is expected that there is not an uptake in the number of engineers until the technology shows more promise.

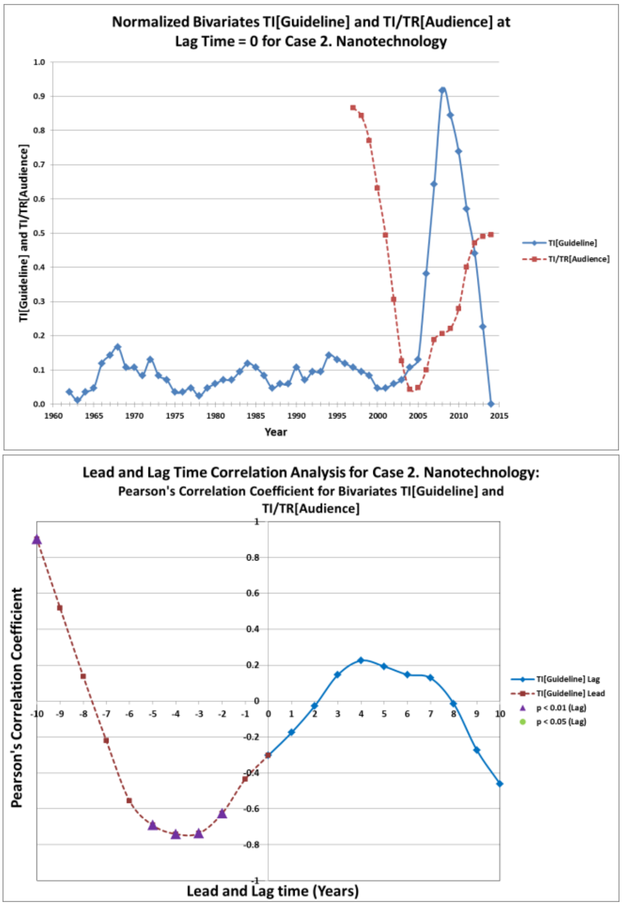
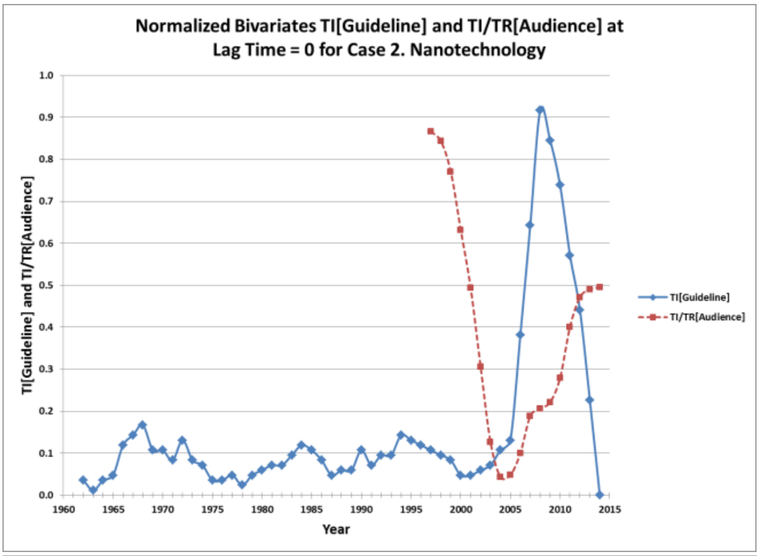


Figure 6B-10a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TI/TR[Audience]



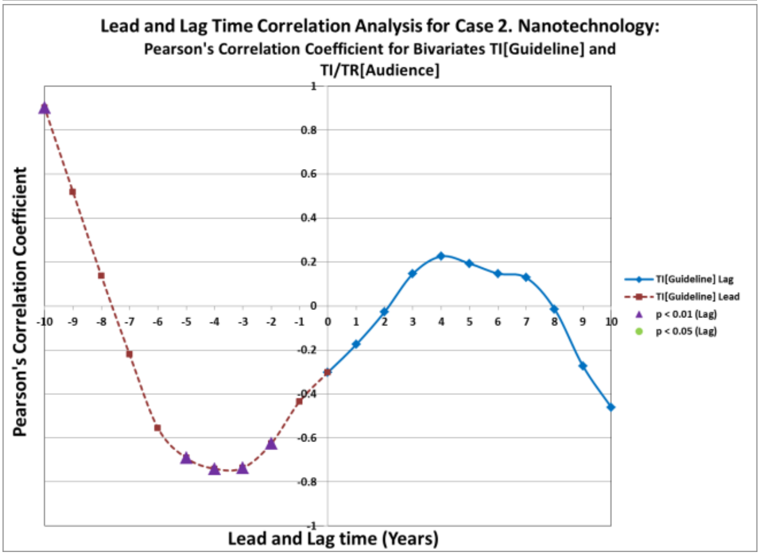


Figure 6B-10b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TI/TR[Audience]

TI[Guideline] and TR[Schedule]

The results for TI[Guideline] and TR[Schedule] are shown in Figure 6B-11a and Figure 6B-11b. In the conservative case, TI[Guideline] inversely lags TR[Schedule] by about 2-5 years, as well as positively leads by 2-3 years. In the un-conservative case, the most significant positive correlation occurs when TI[Guideline] leads TR[Schedule] by about 2-3 years. As this is a technology that is early in the maturity cycle, it is not expected that training occurs later when the technology shows more promise.

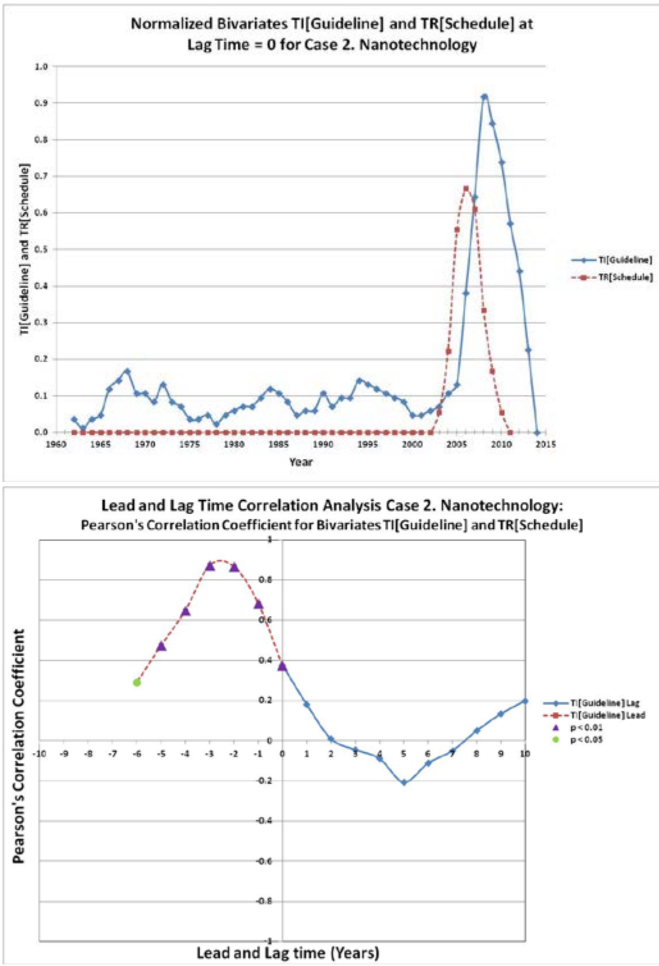


Figure 6B-11a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Schedule]

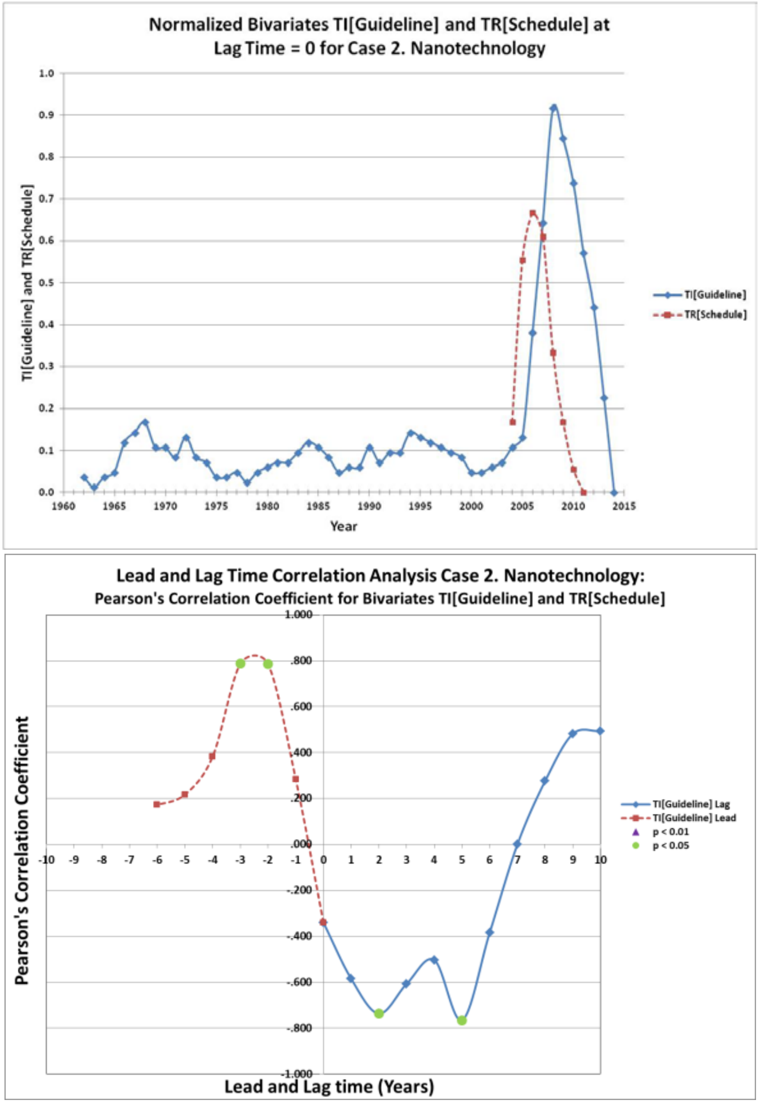
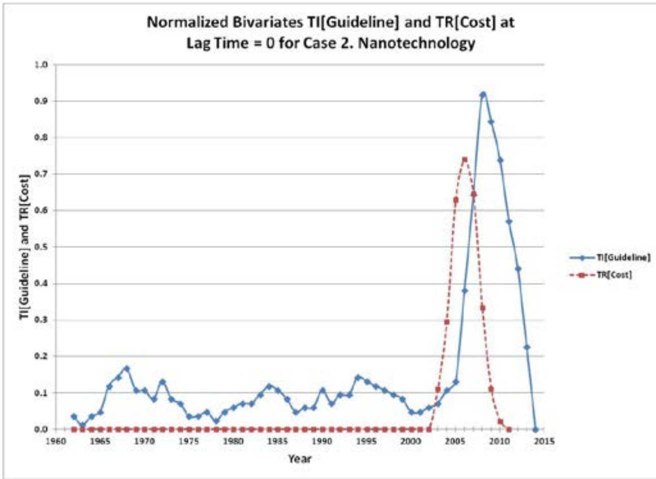


Figure 6B-11b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TR[Schedule] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Schedule]

TI[Guideline] and TR[Cost]

The results for TI[Guideline] and TR[Cost] are shown in Figure 6B-12a and Figure 6B-12b. In the conservative case, TI[Guideline] inversely lags TR[Cost] by about 1-5 years, as well as positively leads by 2-3 years. In the un-conservative case, the most significant positive correlation occurs when TI[Guideline] leads TR[Cost] by about 2-3 years. As this is a technology that is early in the maturity cycle, it is not expected that training occurs later when the technology shows more promise.



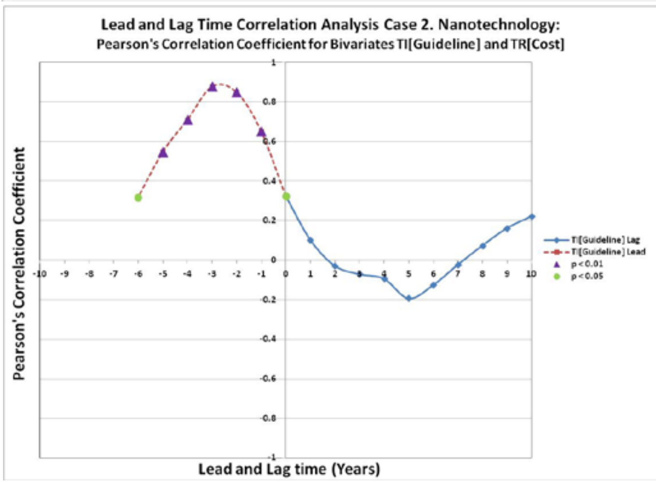


Figure 6B-12a. Comparison using leading zeroes between normalized bivariates TI[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Cost]

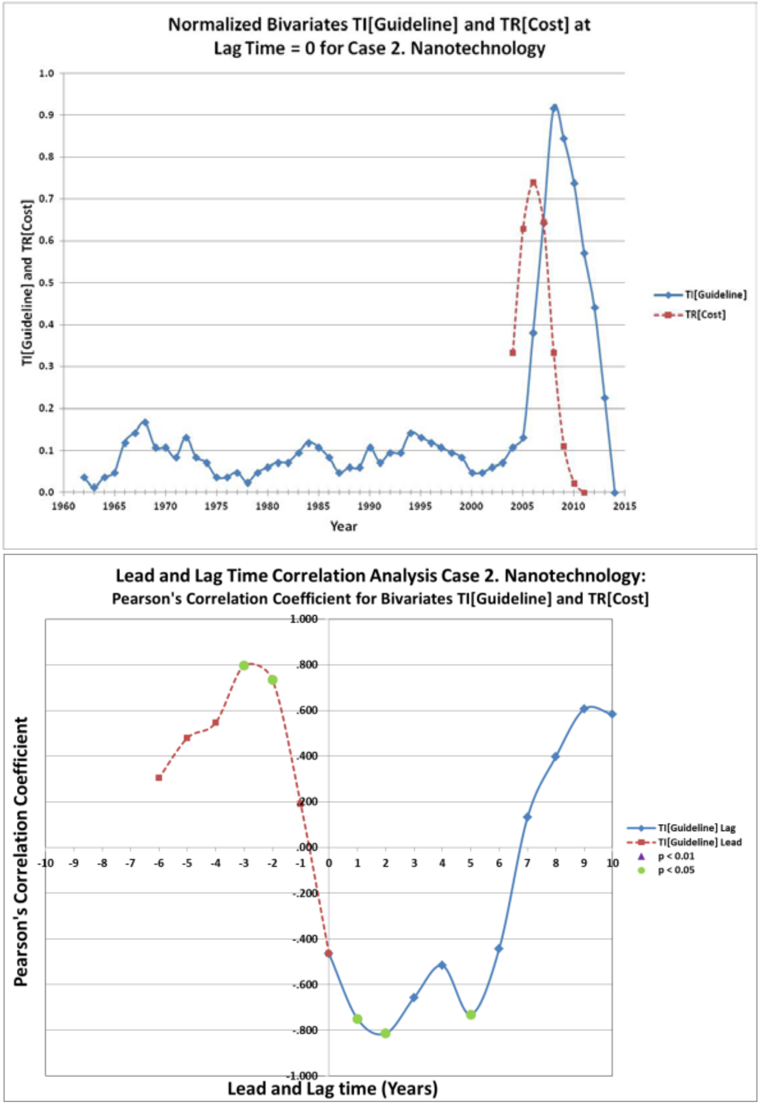


Figure 6B-12b. Comparison removing leading zeroes between normalized bivariates TI[Guideline] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TI[Guideline] and TR[Cost]

TR[Schedule] and TI/TR[Audience]

The results for TR[Schedule] and TI/TR[Audience] are shown in Figure 6B-13a and Figure 6B-13b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. In both the conservative and un-conservative cases, the most significant positive correlation occurs when TI/TR[Audience] lags TR[Schedule] by about 8 years. In this case, where the technology is early in the maturity cycle, it is expected that the training was offered too early, where the targeted audience was not available and/or not ready to take the courses.

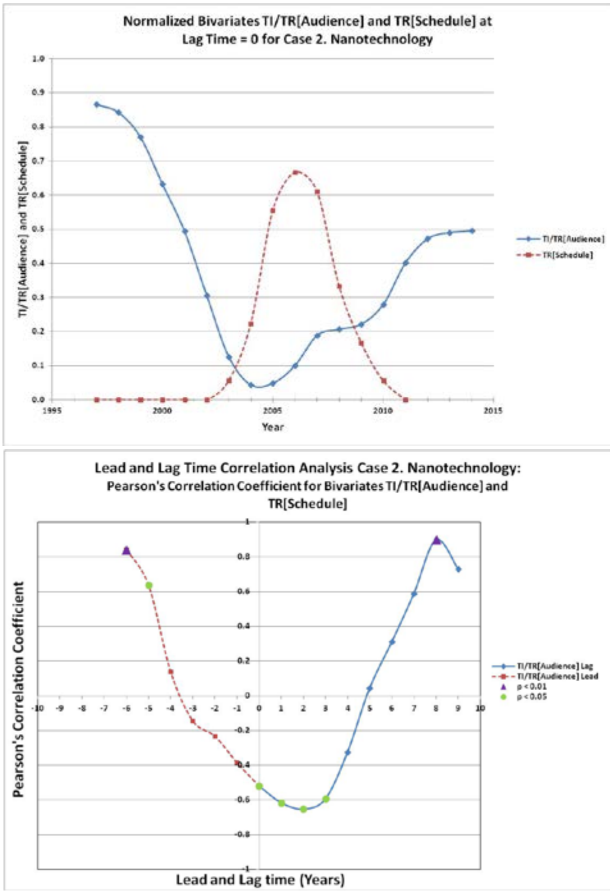


Figure 6B-13a. Comparison using leading zeroes between normalized bivariates TR[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TI/TR[Audience]

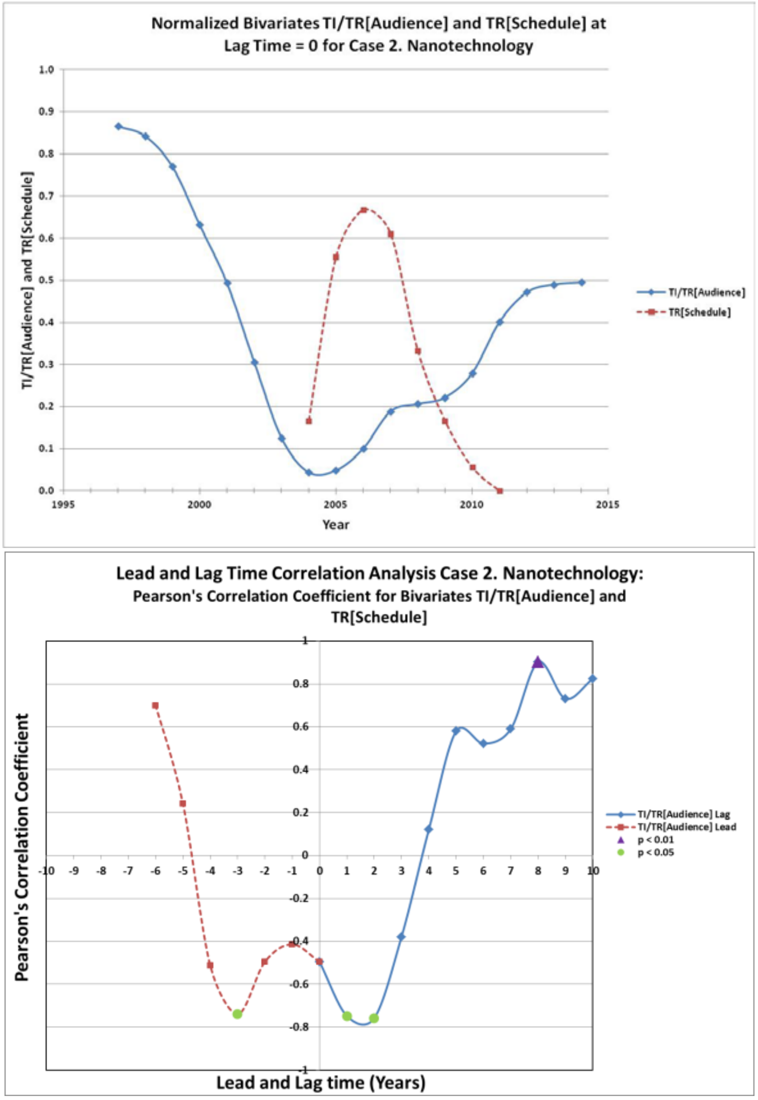


Figure 6B-13b. Comparison removing leading zeroes between normalized bivariates TR[Schedule] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TI/TR[Audience]

TR[Cost] and TI/TR[Audience]

The results for TR[Cost] and TI/TR[Audience] are shown in Figure 6B-14a and Figure 6B-14b. All data for TI/TR[Audience] should be considered cautiously as the set of data for TI/TR[Audience] does not contain only the audience in which the training referred to in this research was designed for. It may be possible that not all the audience included in this data set will need to take the training that is described in this research. Similar to TR[Schedule], in both the conservative and un-conservative cases, the most significant positive correlation occurs when TI/TR[Audience] lags TR[Cost] by about 8 years. In this case, where the technology is early in the maturity cycle, it is expected that the training was offered too early, where the targeted audience was not available and/or not ready to take the courses.

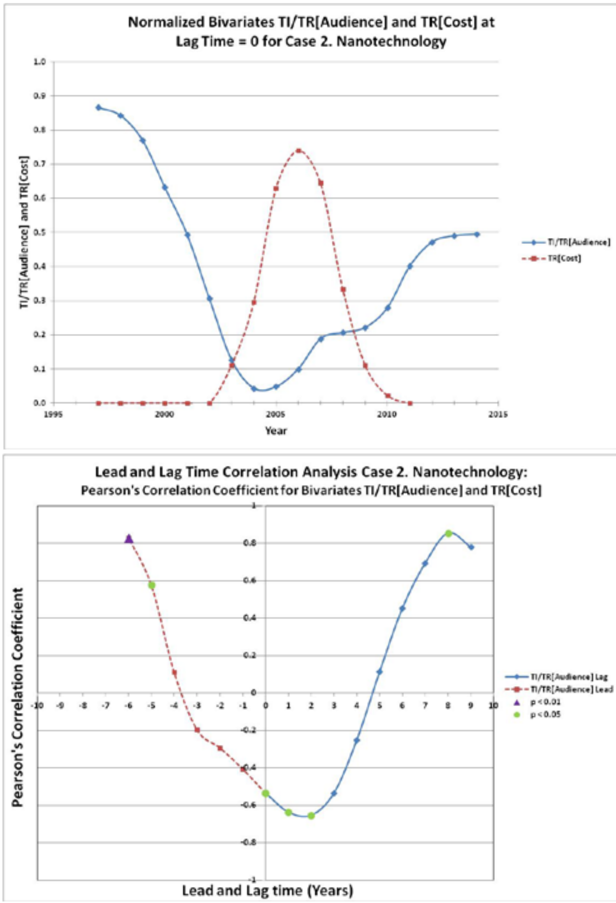


Figure 6B-14a. Comparison using leading zeroes between normalized bivariates TR[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Cost] and TI/TR[Audience]

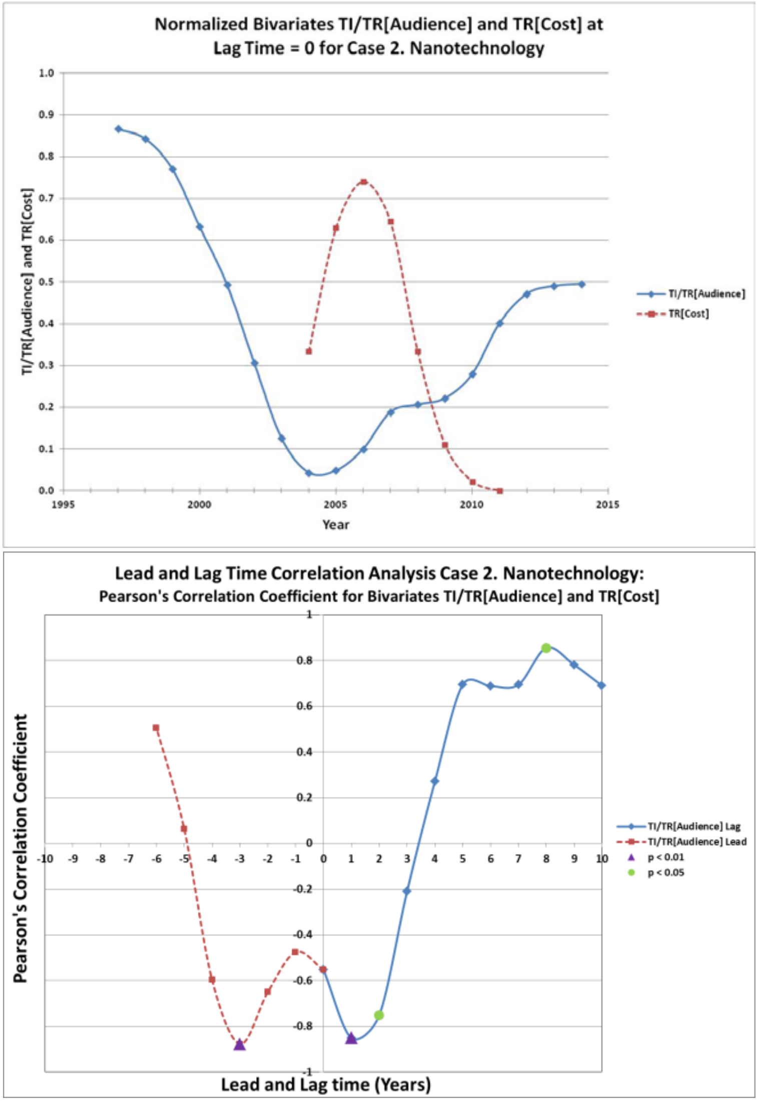


Figure 6B-14b. Comparison removing leading zeroes between normalized bivariates TR[Cost] and TI/TR[Audience] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Cost] and TI/TR[Audience]

TR[Schedule] and TR[Cost]

The results for TR[Schedule] and TR[Cost] are shown in Figure 6B-15a and Figure 6B-15b. The results for this data set are inconclusive, as there are not enough data points to show any significance. However, if there were more data available for this bivariate set, it would be expected that there is a strong positive correlation. The number of student hours completing courses per technology per year is derived from the number of courses delivered per technology innovation per year.

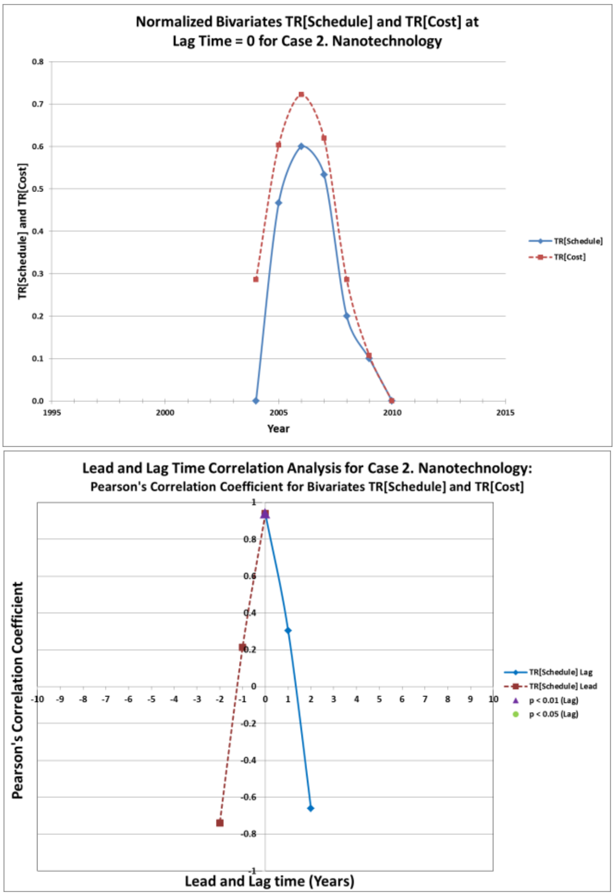


Figure 6B-15a. Comparison using leading zeroes between normalized bivariates TR[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TR[Cost]

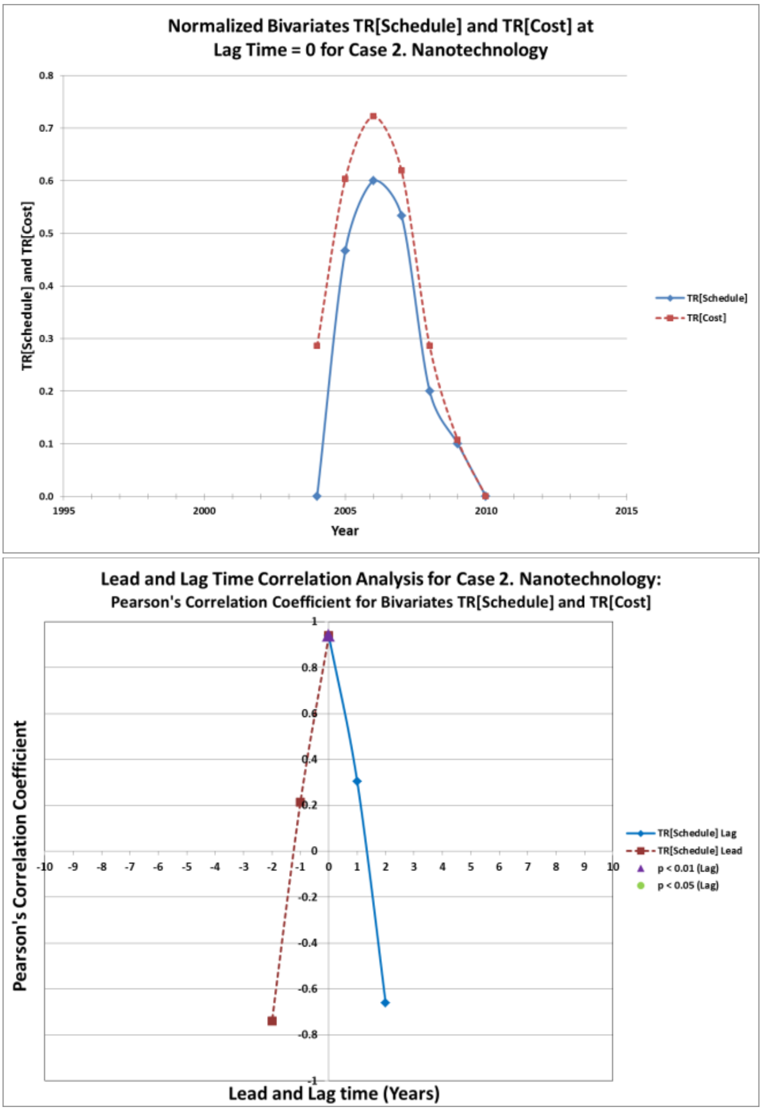


Figure 6B-15b. Comparison removing leading zeroes between normalized bivariates TR[Schedule] and TR[Cost] at lag time = 0, and lead and lag time correlation analysis using Pearson's correlation coefficient for bivariates TR[Schedule] and TR[Cost]

Appendix 6C

Cross Correlation Coefficient Matrices for Case 1 – Composites

Appendix 6C lists the cross correlation coefficient matrices for case study 1 – composites. The cross correlation coefficient matrices corresponding to each of the lag and lead times are listed, where the summary of the most significant bivariates are summarized in Table 6C-1.

The overall summary of the most significant bivariates Case 1 - Composites are shown in the summary cross correlation coefficient matrix in Table 6C-1. The cross correlation coefficient matrices with p-values for Case 1 - Composites are shown in Table 6C-2 through Table 6C-22.

Table 6C-1. Summary of most significant bivariates

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.668* (TIOE[Guideline], x-10)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.978** (TIOE[Schedule], x+10)	-0.904** (TIOE[Guideline], x+8)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.806** (TI[Schedule], x+7)	-0.420* (TIOE[Guideline], x+1)	0.870* (TI[Schedule], x-6)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.852** (TIOE[Schedule], x+9)	-0.433* (TI[Guideline], x-8)	0.902** (TI[Guideline], x=0)	*no significant correlation*	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.908** (TIOE[Schedule], x-10)	-0.906** (TIOE[Guideline], x-5)	-0.892** (TI/TR[Audience], x+5)	*no significant correlation*	-0.706** (TI[Guideline], x-3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	*no significant correlation*	*no significant correlation*	0.998* (TIOE[Cost], x=0)	*no significant correlation*	*no significant correlation*	*no significant correlation*	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation*	*no significant correlation - too little data points*	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

Table 6C-2. Cross correlation coefficient matrix for lag = 0

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.041 (p = 0.862)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.827**	0.829**	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.505*	-0.240 (p = 0.249)	0.173 (p = 0.657)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.303 (p = 0.194)	0.353 (p = 0.056)	0.902**	0.090 (p = 0.669)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.250 (p = 0.318)	0.354 (p = 0.149)	0.670*	-0.238 (p = 0.883)	-0.130 (p = 0.608)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.492 (p = 0.322)	-0.388 (p = 0.448)	0.998*	-0.309 (p = 0.552)	-0.409 (p = 0.421)	0.158 (p = 0.765)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.269 (p = 0.607)	-0.388 (p = 0.448)	0.379 (p = 0.752)	0.173 (p = 0.743)	-0.226 (p = 0.667)	0.666 (p = 0.149)	0.361 (p = 0.482)	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-3. Cross correlation coefficient matrix for lag = 1

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.036 (p = 0.880) (TIOE[Guideline], x+1)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.714* (TIOE[Schedule], x+1)	0.733* (TIOE[Guideline], x+1)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.475* (TI[Schedule], x+1)	-0.420* (TIOE[Guideline], x+1)	0.474 (p = 0.197) (TI[Schedule], x+1)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.239 (p = 0.325) (TIOE[Schedule], x+1)	0.317 (p = 0.088) (TI[Guideline], x+1)	0.797* (TI[Guideline], x+1)	-0.085 (p = 0.686) (TI[Guideline], x+1)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.195 (p = 0.439) (TIOE[Schedule], x+1)	0.658** (TIOE[Guideline], x+1)	0.054 (p = 0.890) (TI/TR[Audience], x+1)	-0.137 (p = 0.936) (TI/TR[Audience], x+1)	0.159 (p = 0.529) (TI[Guideline], x+1)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.195 (p = 0.711) (TIOE[Schedule], x+1)	-0.337 (p = 0.514) (TIOE[Guideline], x+1)	0.855 (p = 0.145) (TIOE[Cost], x+1)	0.210 (p = 0.690) (TI[Schedule], x+1)	-0.238 (p = 0.650) (TI[Guideline], x+1)	0.440 (p = 0.382) (TI/TR[Audience], x+1)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.223 (p = 0.671) (TIOE[Schedule], x+1)	-0.337 (p = 0.514) (TIOE[Guideline], x+1)	-0.666 (p = 0.334) (TIOE[Cost], x+1)	0.796 (p = 0.058) (TI[Schedule], x+1)	-0.100 (p = 0.851) (TI[Guideline], x+1)	0.422 (p = 0.404) (TI/TR[Audience], x+1)	0.215 (p = 0.729) (TR[Cost], x+1)	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-4. Cross correlation coefficient matrix for lag = 2

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.015 (p = 0.949) (TIOE[Guideline], x+2)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.403 (p = 0.282) (TIOE[Schedule], x+2)	0.692* (TIOE[Guideline], x+2)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.402 (p = 0.079) (TI[Schedule], x+2)	-0.365 (p = 0.073) (TIOE[Guideline], x+2)	0.785* (TI[Schedule], x+2)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.229 (p = 0.361) (TIOE[Schedule], x+2)	0.055 (p = 0.774) (TI[Guideline], x+2)	0.611 (p = 0.081) (TI[Guideline], x+2)	0.008 (p = 0.970) (TI[Guideline], x+2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.019 (p = 0.939) (TIOE[Schedule], x+2)	0.858** (TIOE[Guideline], x+2)	-0.500 (p = 0.171) (TI/TR[Audience], x+2)	-0.168 (p = 0.802) (TI/TR[Audience], x+2)	0.458 (p = 0.056) (TI[Guideline], x+2)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.532 (p = 0.277) (TIOE[Schedule], x+2)	0.230 (p = 0.661) (TIOE[Guideline], x+2)	-0.307 (p = 0.615) (TIOE[Cost], x+2)	0.139 (p = 0.793) (TI[Schedule], x+2)	0.231 (p = 0.660) (TI[Guideline], x+2)	0.413 (p = 0.415) (TI/TR[Audience], x+2)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.212 (p = 0.686) (TIOE[Schedule], x+2)	-0.069 (p = 0.897) (TIOE[Guideline], x+2)	-0.675 (p = 0.211) (TIOE[Cost], x+2)	-0.416 (p = 0.412) (TI[Schedule], x+2)	-0.694 (p = 0.126) (TI[Guideline], x+2)	-0.081 (p = 0.878) (TI/TR[Audience], x+2)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-5. Cross correlation coefficient matrix for lag = 3

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.070 (p = 0.768) (TIOE[Guideline], x+3)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.079 (p = 0.841) (TIOE[Schedule], x+3)	0.400 (p = 0.400) (TIOE[Guideline], x+3)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.341 (p = 0.141) (TI[Schedule], x+3)	-0.354 (p = 0.083) (TIOE[Guideline], x+3)	0.582 (p = 0.100) (TI[Schedule], x+3)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.187 (p = 0.473) (TIOE[Schedule], x+3)	0.056 (p = 0.770) (TI[Guideline], x+3)	0.353 (p = 0.351) (TI[Guideline], x+3)	0.130 (p = 0.536) (TI[Guideline], x+3)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.186 (p = 0.474) (TIOE[Schedule], x+3)	0.900** (TIOE[Guideline], x+3)	-0.793* (TI/TR[Audience], x+3)	-0.135 (p = 0.505) (TI/TR[Audience], x+3)	0.542* (TI[Guideline], x+3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.576 (p = 0.231) (TIOE[Schedule], x+3)	0.338 (p = 0.513) (TIOE[Guideline], x+3)	0.011 (p = 0.983) (TIOE[Cost], x+3)	-0.019 (p = 0.972) (TI[Schedule], x+3)	-0.109 (p = 0.838) (TI[Guideline], x+3)	-0.249 (p = 0.635) (TI/TR[Audience], x+1)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.108 (p = 0.839) (TIOE[Schedule], x+3)	0.375 (p = 0.464) (TIOE[Guideline], x+3)	0.154 (p = 0.770) (TIOE[Cost], x+3)	-0.233 (p = 0.657) (TI[Schedule], x+3)	-0.266 (p = 0.610) (TI[Guideline], x+3)	-0.241 (p = 0.645) (TI/TR[Audience], x+3)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-6. Cross correlation coefficient matrix for lag = 4

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.062 (p = 0.794) (TIOE[Guideline], x+4)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.754* (TIOE[Schedule], x+4)	-0.088 (p = 0.821) (TIOE[Guideline], x+4)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.177 (p = 0.455) (TI[Schedule], x+4)	-0.350 (p = 0.086) (TIOE[Guideline], x+4)	0.483 (p = 0.188) (TI[Schedule], x+4)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.199 (p = 0.460) (TIOE[Schedule], x+4)	-0.001 (p = 0.996) (TI[Guideline], x+4)	0.020 (p = 0.958) (TI[Guideline], x+4)	0.164 (p = 0.433) (TI[Guideline], x+4)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.170 (p = 0.530) (TIOE[Schedule], x+4)	0.852** (TIOE[Guideline], x+4)	-0.763* (TI/TR[Audience], x+4)	-0.168 (p = 0.593) (TI/TR[Audience], x+4)	0.496* (TI[Guideline], x+4)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.211 (p = 0.688) (TIOE[Schedule], x+4)	-0.125 (p = 0.814) (TIOE[Guideline], x+4)	0.167 (p = 0.752) (TIOE[Cost], x+4)	-0.714 (p = 0.111) (TI[Schedule], x+4)	0.014 (p = 0.978) (TI[Guideline], x+4)	0.185 (p = 0.726) (TI/TR[Audience], x+4)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.014 (p = 0.979) (TIOE[Schedule], x+4)	0.021 (p = 0.968) (TIOE[Guideline], x+4)	0.311 (p = 0.549) (TIOE[Cost], x+4)	-0.657 (p = 0.157) (TI[Schedule], x+4)	0.219 (p = 0.676) (TI[Guideline], x+4)	0.558 (p = 0.250) (TI/TR[Audience], x+4)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-7. Cross correlation coefficient matrix for lag = 5

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.112 (p = 0.639) (TIOE[Guideline], x+5)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.921** (TIOE[Schedule], x+5)	-0.592 (p = 0.093) (TIOE[Guideline], x+5)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.245 (p = 0.297) (TI[Schedule], x+5)	-0.417* (TIOE[Guideline], x+5)	0.118 (p = 0.763) (TI[Schedule], x+5)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.309 (p = 0.263) (TIOE[Schedule], x+5)	-0.103 (p = 0.587) (TI[Guideline], x+5)	-0.381 (p = 0.311) (TI[Guideline], x+5)	0.111 (p = 0.597) (TI[Guideline], x+5)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.223 (p = 0.424) (TIOE[Schedule], x+5)	0.829** (TIOE[Guideline], x+5)	-0.892** (TI/TR[Audience], x+5)	-0.064 (p = 0.505) (TI/TR[Audience], x+5)	0.462 (p = 0.053) (TI[Guideline], x+5)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.249 (p = 0.634) (TIOE[Schedule], x+5)	0.630 (p = 0.180) (TIOE[Guideline], x+5)	0.391 (p = 0.443) (TIOE[Cost], x+5)	0.468 (p = 0.349) (TI[Schedule], x+5)	0.376 (p = 0.463) (TI[Guideline], x+5)	0.333 (p = 0.519) (TI/TR[Audience], x+5)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.606 (p = 0.203) (TIOE[Schedule], x+5)	0.422 (p = 0.405) (TIOE[Guideline], x+5)	0.276 (p = 0.597) (TIOE[Cost], x+5)	0.044 (p = 0.934) (TI[Schedule], x+5)	0.601 (p = 0.207) (TI[Guideline], x+5)	0.605 (p = 0.203) (TI/TR[Audience], x+5)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-8. Cross correlation coefficient matrix for lag = 6

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.236 (p = 0.317) (TIOE[Guideline], x+6)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.500 (p = 0.170) (TIOE[Schedule], x+6)	-0.663 (p = 0.051) (TIOE[Guideline], x+6)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.460* (TI[Schedule], x+6)	-0.400 (p = 0.053) (TIOE[Guideline], x+6)	-0.383 (p = 0.308) (TI[Schedule], x+6)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.324 (p = 0.258) (TIOE[Schedule], x+6)	-0.302 (p = 0.105) (TI[Guideline], x+6)	-0.497 (p = 0.174) (TI[Guideline], x+6)	0.060 (p = 0.774) (TI[Guideline], x+6)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.332 (p = 0.247) (TIOE[Schedule], x+6)	0.646** (TIOE[Guideline], x+6)	-0.839** (TI/TR[Audience], x+6)	0.020 (p = 0.588) (TI/TR[Audience], x+6)	0.235 (p = 0.347) (TI[Guideline], x+6)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.476 (p = 0.340) (TIOE[Schedule], x+6)	-0.171 (p = 0.746) (TIOE[Guideline], x+6)	0.139 (p = 0.793) (TIOE[Cost], x+6)	-0.285 (p = 0.584) (TI[Schedule], x+6)	0.317 (p = 0.540) (TI[Guideline], x+6)	0.342 (p = 0.508) (TI/TR[Audience], x+6)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.541 (p = 0.268) (TIOE[Schedule], x+6)	0.268 (p = 0.608) (TIOE[Guideline], x+6)	0.671 (p = 0.145) (TIOE[Cost], x+6)	0.198 (p = 0.707) (TI[Schedule], x+6)	0.483 (p = 0.332) (TI[Guideline], x+6)	0.520 (p = 0.291) (TI/TR[Audience], x+6)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-9. Cross correlation coefficient matrix for lag = 7

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.381 (p = 0.097) (TIOE[Guideline], x+7)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.085 (p = 0.827) (TIOE[Schedule], x+7)	-0.873** (TIOE[Guideline], x+7)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.806** (TI[Schedule], x+7)	-0.319 (p = 0.138) (TIOE[Guideline], x+7)	-0.223 (p = 0.564) (TI[Schedule], x+7)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.230 (p = 0.449) (TIOE[Schedule], x+7)	-0.281 (p = 0.133) (TI[Guideline], x+7)	-0.643 (p = 0.062) (TI[Guideline], x+7)	0.054 (p = 0.799) (TI[Guideline], x+7)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.082 (p = 0.789) (TIOE[Schedule], x+7)	0.385 (p = 0.114) (TIOE[Guideline], x+7)	-0.651 (p = 0.113) (TI/TR[Audience], x+7)	0.037 (p = 0.883) (TI/TR[Audience], x+7)	-0.217 (p = 0.386) (TI[Guideline], x+7)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.157 (p = 0.767) (TIOE[Schedule], x+7)	0.804 (p = 0.054) (TIOE[Guideline], x+7)	0.237 (p = 0.701) (TIOE[Cost], x+7)	0.567 (p = 0.240) (TI[Schedule], x+7)	0.495 (p = 0.318) (TI[Guideline], x+7)	-0.124 (p = 0.815) (TI/TR[Audience], x+7)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.279 (p = 0.592) (TIOE[Schedule], x+7)	0.598 (p = 0.210) (TIOE[Guideline], x+7)	0.224 (p = 0.717) (TIOE[Cost], x+7)	0.651 (p = 0.162) (TI[Schedule], x+7)	-0.075 (p = 0.888) (TI[Guideline], x+7)	0.156 (p = 0.768) (TI/TR[Audience], x+7)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-10. Cross correlation coefficient matrix for lag = 8

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	SMA Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
SMA Number of Memos relating to Composites [TIOE(Guideline)]	-0.490* (TIOE[Guideline], x+8)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.666 (p = 0.072) (TIOE[Schedule], x+8)	-0.904** (TIOE[Guideline], x+8)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.655** (TI[Schedule], x+8)	-0.305 (p = 0.168) (TIOE[Guideline], x+8)	-0.214 (p = 0.580) (TI[Schedule], x+8)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.383 (p = 0.219) (TIOE[Schedule], x+8)	-0.282 (p = 0.131) (TI[Guideline], x+8)	-0.965** (TI[Guideline], x+8)	0.048 (p = 0.821) (TI[Guideline], x+8)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.072 (p = 0.824) (TIOE[Schedule], x+8)	0.273 (p = 0.273) (TIOE[Guideline], x+8)	-0.557 (p = 0.251) (TI/TR[Audience], x+8)	-0.001 (p = 0.996) (TI/TR[Audience], x+8)	-0.385 (p = 0.115) (TI[Guideline], x+8)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.131 (p = 0.805) (TIOE[Schedule], x+8)	0.091 (p = 0.863) (TIOE[Guideline], x+8)		0.307 (p = 0.554) (TI[Schedule], x+8)	-0.322 (p = 0.534) (TI[Guideline], x+8)	-0.119 (p = 0.822) (TI/TR[Audience], x+8)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.489 (p = 0.325) (TIOE[Schedule], x+8)	-0.028 (p = 0.959) (TIOE[Guideline], x+8)		0.351 (p = 0.496) (TI[Schedule], x+8)	-0.656 (p = 0.157) (TI[Guideline], x+8)	-0.233 (0.656) (TI/TR[Audience], x+8)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-11. Cross correlation coefficient matrix for lag = 9

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.405 (p = 0.076) (TIOE[Guideline], x+9)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.847* (TIOE[Schedule], x+9)	-0.637 (p = 0.065) (TIOE[Guideline], x+9)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.720** (TI[Schedule], x+9)	-0.224 (p = 0.328) (TIOE[Guideline], x+9)	0.296 (p = 0.440) (TI[Schedule], x+9)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.852** (TIOE[Schedule], x+9)	-0.241 (p = 0.199) (TI[Guideline], x+9)	-0.600 (p = 0.087) (TI[Guideline], x+9)	0.158 (p = 0.451) (TI[Guideline], x+9)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.022 (p = 0.948) (TIOE[Schedule], x+9)	0.196 (p = 0.435) (TIOE[Guideline], x+9)	-0.358 (p = 0.554) (TI/TR[Audience], x+9)	0.033 (p = 0.904) (TI/TR[Audience], x+9)	-0.179 (p = 0.477) (TI[Guideline], x+9)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.180 (p = 0.734) (TIOE[Schedule], x+9)	-0.327 (p = 0.527) (TIOE[Guideline], x+9)		-0.106 (p = 0.841) (TI[Schedule], x+9)	-0.532 (p = 0.277) (TI[Guideline], x+9)	-0.200 (p = 0.704) (TI/TR[Audience], x+9)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.004 (p = 0.994) (TIOE[Schedule], x+9)	0.174 (p = 0.742) (TIOE[Guideline], x+9)		-0.570 (p = 0.238) (TI[Schedule], x+9)	0.194 (p = 0.712) (TI[Guideline], x+9)	-0.464 (p = 0.354) (TI/TR[Audience], x+9)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-12. Cross correlation coefficient matrix for lag = 10

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.445* (TIOE[Guideline], x+10)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.978** (TIOE[Schedule], x+10)	-0.642 (p = 0.063) (TIOE[Guideline], x+10)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.151 (p = 0.591) (TI[Schedule], x+10)	-0.365 (p = 0.114) (TIOE[Guideline], x+10)	0.335 (p = 0.377) (TI[Schedule], x+10)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.748* (TIOE[Schedule], x+10)	-0.268 (p = 0.153) (TI[Guideline], x+10)	-0.230 (p = 0.551) (TI[Guideline], x+10)	0.239 (p = 0.249) (TI[Guideline], x+10)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.126 (p = 0.729) (TIOE[Schedule], x+10)	-0.072 (p = 0.776) (TIOE[Guideline], x+10)	0.455 (p = 0.545) (TI/TR[Audience], x+10)	-0.223 (p = 0.425) (TI/TR[Audience], x+10)	-0.123 (p = 0.626) (TI[Guideline], x+10)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.387 (p = 0.448) (TIOE[Schedule], x+10)	-0.062 (p = 0.906) (TIOE[Guideline], x+10)		0.104 (p = 0.845) (TI[Schedule], x+10)	0.298 (p = 0.566) (TI[Guideline], x+10)	-0.397 (p = 0.436) (TI/TR[Audience], x+10)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.394 (p = 0.440) (TIOE[Schedule], x+10)	0.331 (p = 0.522) (TIOE[Guideline], x+10)		-0.252 (p = 0.631) (TI[Schedule], x+10)	0.766 (p = 0.076) (TI[Guideline], x+10)	-0.163 (p = 0.757) (TI/TR[Audience], x+10)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-13. Cross correlation coefficient matrix for lag = -1 (i.e. lead = 1)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.107 (p = 0.664) (TIOE[Guideline], x-1)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.727* (TIOE[Schedule], x-1)	0.774* (TIOE[Guideline], x-1)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.452 (p = 0.052) (TI[Schedule], x-1)	-0.253 (p = 0.234) (TIOE[Guideline], x-1)	-0.323 (p = 0.397) (TI[Schedule], x-1)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.024 (p = 0.920) (TIOE[Schedule], x-1)	0.177 (p = 0.360) (TI[Guideline], x-1)	0.775* (TI[Guideline], x-1)	0.203 (p = 0.341) (TI[Guideline], x-1)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.206 (p = 0.427) (TIOE[Schedule], x-1)	-0.081 (p = 0.757) (TIOE[Guideline], x-1)	0.653 (p = 0.057) (TI/TR[Audience], x-1)	-0.392 (p = 0.120) (TI/TR[Audience], x-1)	-0.412 (p = 0.101) (TI[Guideline], x-1)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.237 (p = 0.651) (TIOE[Schedule], x-1)	-0.208 (p = 0.692) (TIOE[Guideline], x-1)		0.624 (p = 0.185) (TI[Schedule], x-1)	-0.336 (p = 0.515) (TI[Guideline], x-1)	-0.036 (p = 0.947) (TI/TR[Audience], x-1)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.492 (p = 0.321) (TIOE[Schedule], x-1)	-0.713 (p = 0.112) (TIOE[Guideline], x-1)		0.189 (p = 0.720) (TI[Schedule], x-1)	-0.558 (p = 0.250) (TI[Guideline], x-1)	0.000 (p = 1) (TI/TR[Audience], x-1)	-0.374 (p = 0.536) (TR[Cost], x-1)	1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-14. Cross correlation coefficient matrix for lag = -2 (i.e. lead = 2)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.123 (p = 0.628) (TIOE[Guideline], x-2)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.510 (p = 0.161) (TIOE[Schedule], x-2)	0.666 (p = 0.050) (TIOE[Guideline], x-2)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.204 (p = 0.416) (TI[Schedule], x-2)	-0.140 (p = 0.523) (TIOE[Guideline], x-2)	-0.505 (p = 0.166) (TI[Schedule], x-2)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.379 (p = 0.099) (TIOE[Schedule], x-2)	-0.007 (p = 0.972) (TI[Guideline], x-2)	0.428 (p = 0.251) (TI[Guideline], x-2)	0.351 (p = 0.101) (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.032 (p = 0.907) (TIOE[Schedule], x-2)	-0.556* (TIOE[Guideline], x-2)	0.659 (p = 0.054) (TI/TR[Audience], x-2)	-0.449 (p = 0.081) (TI/TR[Audience], x-2)	-0.645** (TI[Guideline], x-2)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.279 (p = 0.649) (TIOE[Schedule], x-2)	0.020 (p = 0.975) (TIOE[Guideline], x-2)		0.030 (p = 0.962) (TI[Schedule], x-2)	-0.089 (p = 0.886) (TI[Guideline], x-2)	0.194 (p = 0.755) (TI/TR[Audience], x-2)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	0.435 (p = 0.464) (TIOE[Schedule], x-2)	-0.068 (p = 0.913) (TIOE[Guideline], x-2)		0.221 (p = 0.720) (TI[Schedule], x-2)	-0.358 (p = 0.554) (TI[Guideline], x-2)	-0.396 (p = 0.510) (TI/TR[Audience], x-2)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-15. Cross correlation coefficient matrix for lag = -3 (i.e. lead = 3)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.135 (p = 0.606) (TIOE[Guideline], x-3)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.422 (p = 0.258) (TIOE[Schedule], x-3)	0.555 (p = 0.121) (TIOE[Guideline], x-3)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.027 (p = 0.918) (TI[Schedule], x-3)	-0.014 (p = 0.952) (TIOE[Guideline], x-3)	-0.164 (p = 0.673) (TI[Schedule], x-3)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.540* (TIOE[Schedule], x-3)	0.029 (p = 0.887) (TI[Guideline], x-3)	-0.139 (p = 0.721) (TI[Guideline], x-3)	0.306 (p = 0.166) (TI[Guideline], x-3)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.238 (p = 0.393) (TIOE[Schedule], x-3)	-0.737** (TIOE[Guideline], x-3)	0.730* (TI/TR[Audience], x-3)	-0.427 (p = 0.113) (TI/TR[Audience], x-3)	-0.706** (TI[Guideline], x-3)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	-0.644 (p = 0.356) (TIOE[Schedule], x-3)	0.237 (p = 0.763) (TIOE[Guideline], x-3)		-0.474 (p = 0.526) (TI[Schedule], x-3)	0.464 (p = 0.536) (TI[Guideline], x-3)	-0.394 (p = 0.606) (TI/TR[Audience], x-3)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.419 (p = 0.581) (TIOE[Schedule], x-3)	0.724 (p = 0.276) (TIOE[Guideline], x-3)		0.346 (p = 0.654) (TI[Schedule], x-3)	0.482 (p = 0.518) (TI[Guideline], x-3)	-0.711 (p = 0.289) (TI/TR[Audience], x-3)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-16. Cross correlation coefficient matrix for lag = -4 (i.e. lead = 4)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.052 (p = 0.849) (TIOE[Guideline], x-4)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.570 (p = 0.109) (TIOE[Schedule], x-4)	-0.171 (p = 0.660) (TIOE[Guideline], x-4)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.233 (p = 0.386) (TI[Schedule], x-4)	0.055 (p = 0.812) (TIOE[Guideline], x-4)	0.043 (p = 0.912) (TI[Schedule], x-4)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.578** (TIOE[Schedule], x-4)	-0.073 (p = 0.722) (TI[Guideline], x-4)	-0.696* (TI[Guideline], x-4)	0.248 (p = 0.278) (TI[Guideline], x-4)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.444 (p = 0.112) (TIOE[Schedule], x-4)	-0.820** (TIOE[Guideline], x-4)	0.779* (TI/TR[Audience], x-4)	-0.397 (p = 0.159) (TI/TR[Audience], x-4)	-0.634* (TI[Guideline], x-4)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	0.910 (p = 0.272) (TIOE[Schedule], x-4)				-0.684 (p = 0.521) (TI[Guideline], x-4)	0.160 (p = 0.898) (TI/TR[Audience], x-4)	1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]	-0.687 (p = 0.517) (TIOE[Schedule], x-4)			-0.936 (p = 0.229) (TI[Schedule], x-4)	0.912 (p = 0.269) (TI[Guideline], x-4)	0.882 (p = 0.313) (TI/TR[Audience], x-4)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-17. Cross correlation coefficient matrix for lag = -5 (i.e. lead = 5)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.082 (p = 0.771) (TIOE[Guideline], x-5)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.871** (TIOE[Schedule], x-5)	-0.543 (p = 0.164) (TIOE[Guideline], x-5)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.219 (p = 0.433) (TI[Schedule], x-5)	0.114 (p = 0.633) (TIOE[Guideline], x-5)	0.599 (p = 0.117) (TI[Schedule], x-5)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.570** (TIOE[Schedule], x-5)	-0.156 (p = 0.458) (TI[Guideline], x-5)	-0.873** (TI[Guideline], x-5)	0.122 (p = 0.610) (TI[Guideline], x-5)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.515 (p = 0.071) (TIOE[Schedule], x-5)	-0.906** (TIOE[Guideline], x-5)	0.786* (TI/TR[Audience], x-5)	-0.279 (p = 0.355) (TI/TR[Audience], x-5)	-0.569* (TI[Guideline], x-5)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-18. Cross correlation coefficient matrix for lag = -6 (i.e. lead = 6)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.059 (p = 0.840) (TIOE[Guideline], x-6)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.813* (TIOE[Schedule], x-6)	-0.799* (TIOE[Guideline], x-6)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.581* (TI[Schedule], x-6)	0.017 (p = 0.943) (TIOE[Guideline], x-6)	0.870* (TI[Schedule], x-6)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.479* (TIOE[Schedule], x-6)	-0.324 (p = 0.123) (TI[Guideline], x-6)	-0.816* (TI[Guideline], x-6)	-0.058 (p = 0.812) (TI[Guideline], x-6)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.508 (p = 0.092) (TIOE[Schedule], x-6)	-0.862** (TIOE[Guideline], x-6)	0.762* (TI/TR[Audience], x-6)	-0.047 (p = 0.884) (TI/TR[Audience], x-6)	-0.464 (p = 0.129) (TI[Guideline], x-6)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-19. Cross correlation coefficient matrix for lag = -7 (i.e. lead = 7)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	-0.027 (p = 0.931) (TIOE[Guideline], x-7)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.852* (TIOE[Schedule], x-7)	-0.814* (TIOE[Guideline], x-7)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.617* (TI[Schedule], x-7)	0.057 (p = 0.824) (TIOE[Guideline], x-7)	0.510 (p = 0.302) (TI[Schedule], x-7)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	0.131 (p = 0.581) (TIOE[Schedule], x-7)	-0.370 (p = 0.083) (TI[Guideline], x-7)	-0.797 (p = 0.058) (TI[Guideline], x-7)	-0.235 (p = 0.348) (TI[Guideline], x-7)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.624* (TIOE[Schedule], x-7)	-0.634* (TIOE[Guideline], x-7)	0.355 (p = 0.490) (TI/TR[Audience], x-7)	0.158 (p = 0.644) (TI/TR[Audience], x-7)	-0.150 (p = 0.660) (TI[Guideline], x-7)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-20. Cross correlation coefficient matrix for lag = -8 (i.e. lead = 8)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.348 (p = 0.268) (TIOE[Guideline], x-8)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	0.450 (p = 0.447) (TIOE[Schedule], x-8)	-0.201 (p = 0.746) (TIOE[Guideline], x-8)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.563 (p = 0.056) (TI[Schedule], x-8)	-0.024 (p = 0.926) (TIOE[Guideline], x-8)	0.135 (p = 0.828) (TI[Schedule], x-8)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.356 (p = 0.123) (TIOE[Schedule], x-8)	-0.433* (TI[Guideline], x-8)	-0.432 (p = 0.468) (TI[Guideline], x-8)	-0.309 (p = 0.228) (TI[Guideline], x-8)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.692* (TIOE[Schedule], x-8)	-0.429 (p = 0.216) (TIOE[Guideline], x-8)	-0.376 (p = 0.533) (TI/TR[Audience], x-8)	-0.024 (p = 0.948) (TI/TR[Audience], x-8)	0.274 (p = 0.444) (TI[Guideline], x-8)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6C-21. Cross correlation coefficient matrix for lag = -9 (i.e. lead = 9)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.556 (p = 0.076) (TIOE[Guideline], x-9)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.102 (p = 0.898) (TIOE[Schedule], x-9)	0.448 (p = 0.552) (TIOE[Guideline], x-9)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.076 (p = 0.824) (TI[Schedule], x-9)	0.132 (p = 0.626) (TIOE[Guideline], x-9)	0.639 (p = 0.361) (TI[Schedule], x-9)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.418 (p = 0.067) (TIOE[Schedule], x-9)	-0.395 (p = 0.076) (TI[Guideline], x-9)	0.158 (p = 0.842) (TI[Guideline], x-9)	-0.295 (p = 0.268) (TI[Guideline], x-9)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.775* (TIOE[Schedule], x-9)	0.036 (p = 0.927) (TIOE[Guideline], x-9)	-0.681 (p = 0.319) (TI/TR[Audience], x-9)	-0.170 (p = 0.662) (TI/TR[Audience], x-9)	0.274 (p = 0.444) (TI[Guideline], x-9)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6C-22. Cross correlation coefficient matrix for lag = -10 (i.e. lead = 10)

	Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	Number of Memos relating to Composites [TIOE(Guideline)]	Total Commercial Composite Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Composite TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]	Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]
Total Commercial 777 and 787 Airplanes Delivered [TIOE(Schedule)]	1.000							
Number of Memos relating to Composites [TIOE(Guideline)]	0.668* (TIOE[Guideline], x-10)	1.000						
Total Commercial Composite Investment [TIOE(Cost)]	-0.496 (p = 0.670) (TIOE[Schedule], x-10)	0.976 (p = 0.141) (TIOE[Guideline], x-10)	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.601 (p = 0.066) (TI[Schedule], x-10)	0.464 (p = 0.082) (TIOE[Guideline], x-10)	-0.826 (p = 0.381) (TI[Schedule], x-10)	1.000				
Total Commercial Composite TI Patents Filed [TI(Guideline)]	-0.311 (p = 0.183) (TIOE[Schedule], x-10)	-0.331 (p = 0.153) (TI[Guideline], x-10)	0.789 (p = 0.421) (TI[Guideline], x-10)	0.303 (p = 0.273) (TI[Guideline], x-10)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.908** (TIOE[Schedule], x-10)	0.545 (p = 0.163) (TIOE[Guideline], x-10)	0.968 (p = 0.160) (TI/TR[Audience], x-10)	-0.347 (p = 0.399) (TI/TR[Audience], x-10)	0.274 (p = 0.444) (TI[Guideline], x-10)	1.000		
Total Number of Course Hours Delivered (Structures University) [TR(Schedule)]							1.000	
Total Number of Student Hours Completing Course (Structures University) [TR(Cost)]								1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

APPENDIX 6D

CROSS CORRELATION COEFFICIENT MATRICES FOR CASE 2 – NANOTECHNOLOGY

Appendix 6D lists the cross correlation coefficient matrices for case study 2 – nanotechnology. The cross correlation coefficient matrices corresponding to each of the lag and lead times are listed, where the summary of the most significant bivariates are summarized in Table 6D-1.

The overall summary of the most significant bivariates for Case 2 - Nanotechnology are shown in the summary cross correlation coefficient matrix in Table 6D-1. The cross correlation coefficient matrices with p-values for Case 2 - Nanotechnology are shown in Table 6D-2 through Table 6D-22.

Table 6D-1. Summary of most significant bivariates

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	no significant correlation	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	no significant correlation	0.703** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	no significant correlation	no significant correlation	no significant correlation	1.000		
Total Number of Courses Delivered [TR(Schedule)]	no significant correlation	-0.774* (TI[Schedule], x-3)	0.787* (TI[Guideline], x-3)	0.901** (TI/TR[Audience], x+8)	1.000	
Total Number of Students Completing Course [TR(Cost)]	no significant correlation	-0.792* (TI[Schedule], x+4)	-0.814* (TI[Guideline], x+2)	-0.878** (TI/TR[Audience], x-3)	no significant correlation - too little data points	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

'no significant correlation' means that there are no correlation coefficients in any lag or lead time that has a p-value < 0.05.

Table 6D-2. Cross correlation coefficient matrix for lag = 0

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.203 (p = 0.600)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.019 (p = 0.961)	0.238 (p = 0.252)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.550 (p = 0.125)	-0.238 (p = 0.037)	-0.302 (p = 0.224)	1.000		
Total Number of Courses Delivered [TR(Schedule)]	-0.006 (p = 0.989)	0.337 (p = 0.415)	-0.341 (p = 0.408)	-0.496 (p = 0.212)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.148 (p = 0.751)	0.458 (p = 0.253)	-0.466 (p = 0.245)	-0.553 (p = 0.155)	0.939**	1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Table 6D-3. Cross correlation coefficient matrix for lag = 1

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.003 (p = 0.994) (TI[Schedule], x+1)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.175 (p = 0.652) (TI[Guideline], x+1)	0.125 (p = 0.553) (TI[Guideline], x+1)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.505 (p = 0.166) (TI/TR[Audience], x+1)	-0.137 (p = 0.936) (TI[Schedule], x+1)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.308 (p = 0.458) (TIOE[Cost], x+1)	0.649 (p = 0.081) (TI[Schedule], x+1)	-0.585 (p = 0.127) (TI[Guideline], x+1)	-0.748* (TI[Audience], x+1)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.280 (p = 0.501) (TIOE[Cost], x+1)	0.505 (p = 0.202) (TI[Schedule], x+1)	-0.750* (TI[Guideline], x+1)	-0.852** (TI/TR[Audience], x+1)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-4. Cross correlation coefficient matrix for lag = 2

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.122 (p = 0.755) (TI[Schedule], x+2)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.258 (p = 0.502) (TI[Guideline], x+2)	0.362 (p = 0.075) (TI[Guideline], x+2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.424 (p = 0.256) (TI/TR[Audience], x+2)	-0.168 (p = 0.802) (TI[Schedule], x+2)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.580 (p = 0.132) (TIOE[Cost], x+2)	0.012 (p = 0.977) (TI[Schedule], x+2)	-0.737* (TI[Guideline], x+2)	-0.758* (TI[Audience], x+2)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.405 (p = 0.319) (TIOE[Cost], x+2)	-0.040 (p = 0.924) (TI[Schedule], x+2)	-0.814* (TI[Guideline], x+2)	-0.752* (TI/TR[Audience], x+2)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6D-5. Cross correlation coefficient matrix for lag = 3

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.354 (p = 0.351) (TI[Schedule], x+3)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.547 (p = 0.128) (TI[Guideline], x+3)	0.358 (p = 0.079) (TI[Guideline], x+3)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.043 (p = 0.913) (TI/TR[Audience], x+3)	-0.135 (p = 0.505) (TI[Schedule], x+3)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	-0.112 (p = 0.811) (TIOE[Cost], x+3)	-0.485 (p = 0.223) (TI[Schedule], x+3)	-0.608 (p = 0.110) (TI[Guideline], x+3)	-0.379 (p = 0.354) (TI[Audience], x+3)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.007 (p = 0.988) (TIOE[Cost], x+3)	-0.593 (p = 0.121) (TI[Schedule], x+3)	-0.657 (p = 0.077) (TI[Guideline], x+3)	-0.210 (p = 0.617) (TI/TR[Audience], x+3)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Table 6D-6. Cross correlation coefficient matrix for lag = 4

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.091 (p = 0.815) (TI[Schedule], x+4)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.243 (p = 0.528) (TI[Guideline], x+4)	0.437* (TI[Guideline], x+4)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.113 (p = 0.773) (TI/TR[Audience], x+4)	-0.168 (p = 0.593) (TI[Schedule], x+4)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	-0.529 (p = 0.281) (TIOE[Cost], x+4)	-0.698 (p = 0.054) (TI[Schedule], x+4)	-0.504 (p = 0.203) (TI[Guideline], x+4)	0.121 (p = 0.776) (TI[Audience], x+4)	1.000	
Total Number of Students Completing Course [TR(Cost)]	-0.567 (p = 0.241) (TIOE[Cost], x+4)	-0.792* (TI[Schedule], x+4)	-0.517 (p = 0.190) (TI[Guideline], x+4)	0.271 (p = 0.516) (TI/TR[Audience], x+4)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6D-7. Cross correlation coefficient matrix for lag = 5

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.498 (p = 0.173) (TI[Schedule], x+5)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.524 (p = 0.147) (TI[Guideline], x+5)	0.482* (TI[Guideline], x+5)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.004 (p = 0.993) (TI/TR[Audience], x+5)	-0.064 (p = 0.505) (TI[Schedule], x+5)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		-0.576 (p = 0.135) (TI[Schedule], x+5)	-0.766* (TI[Guideline], x+5)	0.579 (p = 0.132) (TI[Audience], x+5)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.593 (p = 0.121) (TI[Schedule], x+5)	-0.731* (TI[Guideline], x+5)	0.695 (p = 0.056) (TI/TR[Audience], x+5)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-8. Cross correlation coefficient matrix for lag = 6

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.306 (p = 0.423) (TI[Schedule], x+6)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.134 (p = 0.731) (TI[Guideline], x+6)	0.503* (TI[Guideline], x+6)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.567 (p = 0.143) (TI/TR[Audience], x+6)	0.020 (p = 0.588) (TI[Schedule], x+6)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		-0.286 (p = 0.493) (TI[Schedule], x+6)	-0.384 (p = 0.348) (TI[Guideline], x+6)	0.521 (p = 0.185) (TI[Audience], x+6)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.287 (p = 0.491) (TI[Schedule], x+6)	-0.444 (p = 0.270) (TI[Guideline], x+6)	0.688 (p = 0.059) (TI/TR[Audience], x+6)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-9. Cross correlation coefficient matrix for lag = 7

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.043 (p = 0.912) (TI[Schedule], x+7)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.235 (p = 0.542) (TI[Guideline], x+7)	0.401* (TI[Guideline], x+7)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.570 (p = 0.182) (TI/TR[Audience], x+7)	0.037 (p = 0.883) (TI[Schedule], x+7)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		0.049 (p = 0.909) (TI[Schedule], x+7)	0.000 (p = 1.000) (TI[Guideline], x+7)	0.590 (p = 0.124) (TI[Audience], x+7)	1.000	
Total Number of Students Completing Course [TR(Cost)]		0.211 (p = 0.617) (TI[Schedule], x+7)	0.133 (p = 0.754) (TI[Guideline], x+7)	0.694 (p = 0.056) (TI/TR[Audience], x+7)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-10. Cross correlation coefficient matrix for lag = 8

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.304 (p = 0.426) (TI[Schedule], x+8)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.232 (p = 0.548) (TI[Guideline], x+8)	0.211 (p = 0.312) (TI[Guideline], x+8)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.565 (p = 0.243) (TI/TR[Audience], x+8)	-0.001 (p = 0.996) (TI[Schedule], x+8)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		0.382 (p = 0.350) (TI[Schedule], x+8)	0.276 (p = 0.508) (TI[Guideline], x+8)	0.901** (TI[Audience], x+8)	1.000	
Total Number of Students Completing Course [TR(Cost)]		0.330 (p = 0.425) (TI[Schedule], x+8)	0.398 (p = 0.328) (TI[Guideline], x+8)	0.855* (TI/TR[Audience], x+8)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6D-11. Cross correlation coefficient matrix for lag = 9

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.717* (TI[Schedule], x+9)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.368 (p = 0.330) (TI[Guideline], x+9)	0.165 (p = 0.429) (TI[Guideline], x+9)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.560 (p = 0.326) (TI/TR[Audience], x+9)	0.033 (p = 0.904) (TI[Schedule], x+9)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		0.024 (p = 0.954) (TI[Schedule], x+9)	0.481 (p = 0.227) (TI[Guideline], x+9)	0.731 (p = 0.099) (TI[Audience], x+9)	1.000	
Total Number of Students Completing Course [TR(Cost)]		0.073 (p = 0.864) (TI[Schedule], x+9)	0.607 (p = 0.111) (TI[Guideline], x+9)	0.781 (p = 0.067) (TI/TR[Audience], x+9)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-12. Cross correlation coefficient matrix for lag = 10

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.538 (p = 0.135) (TI[Schedule], x+10)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.630 (p = 0.069) (TI[Guideline], x+10)	-0.026 (p = 0.902) (TI[Guideline], x+10)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.347 (p = 0.653) (TI/TR[Audience], x+10)	-0.223 (p = 0.425) (TI[Schedule], x+10)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		0.188 (p = 0.656) (TI[Schedule], x+10)	0.494 (p = 0.214) (TI[Guideline], x+10)	0.823 (p = 0.087) (TI[Audience], x+10)	1.000	
Total Number of Students Completing Course [TR(Cost)]		0.106 (p = 0.802) (TI[Schedule], x+10)	0.584 (p = 0.128) (TI[Guideline], x+10)	0.690 (p = 0.197) (TI/TR[Audience], x+10)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Table 6D-13. Cross correlation coefficient matrix for lag = -1 (i.e. lead = 1)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.403 (p = 0.282) (TI[Schedule], x-1)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.015 (p = 0.969) (TI[Guideline], x-1)	0.409* (TI[Guideline], x-1)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.421 (p = 0.259) (TI/TR[Audience], x-1)	-0.392 (p = 0.120) (TI[Schedule], x-1)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.558 (p = 0.250) (TIOE[Cost], x-1)	0.365 (p = 0.375) (TI[Schedule], x-1)	0.283 (p = 0.496) (TI[Guideline], x-1)	-0.414 (p = 0.308) (TI[Audience], x-1)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.617 (p = 0.192) (TIOE[Cost], x-1)	0.430 (p = 0.288) (TI[Schedule], x-1)	0.191 (p = 0.650) (TI[Guideline], x-1)	-0.475 (p = 0.234) (TI/TR[Audience], x-1)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-14. Cross correlation coefficient matrix for lag = -2 (i.e. lead = 2)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.134 (p = 0.731) (TI[Schedule], x-2)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.136 (p = 0.727) (TI[Guideline], x-2)	0.703** (TI[Guideline], x-2)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.192 (p = 0.621) (TI/TR[Audience], x-2)	-0.449 (p = 0.081) (TI[Schedule], x-2)		1.000		
Total Number of Courses Delivered [TR(Schedule)]	0.234 (p = 0.705) (TIOE[Cost], x-2)	-0.271 (p = 0.517) (TI[Schedule], x-2)	0.785* (TI[Guideline], x-2)	-0.495 (p = 0.212) (TI[Audience], x-2)	1.000	
Total Number of Students Completing Course [TR(Cost)]	0.495 (p = 0.397) (TIOE[Cost], x-2)	-0.298 (p = 0.473) (TI[Schedule], x-2)	0.736* (TI[Guideline], x-2)	-0.650 (p = 0.081) (TI/TR[Audience], x-2)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6D-15. Cross correlation coefficient matrix for lag = -3 (i.e. lead = 3)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.065 (p = 0.896) (TI[Schedule], x-3)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.577 (p = 0.104) (TI[Guideline], x+3)	0.560** (TI[Guideline], x-3)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.099 (p = 0.800) (TI/TR[Audience], x-3)	-0.427 (p = 0.113) (TI[Schedule], x-3)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		-0.774* (TI[Schedule], x-3)	0.787* (TI[Guideline], x-3)	-0.740* (TI[Audience], x-3)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.677 (p = 0.065) (TI[Schedule], x-3)	0.798* (TI[Guideline], x-3)	-0.878** (TI/TR[Audience], x-3)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means most significant value between lag time = 10 and lead time = 10

Means significant value between lag time = 10 and lead time = 10

Table 6D-16. Cross correlation coefficient matrix for lag = -4 (i.e. lead = 4)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.347 (p = 0.361) (TI[Schedule], x-4)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.648 (p = 0.059) (TI[Guideline], x-4)	0.569** (TI[Guideline], x-4)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.088 (p = 0.821) (TI/TR[Audience], x-4)	-0.397 (p = 0.159) (TI[Schedule], x-4)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		-0.534 (p = 0.217) (TI[Schedule], x-4)	0.383 (p = 0.397) (TI[Guideline], x+4)	-0.514 (p = 0.238) (TI[Audience], x-4)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.578 (p = 0.175) (TI[Schedule], x-4)	0.548 (p = 0.203) (TI[Guideline], x-4)	-0.598 (p = 0.156) (TI/TR[Audience], x-4)		1.000

*$p < 0.05$ is denoted as **

*$p < 0.01$ is denoted as ***

Means significant value between lag time = 10 and lead time = 10

Table 6D-17. Cross correlation coefficient matrix for lag = -5 (i.e. lead = 5)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.591 (p = 0.123) (TI[Schedule], x-5)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	0.055 (p = 0.896) (TI[Guideline], x-5)	0.300 (p = 0.198) (TI[Guideline], x-5)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.021 (p = 0.961) (TI/TR[Audience], x-5)	-0.279 (p = 0.355) (TI[Schedule], x-5)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		0.001 (p = 1.000) (TI[Schedule], x-5)	0.217 (p = 0.680) (TI[Guideline], x-5)	0.241 (p = 0.646) (TI[Audience], x-5)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.326 (p = 0.529) (TI[Schedule], x-5)	0.480 (p = 0.335) (TI[Guideline], x-5)	0.062 (p = 0.907) (TI/TR[Audience], x-5)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Table 6D-18. Cross correlation coefficient matrix for lag = -6 (i.e. lead = 6)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.103 (p = 0.826) (TI[Schedule], x-6)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.357 (p = 0.432) (TI[Guideline], x-6)	0.058 (p = 0.814) (TI[Guideline], x-6)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	-0.016 (p = 0.973) (TI/TR[Audience], x-6)	-0.047 (p = 0.884) (TI[Schedule], x-6)		1.000		
Total Number of Courses Delivered [TR(Schedule)]		-0.275 (p = 0.654) (TI[Schedule], x-6)	0.173 (p = 0.781) (TI[Guideline], x-6)	0.699 (p = 0.189) (TI[Audience], x-6)	1.000	
Total Number of Students Completing Course [TR(Cost)]		-0.395 (p = 0.510) (TI[Schedule], x-6)	0.304 (p = 0.619) (TI[Guideline], x-6)	0.506 (p = 0.385) (TI/TR[Audience], x-6)		1.000

*p < 0.05 is denoted as **

*p < 0.01 is denoted as ***

Table 6D-19. Cross correlation coefficient matrix for lag = -7 (i.e. lead = 7)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	0.567 (p = 0.241) (TI[Schedule], x-7)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.326 (p = 0.528) (TI[Guideline], x-7)	-0.052 (p = 0.837) (TI[Guideline], x-7)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.634 (p = 0.177) (TI/TR[Audience], x-7)	0.158 (p = 0.644) (TI[Schedule], x-7)		1.000		
Total Number of Courses Delivered [TR(Schedule)]					1.000	
Total Number of Students Completing Course [TR(Cost)]						1.000

*$p < 0.05$ is denoted as **
*$p < 0.01$ is denoted as ***

Table 6D-20. Cross correlation coefficient matrix for lag = -8 (i.e. lead = 8)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	-0.140 (p = 0.823) (TI[Schedule], x-8)	1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]	-0.051 (p = 0.935) (TI[Guideline], x-8)	-0.116 (p = 0.658) (TI[Guideline], x-8)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	0.795 (p = 0.108) (TI/TR[Audience], x-8)	-0.024 (p = 0.948) (TI[Schedule], x-8)		1.000		
Total Number of Courses Delivered [TR(Schedule)]					1.000	
Total Number of Students Completing Course [TR(Cost)]						1.000

*$p < 0.05$ is denoted as **
*$p < 0.01$ is denoted as ***

Table 6D-21. Cross correlation coefficient matrix for lag = -9 (i.e. lead = 9)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]		1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]		-0.147 (p = 0.588) (TI[Guideline], x-9)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]		-0.170 (p = 0.662) (TI[Schedule], x-9)		1.000		
Total Number of Courses Delivered [TR(Schedule)]					1.000	
Total Number of Students Completing Course [TR(Cost)]						1.000

*p < 0.05 is denoted as **
*p < 0.01 is denoted as ***

Table 6D-22. Cross correlation coefficient matrix for lag = -10 (i.e. lead = 10)

	Total Commercial Nano Investment [TIOE(Cost)]	Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]	Total Commercial Nano TI Patents Filed [TI(Guideline)]	BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]	Total Number of Courses Delivered [TR(Schedule)]	Total Number of Students Completing Course [TR(Cost)]
Total Commercial Nano Investment [TIOE(Cost)]	1.000					
Total Commercial 777 and 787 Airplanes Ordered [TI(Schedule)]		1.000				
Total Commercial Nano TI Patents Filed [TI(Guideline)]		0.174 (p = 0.536) (TI[Guideline], x-10)	1.000			
BCA Employment Numbers [TI(Audience)], [TR(Audience, Market Need)]		-0.347 (p = 0.399) (TI[Schedule], x-10)		1.000		
Total Number of Courses Delivered [TR(Schedule)]					1.000	
Total Number of Students Completing Course [TR(Cost)]						1.000

*p < 0.05 is denoted as **
*p < 0.01 is denoted as ***

REFERENCES

3DS (2016). *About 3DS*. Dassault Systemes. Retrieved December 04, 2015, from http://www.3ds.com/about-3ds/

Aguinis, H. and Kraiger, K. (2009). Benefits of training and development for individuals and teams, organizations, and society. *Annual Review of Psychology, 60,* 451-474.

Allen, J.A., Baran, B.E., and Scott, C.S. (2010). After-action reviews: A venue for the promotion of safety climate. *Accident Analysis & Prevention, 42,* 750-757.

Alnidawy, A.A.B. (2015). The effect of identifying training needs on the effectiveness of the training process and improving the individual and organizational performance: Applied study in the Jordanian health sector. *International Journal of Business Administration. 6*(4), 48-56.

Amabile, T.M. (1988). A model of creativity and innovation in organizations. In B.M. Staw and L.L. Cummings (Eds.), *Research in Organizational Behavior* (*10,* 123-167). Greenwich, CT: JAI Press.

Aragon-Sanchez, A., Barba-Aragon, I., and Sanz-Valle, R. (2003). Effects of training of business results. *Journal of Human Resource Management. 14*, 956-980.

Armstrong, J.S., Morwitz, V.G., and Kumar, V. (2000). Sales forecasts for existing consumer products and services: Do purchase intentions contribute to accuracy? *International Journal of Forecasting. 16*(3), 383-397.

Arthur, W., Jr., Bennett, W., Jr., Edens, P.S., and Bell, S.T. (2003). Effectiveness of training in organizations: A meta-analysis of design and evaluation features. *Journal of Applied Psychology, 88*, 234-245.

Autant-Bernard, C., Chalaye, S., Manca, F., Moreno, R., and Surinach, J. (2010). Measuring the adoption of innovation. A typology of EU countries based on the innovation survey. *Innovation – The European Journal of Social Science Research, 23*(3), 199-222.

Babbie, E. (1990). *Survey Research Methods* (2nd Ed.). Belmont, CA: Wadsworth.

Bapna, R., Langer, N., Mehra, A., Gopal, R., and Gupta, A. (2013). Human capital investments and employee performance: An analysis of IT services industry. *Management Science*, *59*(3), 641-658.

Baranzini, D., Bacchi, M., and Cacciabue, P.C. (2001). A tool for evaluation and identification of training needs in aircraft. *Human Factors and Aerospace Safety: An International Journal. 1*, 167-193

Bartel, A. (2000). Measuring the employer's return on investments in training: Evidence from the literature. *Industrial Relations, 39*(3), 502-524.

Bell, B.S. and Kozlowski, S.W.J. (2002). Adaptive guidance: Enhancing self-regulation, knowledge and performance in technology-based training. *Personnel Psychology, 55,* 267-306.

Bilgin, M.H., Marco L.C.K., and Demir, E. (2012). Technology transfer, finance channels, and SME Performance: New evidence from developing countries. *The Singapore Economic Review. 57*(3), 1-20.

Bjornberg, L. (2002). Training and development: Best practices. *Public Personnel Management, 31*(4), 507-516.

Blanchard, B.S. and Fabrycky, W.J. (2006). *Systems Engineering and Analysis* (4th Ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Blanchard, P.N. and Thacker J.W. (2007). *Effective Training: Systems, Strategies, and Practices* (3rd Ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Bloom, B.S. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain.* New York City, NY: David McKay Co Inc.

Blundell, R., Dearden, L., Meghir, C., and Sianesi, B. (1999). Human capital investments: The returns from education and training to the individual, the firm and the economy. *Fiscal Studies. 20*(1), 1-23.

Boeing. (2009a). *Develop and Deploy Training.* Boeing, Learning, Training and Development. Everett, WA: Boeing internal document.

Boeing. (2009b). *Enterprise Mechanical Structural Engineering.* Retrieved January 25, 2011, from Engineering, Operations & Technology Enterprise Engineering. Internal Boeing website: http://structuresengineering.web.boeing.com/e_mse/

Boeing. (2009c). *Technology and Application Readiness Criteria.* Boeing Commercial Airplanes. Everett, WA: Boeing internal document.

Boeing. (2014). *About us*. Retrieved April 22, 2014, from http://www.boeing.com/boeing/companyoffices/aboutus/brief.page

Boeing Frontiers. (2009). Play by play: Commercial Airplanes Structures engineers turn to PlayBook to tap the years of experience, knowledge and best practices of their colleagues. Retrieved April 27, 2014, from http://www.boeing.com/news/frontiers/archive/2009/november/cover.pdf

Boeing Frontiers. (2011). Where do I want to be tomorrow? A lifetime of learning prepares employees and the company for the future. Retrieved April 27, 2014, from http://www.boeing.com/news/frontiers/archive/2011/april/ts_sf02.pdf

Boeing Frontiers. (2013). Career Moves: When it comes to career development, experience is a good teacher – but not the only one. Retrieved April 27, 2014, from http://www.boeing.com/news/frontiers/archive/2013/february/#/22/

Boeing in Brief. (2010). *About us*. Retrieved January 14, 2011, from http://www.boeing.com/companyoffices/aboutus/brief.html

Booz & Co. (2016). *Top 20 R&D Spenders 2005-2015*. Retrieved December 04, 2015, from http://www.strategyand.pwc.com/global/home/what-we-think/innovation1000/top-20-rd-spenders-2015

Boudreau, J. and Ramstad, P. (2005). Talentship, talent segmentation, and sustainability: A new HR decision science paradigm for a new strategy definition. *Human Resource Management, 44,* 129-136.

Branson, R.K. (1978). The interservice procedures for instructional systems development. *Educational Technology*, *18*(3), 11-14.

Brock, G.W., McManus, D.J., and Hale, J.E. (2009). Reflections today prevent failures tomorrow. *Communications of the ACM, 52,* 140-144.

Cairns, T.D. (2012). Overcoming the challenges to developing an ROI for training and development. *Employment Relations Today*, *39*(3), 23-27.

Cannon-Bowers, J.A., Tannenbaum, S.I., Salas, E., and Converse, S.A. (1991). Toward an integration of training theory and technique. *Human Factors, 33,* 281-292.

Carayon, P. (2012). *Human Factors and Ergonomics in Health Care and Patient Safety* (2nd Ed.). Boca Raton, FL: Taylor & Francis.

Casner-Lotto, J. (1988). *Successful Training Strategies Twenty-Six Innovative Corporate Models*. San Francisco, CA: Jossey-Bass Inc.

Charmaz, K. (2000). *Grounded theory: Objectivist and constructivist methods*. In N.K. Denzin and Y.S. Lincoln (Eds.), *Handbook of Qualitative Research* (2nd Ed., 509-535). Thousand Oaks, CA: Sage.

Cho, S.H. and McCardle, K.F. (2009). The adoption of multiple dependent technologies. *Operations Research, 57*(1), 157-169.

Cohen, S.L. (2005). Controlling program evaluation. *Performance Improvement, 44*(8), 23-26.

Colquitt, J.A., LePine, J.A., and Noe, R.A. (2000). Toward an integrative theory of training motivation: a meta-analytic path analysis of 20 years of research. *Journal of Applied Psychology, 85,* 678-707.

CorpU Xchange. (2013). *12th Annual LEI Benchmarking Study: Getting Started Guide.* CUX, Inc.

CorpU Xchange. (2016). *2014 Annual Awards for Excellence and Innovation*. Retrieved December 05, 2015, from https://www.corpu.com/xchange/events/awards/2014-annual-award-winners/

Courty, P. and Marschke, G. (2004). Benchmarking performance. *Public Finance and Management, 4*(3), 288-316.

Crawley, E., Malmqvist, J., Ostlund, S., and Brodeur, D. (2008). *Rethinking Engineering Education The CDIO Approach*. New York City, NY: Springer.

Creswell, J.W. (2009). *Research Design Qualitative, Quantitative, and Mixed Methods Approaches* (3rd Ed.). (V. Knight, S. Connelly, S. K. Quesenberry, and M. P. Scott, Eds.). Thousand Oaks, California: SAGE Publications, Inc.

Cyert, R.M. and March, J.G. (1992). *A Behavioral Theory of the Firm*. Cambridge, MA: Blackwell.

Damanpour, F. and Wischnevsky, J.D. (2006). Research on innovation in organisations: Distinguishing innovation-generating from innovation-adopting organsations. *Journal of Engineering and Technology Management, 23*, 269-291.

Delaney, J.T. and Huselid, M.A. (1996). The impact of human resource management practices on perceptions of organizational performance. *Academy of Management Journal, 39,* 949-969.

DoD. (2009). *Technology Readiness Assessment (TRA) Deskbook*. Office of the Director, Defense Research and Engineering (DDR&E), Department of Defense. Washington D.C.: United States government.

Driscoll, M. (2003). Whirlpool: Innovation and organizational learning. *Chief Learning Officer, 2*(2), 48.

Endsley, M. and Rodgers, M.D. (1996). Attention distribution and situation awareness in air traffic control. In *Proceedings of Human Factors and Ergonomics Society 40th Annual Meeting* (82-85). Santa Monica, CA: Human Factors and Ergonomics Society.

Felder, R.M., Brent, R., and Prince, M.J. (2011). Engineering instructional development: Programs, best practices, and recommendations. *Journal of Engineering Education*, *100*(1), 89-122.

Field, A. (2013). *Discovering Statistics using IBM SPSS Statistics* (4th Ed.). Thousand Oaks, CA: Sage Publications, Inc.

Fowlkes, J.E., Salas, E., Baker, D.P., Cannon-Bowers, J.A., and Strout, R.J. (2000). The utility of event-based knowledge elicitation. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 42*, 24-35.

Ford, J.K., Quinones, M.A., Sego, D.J., and Sorra, J.S. (1992). Factors affecting the opportunity to perform trained tasks on the job. *Personnel Psychology, 45,* 511-527.

Gaba, D.M. (2010). Crisis resource management and teamwork training in anaesthesia. *British Journal of Anaesthesia, 107*(3), 3-6.

Gartner. (2009). *Key Initiative Overview – Cloud Computing*. Report retrieved December 05, 2015, from http://www.gartner.com/it/initiatives/pdf/KeyInitiativeOverview_CloudComputing.pdf

Goldstein, I.L. (1986). *Training in Organizations: Needs Assessment, Development, and Evaluation* (2nd Ed.). Monterey, CA: Brooks/Cole.

Goldstein, I.L. and Ford, J.K. (2002). *Training in Organizations: Needs Assessment, Development, and Evaluation* (4th Ed.). Belmont, CA: Wadsworth.

GM. (2016). *About GM*. General Motors. Retrieved December 04, 2015, from http://www.gm.com/company/aboutGM.html

Grossman, R. and Salas, E. (2011). The transfer of training: What really matters. *International Journal of Training and Development, 15,* 103-120.

Guerrero, S. and Barraud-Didier, V. (2004). High-involvement practices and performance of French firms. *International Journal of Human Resource Management, 15*, 1408-1423.

Hemphill, J.F. (2003). Interpreting the magnitudes of correlation coefficients. *American Psychologist*, *58*(1), 78-80.

Hevner, A.R., March, S.T., Park, J., and Ram, S. (2004). Design science in information systems research. *MIS Quarterly, 28*(1), 75-105.

Hill, C.E. and Lent, R.W. (2006). A narrative and meta-analytic review of helping skills training: Time to revive a dormant area of inquiry. *Psychotherapy Theory Research & Practice, 43*, 154-172.

Klein, H.J., Noe, R.A., and Wang, C. (2006). Motivation to learn and course outcomes: The impact of delivery mode, learning goal orientation, and perceived barriers and enablers. *Journal of Personnel Psychology, 59*, 665-702.

Holton, E.F. (1996). The flawed four-level evaluation model. *Human Resource Development Quarterly, 7,* 5-21.

Holton, E.F., Bates, R.A., and Naquin, S.S. (2000). Large-scale performance-driven training needs assessment: A case study. *Public Personnel Management, 29*(2), 249-267.

Holton, E.F., Chen, H.C., and Naquin, S.S. (2003). An examination of learning transfer system characteristic across organizational settings. *Human Resource Development Quarterly, 14,* 459-482.

HP. (2016). *About HP*. Hewlett Packard Company. Retrieved December 04, 2015, from http://www8.hp.com/us/en/hp-information/

Huselid, M.A. (1995). The impact of human resource management practices on turnover, productivity, and corporate financial performance. *Academy of Management Journal, 38,* 635-672.

Huselid, M.A. and Becker, B.E. (2011). Bridging micro and macro domains: Workforce differentiation and strategic human resource management. *Journal of Management, 37,* 421-428.

IET. (2016). *Sector Focus*. The Institute of Engineering and Technology. Retrieved December 04, 2015, from http://www.theiet.org/

Jones, D.G. and Endsley, M.R. (2004). Use of real time probes for measuring the prototype deliverables and/or future design activities, situation awareness. *International Journal of Aviation Psychology, 14,* 343-367.

Kanki, B.G., Helmreich, R.L., and Anca, J. (2010). *Crew Resource Management* (2nd Ed.). San Diego, CA: Academic Press.

Kaplan, R.S. (2012). The demise of cost and profit centers. Working Paper 07-030. *Harvard Business School,* 1-20.

Kirkpatrick, D.L. (1996). Great ideas revisited: Revisiting Kirkpatrick's four-level model. *Training & Development, 50*(1), 54-57.

Kirkpatrick, D.L. (1998). *Evaluating Training Programs* (2nd Ed.). San Francisco, CA: Berrett-Koehler.

Kirkpatrick, D.L. (2004). A training and development classic: How to start an objective evaluation of your training program. *Training and Development, 58*(5), 16-18.

Kozlowski, S.W.J., Brown, K.G., Weisbein, D.A., Cannon-Bowers, J.A., and Salas, E. (2000). A multi-level approach to training effectiveness: Enhancing horizontal and vertical transfer. In K. Klein and S.W.J. Kozlowski (Eds.), *Multilevel theory, research, and methods in organizations.* San Francisco, CA: Jossey-Bass.

Kozlowski, S.W.J. and Salas, E. (1997). An organizational systems approach for the implementation and transfer of training. In *Improving Training Effectiveness in Work Organizations* (247-287). (K. Ford, S.W. Kozlowski, K. Kraiger, E. Salas, and M. Teachout, Eds.). Mahwah, NJ: Erlbaum.

Kraiger, K. (2002). Decision-based evaluation. In *Creating, Implementing, and Maintaining Effective Training and Development: State-of-the-Art Lessons for Practice* (331-375). (K. Kraiger, Ed.). San Francisco, CA: Jossey-Bass.

Kraiger, K. (2003). Perspectives on training and development. In *Handbook of Psychology: Volume 12, Industrial and Organizational Psychology* (171-192). (W.C. Borman, D.R. Ilgen, and R.J. Klimoski, Eds.). Hoboken, NJ: Wiley.

Kujawski, E. (2013). Analysis and critique of the system readiness level. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 43*(4), 979-987.

Lombardo, M.M. and Eichinger, R.W. (2000). *Career Architect Development Planner* (3rd Ed.). Minneapolis, MN: Lominger Limited.

McCune, J.C. (1994). Measuring the value of employee education. *Management Review, 83*(4), 10-15.

McGriff, S.J. (2000). Instructional System Design (ISD): Using the ADDIE Model. *Instructional Systems, College of Education, Penn State University.*

McGrath, C. and Percival, J. (2013). Short-term and long-term returns to innovation from the application of technology and training practices. *International Journal of Innovation Management. 17*(5), 1-18.

Mcgehee, W. and Thayer, P.W. (1961). *Training in Business and Industry.* New York City, NY: Wiley.

Melville, N., Kraemer, K., and Gurbaxani, V. (2004). Review: information technology and organizational performance: An integrative model of IT business value. *MIS Quarterly, 28*(2), 283-322.

Mertens, D.M. (1998). *Research Methods in Education and Psychology: Integrating Diversity with Quantitative and Qualitative Approaches.* Thousand Oaks, CA: Sage Publications, Inc.

Miles, M., Huberman, A., and Saldana, J. (2013). *Qualitative Data Analysis: A Methods Sourcebook* (3rd Ed.). Thousand Oaks, CA: Sage Publications, Inc.

Miller, J.A. and Osinski, D.M. (1996). *Training Needs Assessment.* SHRM Training and Development Committee.

Molenda, M. (2003). In search of the elusive ADDIE model. *Performance Improvement, 42*(5), 34-36.

Morano, R. (1973). Determining organizational training needs. *Personnel Psychology, 25,* 479-487.

Noe, R.A. (1986). Trainees' attributes and attitudes: Some neglected influences on training effectiveness. *Academy of Management Review, 11,* 736-749.

Noe, R.A. (2008). *Employee Training and Development* (4th Ed.). Boston, MA: Irwin-McGraw.

Noe, R.A. and Colquitt, J.A. (2002). Planning for training impact: Principles of training effectiveness. In K. Kraiger (Ed.), *Creating, implementing, and maintaining effective training and development: State-of-the-art lessons for practice* (53-79). San Francisco, CA: Jossey-Bass.

Noe, R.A. and Schmitt, N.M. (1986). The influence of trainee attitudes on training effectiveness: Test of a model. *Personnel Psychology, 39,* 497-523.

Ostroff, C. and Ford, K.J. (1989). *Critical Levels of Analysis.* In I.L.Goldstein (Ed.), *Training and development in organizations* (25-62). San Francisco, CA: Jossey-Bass.

Paradise, A. (2007). *State of the Industry: ASTD's Annual Review of Trends in Workplace Learning and Performance.* Alexandria, VA: ASTD.

Park, Y. and Jacobs, R.L. (2011). The influence of investment in workplace learning on learning outcomes and organizational performance. *Human Resource Development Quarterly, 22*(4), 437-458.

Patel, L. (2010). *2010 State of the Industry Report. American Society for Training & Development*. Alexandria, VA: ASTD.

Patton, M.Q. (1990). *Qualitative evaluation and research methods* (2nd Ed.). Newbury Park, CA: Sage Publications Inc.

Peterson, C. (2003). Bringing ADDIE to life: Instructional design at its best. *Journal of Educational Multimedia and Hypermedia, 12*(3), 227-241.

Pisano, G. (2012). Creating an R&D Strategy. Working Paper 12-095. *Harvard Business School.* 1-9.

Quinones, M.A. (1997). Contextual influences on training effectiveness. In M.A. Quinones and A. Ehrenstein (Eds.), *Training for a rapidly changing workplace* (177-200). Washington, DC: American Psychological Association.

Quinones, M.A., Ford, J.K., Sego, D.J., and Smith, E.M. (1995). The effects of individual and transfer environment characteristics on the opportunity to perform trained tasks. *Training Research Journal, 1,* 29-48.

Reed, R. and Vakola, M. (2006). What role can a training needs analysis play in organisational change? *Journal of Organizational Change Management, 19,* 393-407.

REUTERS. (2009). *Boeing Expects Job Cuts Totaling 10,000 in 2009*. Retrieved January 15, 2011, from The New York Times: http://www.nytimes.com/2009/01/29/business/29boeing.html?_r=2

Richardson, J.W. (2011). Technology adoption in cambodia: Measuring factors impacting adoption rates. *Journal of International Development*, *23*, 697-710.

Rivera, R.J. and Paradise, A. (2006). *State of the Industry: ASTD's Annual Review of Trends in Workplace Learning and Performance*. Alexandria, VA: ASTD.

Robinson, D.G. and Robinson, J.C. (1989). *Training for Impact* (1st Ed.). San Francisco, CA: Jossey-Bass.

Rogers, E.M. (2003). *Diffusion of Innovations* (5th Ed.). New York City, New York: Free Press.

Rosow, J.M. (1988). Introduction: How Leading Companies Are Reshaping Their Training Strategies. In J. Casner-Lotto, *Successful Training Strategies Twenty-Six Innovative Corporate Models* (1-20). San Francisco, CA: Jossey-Bass Inc.

Rossett, A. (1987). *Training Needs Assessment. Techniques in Training and Performance Development Series*. Englewood Cliffs, NJ: Educational Technology Publications, Inc.

Saks, A.M. and Burke-Smalley, L.A. (2014). Is transfer of training related to firm performance? *International Journal of Training and Development, 18*(2), 104-115.

Salas, E. and Cannon-Bowers, J.A. (2001). The science of training: a decade of progress. *Annual Review Psychology, 52,* 471-499.

Salas, E., Tannenbaum, S.I., Kraiger, K., and Smith-Jentsch, K.A. (2012). The science of training and development in organizations: What matters in practice. *Association for Psychological Science, 13*(2), 74-101.

Salas, E., Nichols, D.R., and Driskell, J.E. (2007). Testing three team training strategies in intact teams: A meta-analysis. *Small Group Research, 38,* 471-488.

Salas, E., Wilson, K.A., Priest, H.A., and Guthrie, J. (2006). Training in organizations: The design, delivery and evaluation of training systems. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (3rd Ed., 472-512). Hoboken, NJ: John Wiley.

Saldana, J. (2013). *The Coding Manual for Qualitative Researchers* (2nd Ed.). Thousand Oaks, CA: Sage Publications, Inc.

Satterfield, J.M. and Hughes, E. (2007). Emotion skills training for medical students: A systematic review. *Medical Education, 41*, 935-41.

Sawang, S. and Unsworth, K.L. (2011). A model of organizational innovation implementation effectiveness in small to medium firms. *International Journal of Innovation Management*, *15*(5), 989-1011.

Schenk, J. and Hajos, A.K. (2000). Measures of success. *Applied Clinical Trials,* 50-58.

Sels, L. (2002). 'More is not necessarily better': The relationship between the quantity and quality of training efforts. *International Journal of Human Resource Management, 13*(8), 1279-1298.

Shell. (2016). *About us*. Royal Dutch Shell. Retrieved December 04, 2015, from http://www.shell.com/about-us/who-we-are.html

Singh, R., Mathiassen, L., and Mishra, A. (2015). Organizational path constitution in technological innovation: Evidence from rural telehealth. *MIS Quarterly, 39*(3), 643-665.

Sitzmann, T., Brown, K.G., Ely, K., and Kraiger, K. (2008). Motivation to learn in a military training curriculum: A longitudinal investigation. *Military Psychology, 21,* 534-551.

Sleezer, C.M. (1993). Training needs assessment at work: A dynamic process. *Human Resource Development Quarterly, 4,* 247-264.

Smith, G.F. (1989). Defining managerial problems: A framework for prescriptive theorizing. *Management Science, 35*(8), 963-981.

Sol, H.G. (1982). *Simulation in Information Systems Development.* Ph.D. thesis. Groningen, The Netherlands: University of Groningen.

Stake, R.E. (1995). *The Art of Case Study Research.* Thousand Oaks, CA: Sage Publications, Inc.

Suchman, M.C. (1995). Managing legitimacy: Strategic and institutional approaches. *Academy of Management Review, 20*(3), 571-610.

Swanson, R.A. (2001). *Assessing the Financial Benefits of Human Resource Development.* Cambridge, MA: Perseus.

Tannenbaum, S.I. (2002). A strategic view of organizational training and learning. In K. Kraiger (Ed.), *Creating, implementing, and maintaining effective training and development: State-of-the-art lessons for practice* (10-52). San Francisco, CA: Jossey-Bass.

Tannenbaum, S.I., Mathieu, J.E., Salas, E., and Cannon-Bowers, J.A. (1991). Meeting trainees' expectations: The influence of training fulfillment on the development of commitment, self-efficacy, and motivation. *Journal of Applied Psychology, 76,* 759-769.

Tannenbaum, S.I. and Yukl, G. (1992). Training and development in work organizations. *Annual Review of Psychology, 43*, 474-483

Taylor, R. (1990). Interpretation of the correlation coefficient: A basic review. *Journal of Diagnostic Medical Sonography*, *6*(1), 35-39.

Tharenou, P., Saks, A.M., and Moore, C. (2007). A review and critique of research on training and organizational-level outcomes. *Human Resource Management Review, 17*, 251-273.

Tolbert, P.S. and Zucker, L. (1983). Institutional sources of change in the formal structure of organizations: The diffusion of civil service reform, 1880-1935. *Administrative Science Quarterly, 28*, 22-39.

Tolbert, P.S. and Zucker, L. (1996). The Institutionalization of Institutional Theory. In S. Clegg, C. Hardy, and W. Nord (Eds.), *Handbook of Organization Studies* (175-190). London: SAGE.

Tracey, J.B., Hinkin, T.R., Tannenbaum, S., and Mathieu, J.E. (2001). The influence of individual characteristics and the work environment on varying levels of training outcomes. *Human Resource Development Quarterly, 12*, 5-23.

Ubeda-Garcia, M. (2005). Training and business performance: The Spanish case. *International Journal of Human Resource Management, 16*, 1691-1710.

van Eerde, W., Tang, K.S., and Talbot, G. (2008). The mediating role of training utility in the relationship between training needs assessment and organizational effectiveness. *International Journal of Human Resource Management, 19*(1), 63-73.

van Ittersum, K. and Feinberg, F.M. (2010). Cumulative timed intent: A new predictive tool for technology adoption. *Journal of Marketing Research, 47,* 808-822.

Vorhies, D.W. and Morgan, N.A. (2005). Benchmarking marketing capabilities for sustainable competitive advantage. *Journal of Marketing, 69*, 80-94.

Wang, P. (2010). Chasing the hottest IT: Effects of information technology fashion on organizations. *MIS Quarterly, 34*(1), 63-85.

Wejnert, B. (2002). Integrating models of diffusion of innovations: A conceptual framework. *Annual Review Sociology, 28,* 297-326.

Winfrey, E.C. (1999). *Kirkpatrick's four levels of evaluation*. Encyclopedia of education technology. Retrieved December 04, 2013 from Kirkpatrick's four levels of evaluation, http://coe.sdsu.edu/eet/articles/k4levels/index.htm.

Yin, R.K. (2003). *Case Study Research Design and Methods* (3rd Ed., *5*). (L. Bickman, and D. J. Rog, Eds.). Thousand Oaks, California: Sage Publications, Inc.

Young, M.R., DeSarbo, W.S., and Morwitz, V.G. (1998). The Stochastic Modeling of Purchase Intentions and Behavior. *Marketing Science, 44*(2), 188-202.

Zaltman, G., Duncan, R., and Holbek, J. (1973). *Innovations and Organizations*, New York City, NY: J. Wiley & Sons.

Zamora-Torres, A. (2014). Countries' competitiveness on innovation and technology. *Global Journal of Business Research*, *8*(5), 73-83.

<u>*References for Coding of Interviews*</u>

**[I1]. WS710012. November, 08, 2013. P9.*

**[I2].WS710002. April 27, 2012. P5.*

**[I3]. WS710007. November, 01, 2013. P7.*

**[I4]. WS710001. April 13, 2012. P4.*

**[I5]. WS710004. October 30, 2013. P6.*

**[I6]. WS710008. November 01, 2013. P5.*

**[I7]. WS710015. November 15, 2013. P12.*

**[I8]. WS710020. March 29, 2014. P13.*

**[I9]. WS710010. November 07, 2013. P8.*

**[I10]. WS710017. March 11, 2014. P13.*

**[I11]. WS710022. May 14, 2014. P11.*

**[I12]. WS710013. November 08, 2013. P10.*

**[I13]. WS710019. March 13, 2014. P15.*

**[I14]. WS710018. March 11, 2014. P14.*

***[I15]. November, 05, 2015.*

***[I16]. November 09, 2015.*

***[I17]. November, 09, 2015.*

***[I18]. November 05, 2015.*

***[I19]. November 06, 2015.*

***[I20]. November 24, 2015.*

***[I21]. December 01, 2015.*

***[I22]. December 01, 2015.*

**Exploratory Interview transcripts. For the purposes of shortening the reference, all quote from interviews will be referenced by anonymous ID and Atlas.ti quotation ID [I#, Atlas.ti Document#:Quotation#], as listed in this references section, where readers can reference the exact information as needed. The reference here is listed as: [Interviewee]. Transcript Name. Date of Interview. Atlas.ti Document Number.*

***Evaluation Interview transcripts. For the purposes of shortening the reference, all quote from evaluation interviews will be referenced in Chapter 6 and Chapter 7 by anonymous ID [I#], as listed in this references section. The reference here is listed as: [Interviewee]. Date of Interview.*

SUMMARY

This research focused on technical excellence in engineering companies in terms of training (TR), technology innovation (TI), and organizational effectiveness (OE). Specifically, the interaction between training and technology innovation were investigated to describe when to offer courses for technology innovations with different maturity levels to positively influence organizational effectiveness. This was done based on observing conceptual models developed through empirical studies, where two case studies were analyzed in detail within this research. The case studies explored within this research were intended to be a simplified, conceptualized account of reality, where the overall method developed in the research was tested. It was these conceptual descriptive models that gave a systematic view of how training and technology innovation interact to affect the organizational effectiveness. Ultimately, the aim of this research was to develop a generalized method that any engineering company comparable to Boeing would be able to use to create conceptualized models in the context of training, technology innovation, and organizational effectiveness. In order to accomplish the aim of this research, there was one main research question and four sub-questions:

What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?

What key variables are significant for training, technology innovation, and organizational effectiveness?

What are the relationships between the key variables?

How do the developed conceptual models show when to offer training when technology changes to positively influence organizational effectiveness?

What general method can be proposed by utilizing the approaches for developing the conceptual models?

Chapter one established the importance and significance of managing training changes to align to the technology changes at an aerospace company. Changing the aspect of competencies and managing how and when to offer appropriate training was highlighted. This chapter created a foundation by describing the issue at hand, the main questions needing to be answered to address the issue, and the research approach used to address the research questions. This chapter concluded with a brief overview of how the research was performed.

The research followed an exploratory sequential mixed methods research design approach and was divided into five phases, which was each described in Chapter 2 through Chapter 8. In the first phase of the research, the concepts of TR, TI, and OE were explored and the current situation was described using information from literature review performed in Chapter 2 and Chapter 3. Both theoretical and practical viewpoints were address in Chapter 2 and Chapter 3, respectively. Chapter 2 described the theoretical view point found in current literature and resulted in a list of common variables considered for training, technology innovation, and organizational effectiveness. Chapter 3 described and discussed technology innovation and training, as well as how training relates to technology innovation and organizational effectiveness in a practical environment. The subsections in

Chapter 3 describing technical training within companies included a general description of the various training organizations within the practical environment, strategic decision making about technical training, and challenges that the companies face with training in general. The subsections in Chapter 3 describing technology innovation within companies included a general description of the various technology organizations within the practical environment, strategic decision making about technology adoption, tools used for decision making, and technology challenges faced by companies. The combination of these sections gave an overall view of the practical environment, which included the variables considered for training, technology innovation, and organizational effectiveness within the practical knowledge base.

In the second phase of the research, as described in Chapter 4, the concepts of TR, TI, and OE were explored and empirical data was collected. The goal of this chapter was to substantiate the assumed relationships between the three research constructs of training, technology innovation, and organizational effectiveness. In addition, this chapter addressed the relevance and business needs, as outlined in the research strategy from Chapter 1. In-depth investigations towards real projects were not yet reported. To gather in-depth information on activities in the context of the constructs TR, TI, and OE, an exploratory interview approach was chosen. The exploratory interviews highlighted throughout Chapter 4 gave a practical viewpoint and were used to expand the general observation that training and technology innovation interact in the prediction of organizational effectiveness. In a limited number of exploratory case studies, semi-structured interviews were held with companies outside of Boeing, as well as within Boeing. There were a total of 14 interviews representing five companies: Boeing, Shell, General Motors (GM), Hewlett Packard (HP), and Dassault Systemes (DS). Note that practical applications were investigated in chapter three and the knowledge gained from Chapter two and three contributed to the design of the interviews. Seven exploratory interviews were performed with four companies outside of Boeing, along with seven interviews performed internally at Boeing. The exploratory interviews performed earlier was examined in this second phase to clearly identify the potential relationships between the constructs, as well as any additional variables to consider that were in context of the three constructs. The research in this phase II was qualitatively oriented.

The third phase of the research, as described in Chapter 5, consisted of model development in terms of operationalizing the variables resulting from the exploratory interview analysis performed in the second phase. A general conceptual model representation of the relationships between the three constructs was developed, as shown below in Figure S-1. The aim of this phase was to operationalize the variables for each of the three constructs of TI, TR, and OE. *It was generally observed that in a large engineering organization, OE at an organizational level is further represented by OE at a localized level.* Hence, in the context of this research, because OE at an organizational level is too general, the operationalization of OE was at a localized level. OE was operationalized at TR localized level (referred to as TROE in the research), and at TI localized level (referred to as TIOE in the research). Because the variables representing TROE were the same as the TR construct, TROE was eliminated from the general conceptual model. Thereby, OE was described in terms of TIOE. There was a transition from a general conceptual model towards a revised general conceptual model representing the operationalized variables. These transitions aimed to set a foundation for the fourth phase to link practice with theory. This in turn, further developed and operationalized the general conceptual model. Once the general conceptual model was further developed and operationalized, an operationalized conceptual model for this research became evident. Clearly defining the relationships between the constructs and the relating variables within this research was significant in the development of the conceptual models for this research. In the development of the operationalized conceptual model, the empirical findings from the interviews were confronted with literature findings from Chapter two and three. The interpretation of the general conceptual model resulted in the operationalized conceptual model, as shown below in Figure S-2.

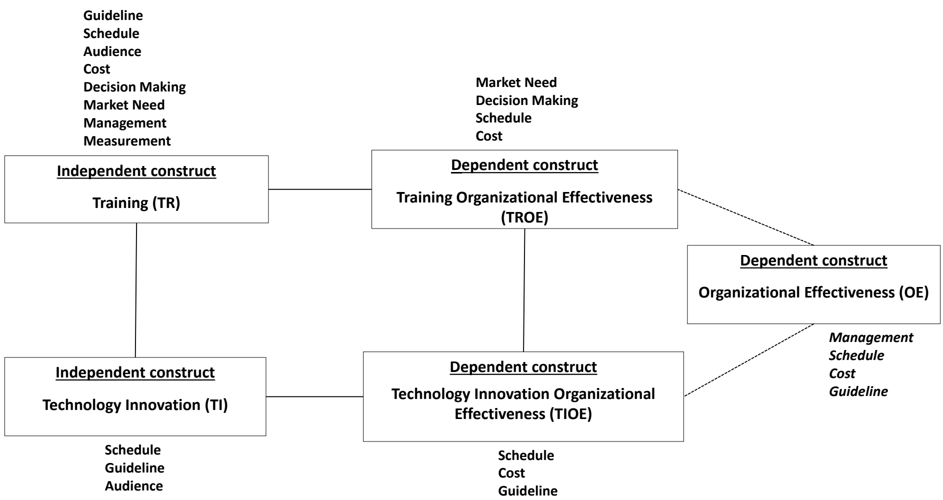


Figure S-1. General conceptual model

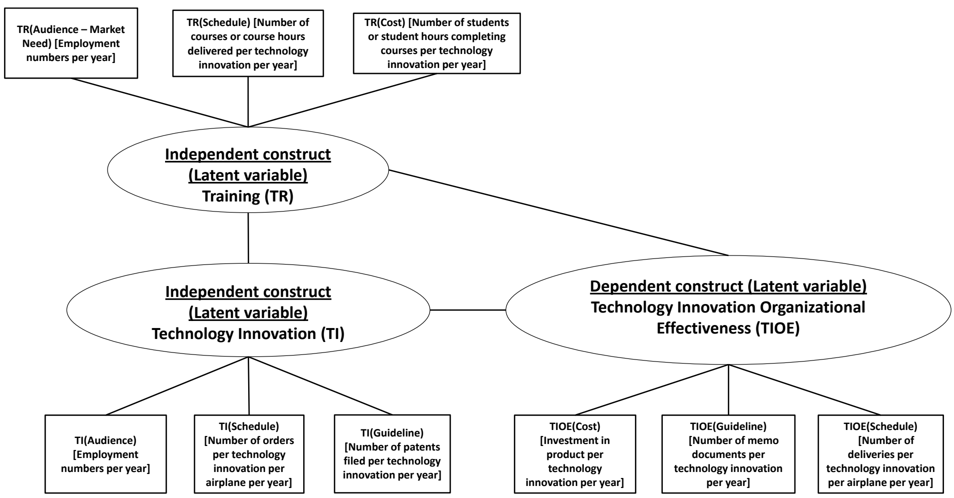


Figure S-2. Operationalized conceptual model

The fourth phase of the research, which was described in Chapter 6 and Chapter 7, consisted of in-depth case studies. Two cases were studied, representing a mature technology innovation and a technology innovation that was early in the maturity cycle. Based on the theory formulation from the third phase, the operationalized conceptual model was implemented and simulated within the two case studies. This phase focused on the assumed relationships between the three constructs, as introduced in the general conceptual model from Phase II. Phase IV had a more explanatory character and was mainly quantitatively oriented. The results from Phase IV yielded a case specific operationalized conceptual model. In addition, there was evaluation interviews performed in Phase IV. These interviews aimed to evaluate the quantitative results in the case specific operationalized conceptual models. Hence, part of Phase IV also was qualitatively oriented. The second and fourth phase together was an example of a mixed methods approach, but was explanatory rather than exploratory. Some of the qualitative findings of Phase II were further explained by means of the quantitative in-depth case studies in Phase IV. Furthermore, the quantitative in-depth case studies in Phase IV were further explained by means of qualitative approaches through the evaluation interviews. The combination of approaches taken in Phase II through Phase IV demonstrated a mixed methods approach to this research.

The fifth and final phase of the research, which was described in Chapter 8, consisted of method development to provide a general process for engineering companies to develop the various descriptive conceptual models, describing the interactions between TR, TI, and OE. It was investigated to what extent the different aspects of TR contribute to TI, and vice versa, and how the newly developed method would help in improving OE at a company. In this final phase of the research, the method developed in this Phase V was further examined through a small evaluation panel study within Boeing. Feedback from the end users (decision makers) were gathered and interpreted. The research in this concluding phase was mainly qualitative. The qualitative information explained how the general method may improve OE.

In summary, the literature review in the first phase began with observations made from literature review and exploratory interviews. The second phase consisted of the analysis of the exploratory interviews. Model development in the third phase operationalized the variables from Phase II and set the foundation for Phase III to link practice with theory, which were confronted with literature findings. This resulted in a general conceptual model that generally characterized TI, TR, and OE. The third phase further explored the relationships between TR, TI and OE. Again results were confronted with theory, resulting in the operationalized conceptual model. The fourth phase implemented the Phase III results by means of quantitative in-depth case studies. This resulted in case specific operationalized conceptual models. In the fifth phase, a general method was developed to generalize the approaches followed during Phase I through Phase IV of this research. This method was then evaluated by subject matter experts, resulting in revised guidelines supporting the general method, thus concluding the research. To strengthen the results, links with literature were established where possible.

Chapter nine discusses the limitations of this research. The main limitations of this research included (1) the limited number of case studies performed, (2) the limited number of companies of similar and various sizes analyzed, (3) the accessibility of data that was publicly available or available between organizations, and (4) the statistical approach used during the quantitative data analysis. The number of case studies performed in this research was limited as it was not within the scope of this research. This research was intended to develop a general method where the case studies were necessary to demonstrate the usability of the method. The number of companies and company sizes were limited as it was within the scope of this research to represent the majority of the five common sectors. The general method was based on the findings of significant correlations between the companies in four of the five sectors. Hence, there were recommendations made to address this limitation and recommend further validation of this general method through future studies with several companies of various company sizes.

The accessibility of data that was publicly available or available between organizations was limited. The input data for the quantitative data analysis for this research was limited by the accessibility of the data, as well as obtaining data that was publicly available. It was a challenge in an organization like Boeing to obtain data between organizations as some data was only accessible within the organizations. In addition, as it is important to companies to ensure that certain data remains private and not be publicly published, it was a challenge to find a way to obtain publicly available data that best represented the operationalized variables. If the general method were to be used within companies and organizations, the guidelines described in Chapter 8 will guide and recommend the users on obtaining the best possible dataset for the operationalized variables to ensure accurate results. As demonstrated within this research, the results found from the quantitative data analysis were high level and did not have the desired level of granularity due to the limited dataset. This leads to findings that were inconclusive.

The statistical approach used during the quantitative data analysis was limited by the number of samples within each case study and the end users of this general method. Hence, a simple time series correlation analysis was performed. It was the intention to keep the statistical approach simple for practicality purposes. The end users would be able to take this method with a complete understanding of why and how the conceptual models were developed. In addition, using a more advanced statistical approach would limit the number of variables and lead to unreliability of the results. The current statistical approach uses bivariate correlation analysis, where the number of usable data is maximized as compared to using multivariate correlation analysis approach.

The theoretical knowledge base, practical knowledge base, qualitative data analysis, and conceptual model development performed in this research ultimately answered the first research sub-question: *What key variables are significant for training, technology innovation, and organizational effectiveness?* The key variables that are significant for training, technology innovation, and organizational effectiveness were general. The variables shown in the general conceptual model deduced in Chapter 5 may be used for any engineering company of similar size to Boeing. These general key variables can be found in Figure 5-2 in Chapter 5 on page 112, and Figure S-1 in this summary. In addition, the key variables that were operationalized specific to the Boeing and are shown in the operationalized conceptual model can be found in Figure 5-4 in Chapter 5 on page 123, and Figure S-2 in this summary.

The quantitative data analysis performed in this research answered the second research sub- question: *What are the relationships between the key variables?* The relationships between the key variables are specific to the company and/or organization. As the data gathered for determining the relationships between the key variables was case specific to Boeing, the conclusions described here are specific to Boeing. Another large engineering company may have different conclusions to this research question. Hence, the conceptual models developed to describe the relationships between the key variables are referred to as *case specific* operationalized conceptual models. In addition, the key variables that showed significance may also differ depending on how the operationalized variables were queried. The relationships between the key variables for both case studies in the context of this research and in the context of the company used within this research can be found in Figure 6-1 to Figure 6-3 in Chapter 6 on page 147-148.

The interpretation of the results from the quantitative data analysis answered the third research sub-question: *How do the developed conceptual models show when to offer training when technology changes to positively influence organizational effectiveness?* The lagged cross correlation analysis performed during the quantitative data analysis in Chapter 6 resulted in case specific operationalized conceptual models. The strength between each of the bivariate, as well as the inferred influences between the constructs was described in Chapter 7. It was the results from the quantitative data analysis that gave the level of significance and strength between each of the bivariate at a certain time period; thereby, quantifying the relationships between the bivariate. Moreover, because each bivariate contained two operationalized variables representing the corresponding construct, the strength between each bivariate inferred influences between the construct. This in turn resulted in case specific operationalized conceptual models that showed when to offer training when technology changes to positively influence organizational effectiveness. It was also observed during this research that the phrase "technology changes" refers to the technology maturity and not the type of technology.

The method development performed in Chapter 8 answered the fourth research sub-question: *What general method can be proposed by utilizing the approaches for developing the conceptual models?* The general method that was proposed by utilizing the approaches for developing the conceptual models was described in Chapter 8, specifically in Figure 8-6 on page 190-191, and Figure S-3a through Figure S-3c in this summary. The general method uses a mixed methods approach and consists of three gates, where Gate 1 and Gate 3 are qualitative in nature, and Gate 2 is generally quantitative. The generalized method for Gate 1 depicts the qualitative data analysis approach, where the input is the latent variables applicable to the organization and the output is the operationalized variables and data applicable to the organization. The general conceptual model and operationalized conceptual model was developed in Gate 1. The generalized method for Gate 2 depicts the quantitative data analysis approach, where the input is the data for the operationalized variables and the output is the case specific operationalized variables. The case specific operationalized conceptual model was developed in Gate 2. The generalized method for Gate 3 depicts the evaluation of the quantitative data analysis results, where the case specific operationalized conceptual models are evaluated. Gate 3 uses a panel of SMEs to evaluate the results from Gate 2 to provide further context behind the numbers that were presented. As the case studies used in this research were specific to Boeing, it was recommended that future research begin at Gate 2 using this general method within Boeing. Furthermore, it is recommended that all other future research using this general method performed outside of Boeing begin at Gate 1.

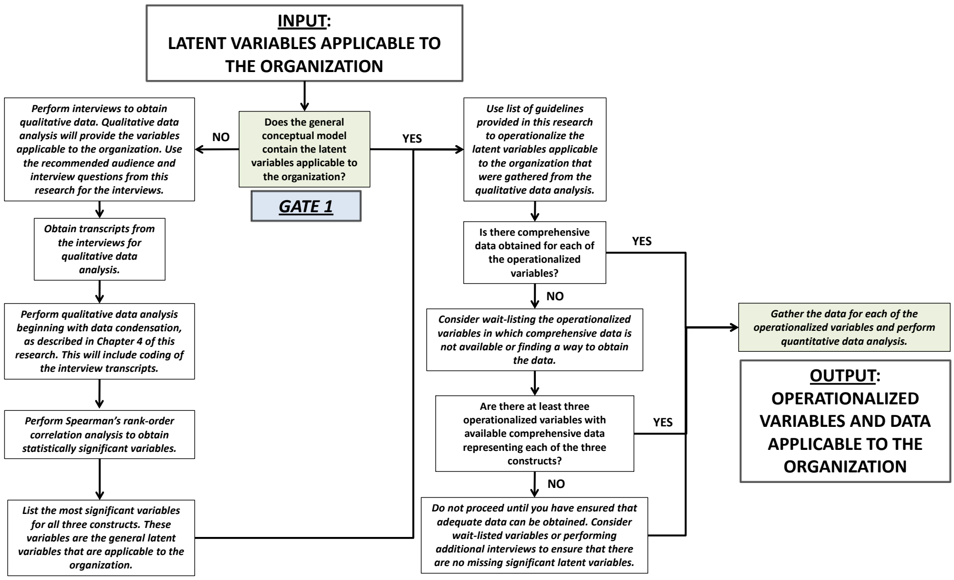


Figure S-3a. Gate 1 of the general method

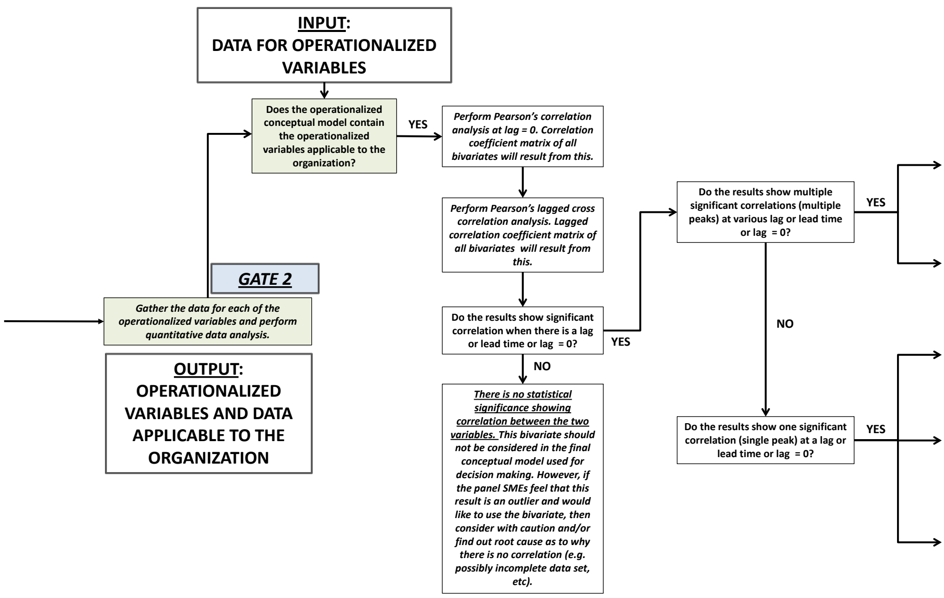


Figure S-3b. Gate 1 leading into Gate 2 of the general method

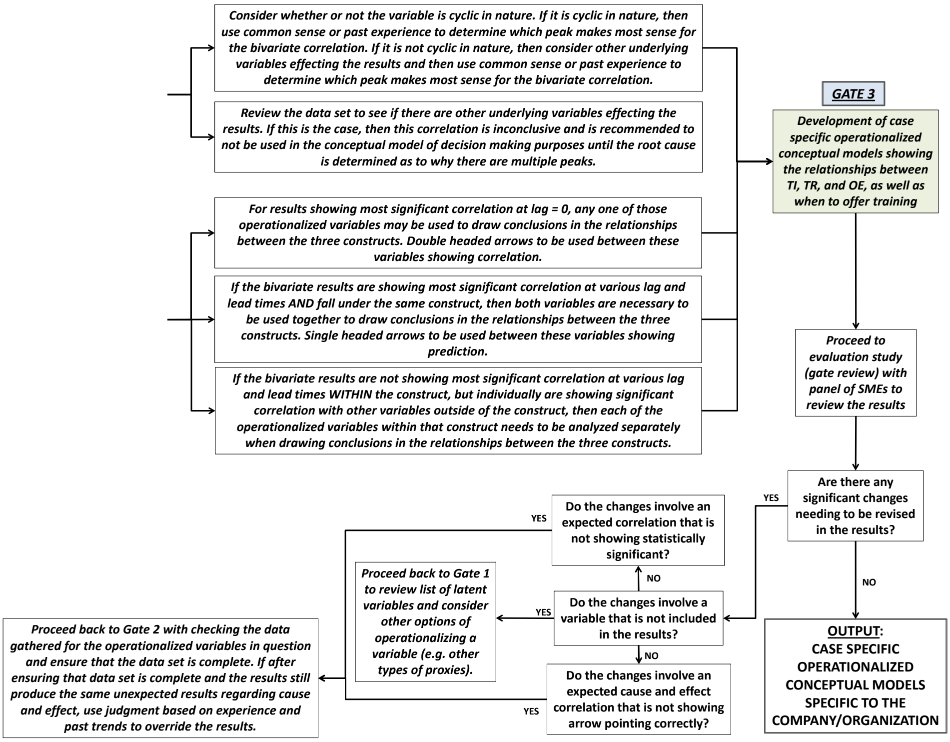


Figure S-3c. Gate 2 leading into Gate 3 of the general method

Having answered the four research sub-questions leads to answering the main research question: *What method can an engineering company use to assess the influence of training and technology innovation on organizational effectiveness?* A method that an engineering company can use to assess the influence of training and technology innovation on organizational effectiveness was first proposed and described in Chapter 8. This general method contained three main gates, where depending on the company size and the type of company sector, the starting point for using this method may begin at Gate 1, Gate 2, or Gate 3. There are several guidelines for determining which gate to begin at as described in Chapter 8. Moreover, this general method demonstrates a mixed methods approach, where Gate 1 and Gate 3 are qualitative in nature and Gate 2 is generally quantitative. It is the combination of these mixed methods approaches that an engineering company can fully capture the complexities in a practical environment, and assess the influence of training and technology innovation on organizational effectiveness.

The result of this research study was a two-fold. The first result, which led to additional future studies, included the specific quantitative results found in Chapter 6 and 7. The second result of this research study was a generalized method that can be used by any engineering company of comparable size to Boeing. It was the combination of these two results that concluded this research and thereby answered the main research question first introduced in Chapter 1.

The recommendations proposed in this research consisted of (1) recommendations for practical applications and validation of the general method proposed in this research, and (2) recommendations for future research in general. The first set of recommendations includes the development of a tool for the method to be used at a company or organization. For the general method to be useful within an engineering company, a tool that accompanies this method would need to be developed. This tool would need to have the ability to store the data for the operationalized variables and perform the correlation analyses for each bivariate of interest. In addition to performing the analyses for each bivariate of interest, the output would be a series of correlation coefficient tables, as well as normalized comparison plots and correlation lag and lead plots as demonstrated within this research. It should be considered that the tool be universally used across the organizations within a company. Hence, the tool would need to be developed using the most common software that is utilized and accessible by everyone in the company. An example would be if Microsoft Excel is commonly and widely used within the company, then the correlation analysis would be performed using this software.

Also within the first set of recommendations is a validation of the method through case studies for several technology innovations at various levels of maturity for a single company of similar size to Boeing, as studied within the scope of this research. The aim of this validation is to study the effect of technology maturity across several types of technology innovations for *one* company or organization to *fully* validate the general method.

The second set of recommendations aims towards future research relating to this research. These recommendations include future research studies that vary the types of companies, company size, and technology types, and technology maturity levels. As demonstrated in this research, varying one variable will lead to extensive future research. This research was exploratory in nature and aimed to develop a general method in which engineering companies similar to Boeing could use. Hence, this research sets the foundation for future research by providing a method and corresponding guidelines to perform extensive research and validation studies in the context of studying the interactions between TR, TI, and OE.

SAMENVATTING

Dit onderzoek is gericht op technische excellentie in grote bedrijven in termen van training (TR), technologie-innovatie (TI), en effectiviteit van de organisatie (OE). In het bijzonder is de interactie tussen training en technologie-innovatie onderzocht met als doel te achterhalen wanneer cursussen voor technologie-innovaties met verschilde niveaus van volwassenheid het best kunnen worden aangeboden zodat ze een positieve invloed hebben op de effectiviteit van de organisatie. Hiervoor zijn conceptuele modellen ontwikkeld op basis van de analyses van een tweetal empirische case studies. De case studies in het onderzoek hadden tot doel een vereenvoudigde conceptualisatie van de werkelijkheid te maken, waar de in het onderzoek ontwikkelde methode kon worden uitgetest. Deze beschrijvende conceptuele modellen verschaften inzicht in hoe de interactie tussen training en technologie-innovatie de effectiviteit van de organisatie beïnvloedt. Het uiteindelijk doel van het onderzoek was het ontwikkelen van een methode die door met Boeing vergelijkbare grote bedrijven kan worden toegepast voor het maken van beschrijvende conceptuele modellen die de relatie tussen training, technologie-innovatie en effectiviteit van de organisatie beschrijven. Om de doelen van het onderzoek te realiseren is een onderzoeksvraag geformuleerd met vier subvragen:

Welke methode kan een technologisch bedrijf gebruiken om de invloed van training en technologie-innovatie op de effectiviteit van de organisatie te bepalen?

> Wat zijn de belangrijkste variabelen om training, technologie-innovatie, en de effectiviteit van de organisatie te beschrijven?
>
> Welke relaties bestaan er tussen deze variabelen?
>
> Hoe kan uit de ontwikkelde conceptuele modellen worden afgeleid wanneer het aanbod van training leidt tot een positieve invloed op de effectiviteit van de organisatie?
>
> Wat voor algemene methode kan worden gepresenteerd voor het ontwikkelen van een passend conceptueel model in verschillende situaties?

In hoofdstuk 1 is het belang vastgesteld van het afstemmen van de interne trainingen en opleidingen op de technologieveranderingen in een lucht- en ruimtevaartbedrijf. Benadrukt werd het aanpassen van de competenties en het hoe en wanneer van het aanbieden van de juiste training op het juiste moment. Met een beschrijving van de achtergrond van dit onderzoek, de vragen die het onderzoek wil beantwoorden en de aanpak waarmee een antwoord wordt gezocht op de onderzoeksvragen legt dit hoofdstuk een basis voor het onderzoeksplan. Het hoofdstuk wordt afgesloten met een kort overzicht van de opzet van het onderzoek.

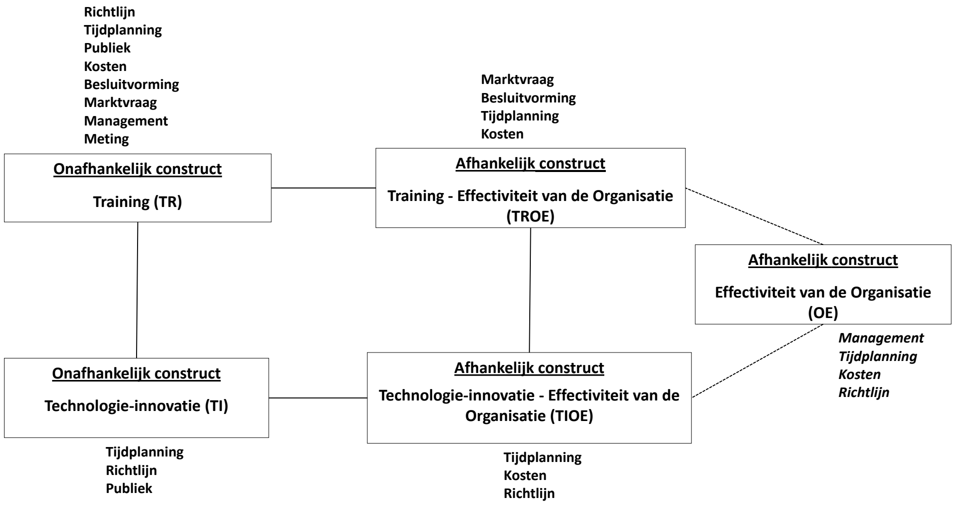
Het onderzoek is opgezet met een exploratief mixed methods onderzoeksdesign, ingedeeld in vijf fasen die in hoofdstuk 2 tot 8 worden beschreven. De eerste onderzoeksfase was gericht op verkenning van de concepten TR, TI en OE en de *state-of-the-art* is beschreven met gebruikmaking van informatie uit het literatuuronderzoek uit hoofdstuk 2 en 3, waar hoofdstuk 2 focust op de theoretische en hoofdstuk 3 op de praktische aspecten van het onderzoek. Hoofdstuk 2 beschrijft de theoretische achtergrond op basis van de huidige literatuur, resulterend in een lijst van mogelijke variabelen voor het beschrijven van training, technologie-innovatie en effectiviteit van de organisatie. Hoofdstuk 3 bespreekt de concepten technologie-innovatie en training en gaat in op de relatie van technologie-innovatie en training met betrekking tot de effectiviteit van de organisatie in een praktische context. Het deel van hoofdstuk 3 dat gaat over technische trainingen in bedrijven bevat een algemene beschrijving van verschillende trainingsorganisaties in een praktische context, strategische besluitvorming ten aanzien van technische training, en de uitdagingen op het gebied van training in het algemeen waarmee bedrijven worden geconfronteerd. De beschrijving van technologie-innovatie in bedrijven in hoofdstuk 3 omvat een algemene beschrijving van de verschillende technologie organisaties in een praktische omgeving, strategische besluitvorming ten aanzien van adoptie van technologie, instrumenten voor het ondersteunen van besluitvorming en de uitdagingen op het gebied van technologie waarmee bedrijven geconfronteerd worden. Een combinatie van de verschillende onderdelen van hoofdstuk 3 resulteert in een totaalbeeld van de praktische omgeving met inbegrip van mogelijke variabelen voor training, technologie-innovatie en effectiviteit van de organisatie.

In de tweede fase van het onderzoek, beschreven in hoofdstuk 4, zijn de concepten TR, TI en OE nader verkend en zijn empirische data verzameld. Dit hoofdstuk heeft tot doel de veronderstelde relatie tussen de drie onderzoeksconstructen training, technologie-innovatie en effectiviteit van de organisatie nader te onderbouwen. Vervolgens gaat dit hoofdstuk in op de relevantie en de zakelijke behoeften zoals beschreven in de onderzoeksstrategie in hoofdstuk 1. Het gaat hier nog niet om gedetailleerd onderzoek met betrekking tot echte projecten. Om meer specifieke informatie te verzamelen over activiteiten met betrekking tot de constructen TR, TI en OE is gekozen voor exploratieve interviews. Vanwege het praktische uitgangspunt van het onderzoek zijn de exploratieve interviews in hoofdstuk 4 gebruikt om de algemene hypothese te ondersteunen dat er interactie is tussen training en technologie-innovatie met het oog op voorspelling van effectiviteit van de organisatie.

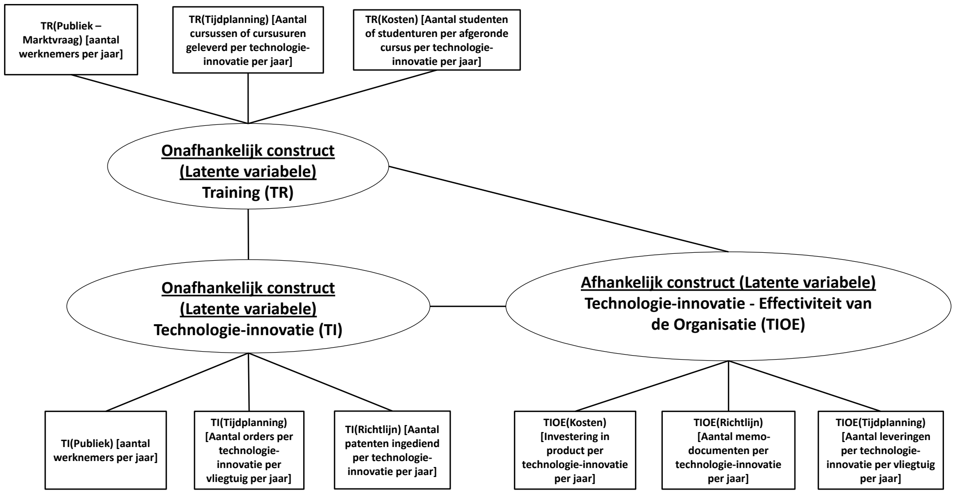
In een beperkt aantal exploratieve case studies zijn semi-gestructureerde interviews gehouden met vertegenwoordigers van zowel Boeing als andere bedrijven. In totaal zijn 14 interviews gehouden, waarvan 7 met medewerkers van Boeing, en in totaal 7 met medewerkers van Shell, General Motors (GM), Hewlett Packard (HP) en Dassault Systemes (DS). De kennis die vergaard is in hoofdstuk 2 en 3 heeft bijgedragen aan het ontwerp van de interviews. De interviews zijn geanalyseerd om de potentiële relaties tussen de constructen te identificeren en om aanvullende relevante variabelen in de context van de drie constructen op het spoor te komen. Het onderzoek in fase II was kwalitatief van aard.

De derde fase van het onderzoek, beschreven in hoofdstuk 5, bestond uit modelontwikkeling in de vorm van het operationaliseren van de variabelen die in fase II in de exploratieve interviews waren geïdentificeerd. Een algemeen conceptueel model van de relaties tussen de drie constructen is ontwikkeld (zie figuur N-1). Het doel van deze fase was om de variabelen voor elk van de drie constructen TI, TR en OE te operationaliseren. *Een algemeen observatie was dat in een groot technisch bedrijf, OE op het niveau van de organisatie te grof is, en moet worden gerepresenteerd door OE op lokaal niveau.*

Omdat OE op het niveau van de organisatie te algemeen is, is OE op het lokale niveau geoperationaliseerd. Dat wil zeggen OE is geoperationaliseerd op het lokale TR niveau (in dit onderzoek aangeduid als TROE) en op het lokale TI niveau (aangeduid als TIOE). Omdat de variabelen die TROE representeerden gelijk waren aan het TR construct, is TROE weggelaten uit het algemene conceptuele model. Derhalve is OE beschreven in termen van TIOE. Het algemene conceptueel model is vertaald naar een herzien conceptueel model op basis van de geoperationaliseerde variabelen (zie figuur N-2). Deze vertaling had tot doel een basis te leggen voor de vierde fase waarin een link wordt gelegd tussen theorie en praktijk. Hiermee werd vervolgens het conceptuele model verder ontwikkeld en geoperationaliseerd. Het helder definiëren van de relaties tussen de constructen en de bijbehorende variabelen was een significant onderdeel van de ontwikkeling van het conceptuele model in dit onderzoek. In het kader van de ontwikkeling van het algemene conceptuele model zijn de empirische gegevens uit de interviews gecontrasteerd met de gegevens uit het literatuuronderzoek in hoofdstuk 2 en 3.



Figuur N-1. Algemeen conceptueel model



Figuur N-2. Geoperationaliseerd conceptueel model

De vierde fase van het onderzoek, beschreven in hoofdstuk 6 en hoofdstuk 7, bestond uit in-depth case studies. Twee gevallen werden bestudeerd, een volwassen technologische innovatie en een technologische innovatie die nog vroeg in de ontwikkelcyclus was. Gebaseerd op de formulering van de theorie uit de derde fase, is het geoperationaliseerd conceptueel model toegepast en gesimuleerd in de twee case-studies. Deze fase richtte zich op de veronderstelde relaties tussen de drie constructen, zoals beschreven in het algemene conceptuele model van fase II. Fase IV had een meer beschrijvende karakter en was hoofdzakelijk kwantitatief georiënteerd. De resultaten van fase IV resulteerden in een case-specifiek geoperationaliseerd conceptueel model. Daarnaast zijn er in fase IV evaluatie-interviews uitgevoerd. Deze interviews hadden tot doel de kwantitatieve resultaten in de case-specifieke geoperationaliseerde conceptuele modellen te evalueren. Daarom was een deel van fase IV ook kwalitatief georiënteerd. De tweede en vierde fase samen zijn een voorbeeld van een mixed methods aanpak, maar meer verklarende dan verkennend van aard. Enkele van de kwalitatieve bevindingen van fase II zijn verder uitgediept aan de hand van de kwantitatieve in-depth case studies in fase IV. Bovendien zijn de kwantitatieve in-depth case studies in fase IV verder uitgewerkt met de kwalitatieve gegevens van de beoordelingsinterviews. De gecombineerde aanpak in fase II tot en met fase IV kenmerkt de benadering van dit onderzoek als mixed methods.

De vijfde en laatste fase van het onderzoek, beschreven in hoofdstuk 8, bestond uit het ontwikkelen van een algemene procedure voor technische bedrijven om de verschillende beschrijvende conceptuele modellen op basis van de interacties tussen TR, TI en OE te ontwikkelen. Onderzocht werd in hoeverre de verschillende aspecten van TR bijdragen aan TI, en vice versa, en hoe de nieuw ontwikkelde methode kan helpen bij het verbeteren van OE bij een bedrijf. In deze laatste fase V van het onderzoek is de ontwikkelde methode verder onderzocht met behulp van een panel evaluatiestudie binnen Boeing. Dat wil zeggen, feedback van de eindgebruikers (beleidsmakers) is verzameld en geïnterpreteerd. Het onderzoek in deze afsluitende fase was hoofdzakelijk kwalitatief. Uit de kwalitatieve informatie werd duidelijk hoe de algemene methode OE kan worden verbeterd.

Samengevat begon het overzicht in de eerste fase met literatuuronderzoek en oriënterende interviews. De tweede fase bestond uit de analyse van de oriënterende interviews. Bij de modelontwikkeling in de derde fase werden de variabelen uit fase II geoperationaliseerd en werd de basis gelegd voor de verbinding van theorie en praktijk in Fase 3. Dit resulteerde in een algemene conceptueel model dat TI, TR en OE karakteriseerde. De derde fase onderzocht de relaties tussen TR, TI en OE nader. De resultaten werden opnieuw geconfronteerd met theorie, resulterend in het geoperationaliseerde conceptuele model. In de vierde fase werden de resultaten van fase III geïmplementeerd door middel van kwantitatieve in-depth case studies. Aan de hand hiervan werden specifieke geoperationaliseerd conceptuele modellen opgesteld.

In de vijfde fase zijn de benaderingen gevolgd tijdens fase I tot en met fase IV van dit onderzoek gegeneraliseerd tot een algemene methode. Deze methode is vervolgens geëvalueerd door vakexperts. Aan de hand van deze evaluaties zijn de leidraden ter ondersteuning van de algemene methode herzien, waarmee het onderzoek kon worden afgesloten. Ter onderbouwing van de resultaten, werden waar mogelijk verbanden met literatuur gelegd.

Hoofdstuk 9 bespreekt de beperkingen van het onderzoek. De belangrijkste beperkingen van dit onderzoek omvatten (1) het beperkte aantal casestudy's, (2) het beperkte aantal bedrijven van verschillende omvang, (3) de toegankelijkheid van gegevens, publiekelijk beschikbaar of uitwisselbaar tussen organisaties en (4) de statistische methoden gebruikt bij de kwantitatieve data-analyse. Het aantal case studies in dit onderzoek was beperkt aangezien het niet binnen de scope van dit onderzoek lag dit verder uit te breiden. Dat wil zeggen, dit onderzoek had tot doel een algemene methode ontwikkelen en de case studies waren nodig om van de bruikbaarheid van de methode aan te tonen. Het aantal bedrijven en de variatie in de omvang van de bedrijven was niet groot, maar het doel om vijf relevante sectoren te vertegenwoordigen is gerealiseerd. De algemene methode is gebaseerd op significante correlaties tussen de bedrijven in vier van de vijf sectoren. Op basis daarvan zijn aanbevelingen gedaan voor het aanpakken van deze beperking verdere validatie van deze algemene methode in toekomstige studies met verschillende bedrijven en verschillende bedrijfsomvang.

De publiekelijk beschikbaarheid van gegevens dan wel de uitwisselbaarheid van gegevens tussen organisaties was beperkt. Daardoor was de invoer van gegevens voor de kwantitatieve analyse beperkt. Het was een uitdaging om in een organisatie zoals Boeing gegevens te verkrijgen voor een analyse tussen organisaties, die gewoonlijk alleen toegankelijk zijn binnen de organisatie, want het is belangrijk voor een bedrijf om te kunnen garanderen dat bepaalde gegevens niet openbaar gepubliceerd worden. Het was ook een uitdaging om een manier te vinden van voor het verkrijgen van publiek beschikbare gegevens die de geoperationaliseerd variabelen het best vertegenwoordigen. Als de algemene methode wordt gebruikt binnen bedrijven en organisaties, dan zijn de in hoofdstuk 8 beschreven richtlijnen een goed uitgangspunt voor het verkrijgen van de beste mogelijke dataset voor de geoperationaliseerde variabelen om passende resultaten te garanderen. Het is gebleken dat de resultaten van de kwalitatieve data-analyse in dit onderzoek als gevolg van de beperkte dataset van een hoog abstractie niveau waren en niet het gewenste detail niveau bereikten. Als gevolg daarvan zijn de conclusies niet eenduidig.

De lage aantallen binnen elke case-studie en het geringe aantal eindgebruikers van deze algemene methode beperken de mogelijkheden van de statistische kwantitatieve data-analyse. Daarom is een eenvoudige time serie correlatie analyse uitgevoerd. Het was de bedoeling de statistische benadering eenvoudig te houden voor praktische doeleinden. Dat wil zeggen, de eindgebruikers moeten aan de hand van deze methode een compleet begrip krijgen van waarom en hoe de conceptuele modellen werden ontwikkeld. Voor meer geavanceerde statistische benadering is het aantal variabelen te beperkt, wat leidt tot onbetrouwbaarheid van de resultaten. De huidige statistische aanpak maakt gebruikt van bivariate correlatie analyse, waarbij het aantal bruikbare gegevens is gemaximaliseerd met behulp van multivariate correlatie analyse. Op basis van de theoretische kennis, de praktische knowledge base, de kwalitatieve data-analyse en het conceptuele model is uiteindelijk de eerste sub-onderzoeksvraag beantwoord: Welke sleutel variabelen zijn van belang voor training en technologie-innovatie op de effectiviteit van de organisatie?

De sleutel variabelen die belangrijk zijn voor opleiding, technologische innovatie en organisatorische doeltreffendheid waren algemeen van aard. Dat wil zeggen, de variabelen weergegeven in het algemene conceptuele model in hoofdstuk 5 kunnen worden gebruikt voor elk technisch bedrijf gelijksoortig aan Boeing. Deze algemene sleutel variabelen kunnen worden gevonden in figuur 5-2 in hoofdstuk 5 op pagina 112 en Figuur N-1 in deze samenvatting. Vervolgens zijn de sleutel variabelen specifiek voor Boeing geoperationaliseerd en verwekt in het geoperationaliseerde conceptuele model in figuur 5-4 in hoofdstuk 5 op pagina 123 en Figuur N-2 in deze samenvatting.

De kwantitatieve data-analyse uitgevoerd in dit onderzoek beantwoordt de tweede sub-onderzoeksvraag: wat zijn de relaties tussen de sleutel variabelen? De relaties tussen de sleutel variabelen zijn specifiek voor het bedrijf en/of organisatie. Aangezien de gegevens met betrekking tot de relaties tussen de sleutel variabelen in dit geval specifiek voor Boeing waren, zijn ook de hier beschreven conclusies specifiek voor Boeing. Dat wil zeggen, bij een andere groot technisch bedrijf kunnen andere conclusies uit deze onderzoeksvraag worden getrokken. Daarom zijn worden de specifieke geoperationaliseerde conceptuele modellen om de relaties tussen de sleutel variabelen te beschrijven aangeduid als case specifieke modellen. Bovendien kan de betekenis van de sleutel variabelen ook verschillen afhankelijk van hoe de geoperationaliseerd variabelen zijn bevraagd. De relaties tussen de sleutel variabelen voor beide case-studies in het kader van dit onderzoek en de context van het specifieke bedrijf gebruikt binnen dit onderzoek kunnen worden gevonden in figuur 6-1 en figuur 6-3 in hoofdstuk 6 op pagina 147-148.

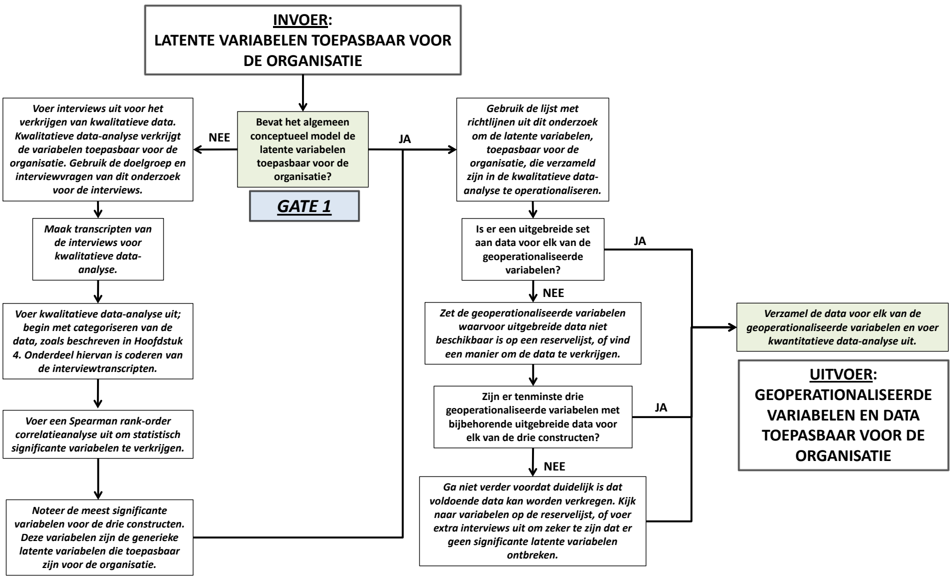
De interpretatie van de resultaten van de kwantitatieve data-analyse beantwoordt de derde sub onderzoeksvraag: hoe kan uit de ontwikkelde conceptuele modellen worden afgeleid wanneer het aanbod van training leidt tot een positieve invloed op de effectiviteit van de organisatie? De cross correlatie analyse uitgevoerd tijdens de kwantitatieve data-analyse in hoofdstuk 6 resulteerde in case specifieke geoperationaliseerd conceptuele modellen. De kracht tussen elk van de bivariate correlaties, evenals de afgeleide invloeden tussen de constructen is beschreven in hoofdstuk 7. De resultaten van de kwantitatieve data-analyse gaven het niveau van significantie tussen elk van de bivariate in een bepaalde periode weer; waarmee de relaties tussen de bivariate correlaties worden gekwantificeerd. Bovendien kunnen, omdat elke bivariate correlatie twee geoperationaliseerd variabelen omvat die het overeenkomstige construct representeren, uit de kracht van de bivariate correlaties de invloeden tussen de constructen worden afgeleid. Dit leidde vervolgens tot case specifieke geoperationaliseerde conceptuele modellen die aangaven wanneer training aan te bieden en wanneer technologische veranderingen een positieve invloed hebben op organisatie-effectiviteit. Er is tijdens dit onderzoek ook opgemerkt dat de zinsnede 'technologieveranderingen' verwijst naar de rijpheid van de technologie en niet het soort technologie.

De methode ontwikkeling uitgevoerd in hoofdstuk 8 beantwoordt de vierde sub onderzoeksvraag: wat voor algemene methode kan worden gepresenteerd voor het ontwikkelen van een passend conceptueel model in verschillende situaties? De methode van aanpak voor de ontwikkeling van de conceptuele modellen wordt beschreven in hoofdstuk 8, specifiek in figuur 8-6 op pagina 190-191, en

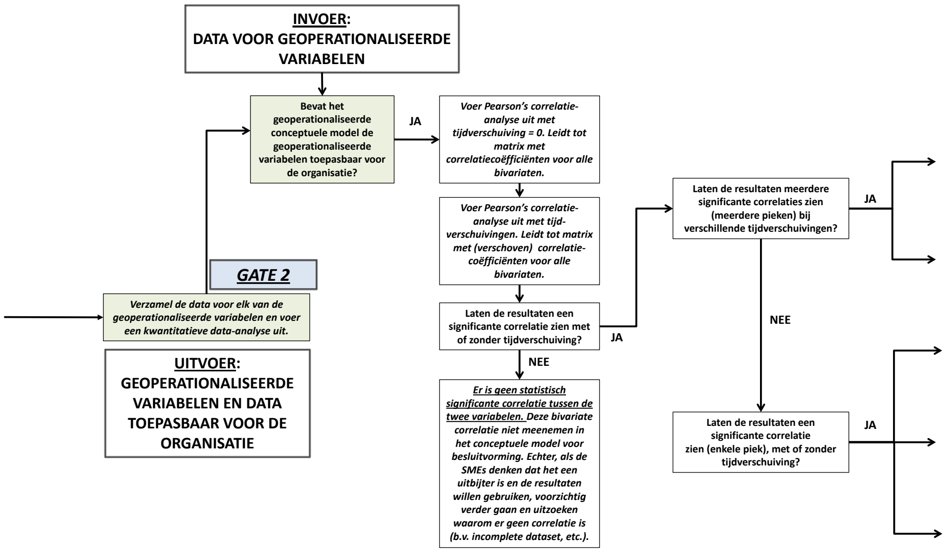
Figuur N-3a tot en met Figuur N-3c in deze samenvatting. De algemene methode maakt is gebaseerd op een mixed methods aanpak en bestaat uit drie gates, Gate 1 en Gate 3 zijn kwalitatief van aard en Gate 2 is overwegend kwantitatief. De methode voor Gate 1 laat een kwalitatieve aanpak zien, met als input is de latente variabelen die van toepassing zijn voor de organisatie en als output de geoperationaliseerd variabelen. Het algemene conceptuele model en het geoperationaliseerde conceptueel model zijn ontwikkeld in Gate 1. De methode voor Gate 2 toont een kwantitatieve data analyse aanpak, met als input de data voor de geoperationaliseerd variabelen en als output de case specifieke geoperationaliseerd variabelen. Het case specifieke geoperationaliseerd conceptueel model is ontwikkeld in Gate 2. De methode voor Gate 3 toont de resultaten van de kwantitatieve data analyse, waarbij de case-specifieke geoperationaliseerd conceptuele modellen worden geëvalueerd.

Gate 3 maakt gebruik van een panel van Midden-en kleinbedrijf om de resultaten van Gate 2 te evalueren en om een nadere context achter de getallen te schetsen. Aangezien de case studies in dit onderzoek specifieke voor Boeing waren, werd als aanbeveling gegeven dat toekomstig onderzoek met behulp van deze methode binnen Boeing bij Gate 2 kan beginnen.

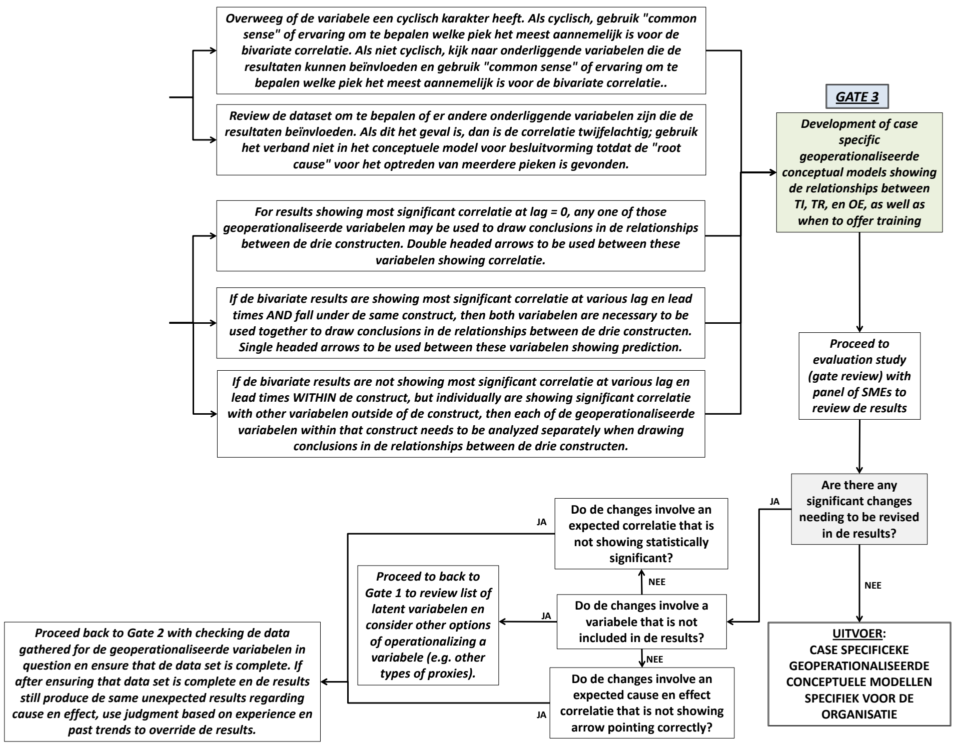
Daarnaast wordt aanbevolen dat alle andere toekomstige onderzoek met behulp van deze algemene methode buiten Boeing begint bij Gate 1.



Figuur N-3a. Gate 1 van de algemene methode



Figuur N-3b. Gate 1 naar Gate 2 van de algemene methode



Figuur N-3c. Gate 2 naar Gate 3 van de algemene methode

Na het beantwoorden van de vier onderzoek sub-vragenkomt de hoofdonderzoeksvraag aan de orde: Wat voor methode kan een technisch bedrijf gebruiken om the invloed van training en technologie-innovatie op the effectiviteit van de organisatie te bepalen? De in dit onderzoek ontwikkelde methode die een technisch bedrijf kan gebruiken om de invloed van opleiding en technologische innovatie op organisatie-effectiviteit te beoordelen is beschreven in hoofdstuk 8. Deze methode bevat drie Gates, afhankelijk van de grootte van het bedrijf en de bedrijfssector kan het vertrekpunt voor de methode bij Gate 1, Gate 2 of Gate 3 worden gekozen.

Zoals beschreven in hoofdstuk 8 zijn er verschillende richtlijnen om te bepalen welke Gate te beginnen. De algemene methode volgt een mixed methods aanpak, waarbij Gate 1 en Gate 3 kwalitatief van aard zijn en Gate 2 overwegend kwantitatief van aard. Het is de combinatie van deze mixed methods die het mogelijk maakt voor een technisch bedrijf de complexiteit in een praktische omgeving volledig te omvatten en de invloed van training en technologische innovatie op organisatie-effectiviteit te beoordelen.

Het resultaat van dit onderzoek was tweevoudig. Het eerste resultaat, wat leidt tot nieuw toekomstige onderzoek, omvatte de kwantitatieve resultaten gevonden in hoofdstuk 6 en 7. Het tweede resultaat van dit onderzoek was een algemene methode die kan worden gebruikt door een technische bedrijf van vergelijkbare omvang als Boeing. Met de combinatie van deze twee resultaten wordt de in hoofdstuk 1 geïntroduceerde hoofdonderzoeksvraag beantwoordt en het onderzoek afgesloten.

De aanbevelingen op basis van dit onderzoek bestaan uit (1) aanbevelingen voor praktische toepassingen en validatie van de methode die in dit onderzoek zijn voorgesteld, en (2) aanbevelingen voor toekomstig onderzoek in op dit gebied. De eerste reeks aanbevelingen omvat de ontwikkeling van een instrument voor de methode te gebruikt door een bedrijf of organisatie. Dat wil zeggen om de methode te kunnen gebruiken in een technisch bedrijf zou een bij de methode horend aangepast instrument moeten worden ontwikkeld. Dit instrument zou de mogelijkheid moeten bieden om de gegevens voor de geoperationaliseerd variabelen op te slaan en voor het uitvoeren van de analyses voor elk bivariate correlatie. Naast het uitvoeren van de analyses voor elke relevante bivariate correlatie zou een reeks tabellen van de correlatiecoëfficiënten, evenals genormaliseerd vergelijkingen en lead plots moeten worden opgeleverd zoal in dit onderzoek is gedaan voor Boeing. Het uitgangspunt is dat dit instrument door de organisaties binnen een bedrijf worden universeel kan worden gebruikt. Daarom zou een hulpprogramma moeten worden ontwikkeld op basis van de meest voorkomende software die voor iedereen in het bedrijf toegankelijk is. Als bij voorbeeld Microsoft Excel overal binnen het bedrijf wordt gebruikt, dan zou de correlatie analyse met behulp van deze software moeten worden uitgevoerd.

Een ander onderdeel van de eerste reeks van aanbevelingen is een validatie van de methode door middel van casestudies voor verschillende technologische innovaties op verschillende niveaus van rijpheid voor een enkel bedrijf van eenzelfde omvang als Boeing. Het doel van deze validatie is het bestuderen van het effect van technologie rijpheid voor verschillende soorten technologische innovaties binnen één bedrijf of organisatie om de algemene methode meer volledig te valideren. Idealiter zou dat ene bedrijf Boeing zijn, zodat direct de vergelijking met de Boeing case studieresultaten uit dit onderzoek kan worden gemaakt. Op dit moment is in dit onderzoek, een soort technologische innovatie gericht in de materiaalkunde onderzocht met twee case studies op verschillende niveaus van technologie rijpheid (Vroeg in het proces en een volledig gerijpte fase).

Aanvullend onderzoek op het gebied van materiaalkunde zou cases voor tussenliggende rijpheid niveaus kunnen bevatten.

De tweede reeks aanbevelingen is gericht op mogelijk toekomstig onderzoek in het verlengde van dit onderzoek. Deze aanbevelingen omvatten toekomstige studies die variëren met betrekking tot de aard van de bedrijven, de grootte van het bedrijf, en technologie typen en technologie rijpheid niveaus. Zoals blijkt uit dit onderzoek, zal het variëren van één variabele leiden tot uitgebreide mogelijkheden aan toekomstig onderzoek. Dit onderzoek was verkennend van aard en gericht op het ontwikkelen van een algemene methode die technische bedrijven zoals Boeing kunnen gebruiken. Daarmee vormt dit onderzoek de basis voor toekomstig onderzoek door het verschaffen van een methode en bijbehorende richtlijnen om uitgebreid onderzoek en validatie en onderzoek te verrichten in het kader van het bestuderen van de interacties tussen TR, TI en OE.

CURRICULUM VITAE

Vivian T. Dang was born in Denver, Colorado, USA on October 11, 1982. She received her Bachelor of Science degree in Aeronautical and Astronautical Engineering at the University of Washington in Seattle, Washington in June 2005. In Spring of 2005, Vivian accepted an engineering position at the Boeing Company. While working full time, she also completed her Master of Science degree in Aeronautical and Astronautical Engineering at the University of Washington in June 2008, with concentration on composite structures.

In 2009, she began working on her Ph.D. in Systems Engineering as an external student at Delft University of Technology in Delft, Netherlands under the direction of Prof. dr. ir. Alexander Verbraeck and Prof. dr. Erik de Graaff. She currently works as a structural analysis engineer at the Boeing Company and has been with the company for over 11 years.

Since beginning her career at the Boeing Company in 2005, Vivian has experience in the areas of program management, technical training, and structural engineering. Specifically, she has worked on developing composite and nanotechnology training programs for the Boeing enterprise, was the principal investigator for research and developmental activities for the 787 airplane technology integration program involving nanotechnology materials, and supported activities for Boeing Commercial Airplanes Structural Methods and Allowables organization involving the application of progressive failure analysis techniques to future airplanes. Vivian has presented and published numerous papers at conferences and journals, where a selected few are listed here. In addition, she was a chapter author for a book publication in 2010.

Selected Publications

(a) Papers presented in Conferences

1. Dang, Vivian et. al., *"An Approach to Enhancement of Conductivity in Composite Material Using Nanotechnology,"* CANEUS 2006, Toulouse, France, Aug. 27-Sept. 01, 2006
2. Dang, Vivian and Richey, Mike et. al., "*Nanotechnology, Education and Workforce Development,"* AIAA Technical Conference 2007, Honolulu, HI, Apr. 23- Apr. 26, 2007
3. Chengalva, M., Huffaker, E., Dang, V.T., Anyasi, J., *"Virtual Testing – The Roadmap from Concept to Implementation – A Case Study from BCA,"* BTEC, Huntington Beach, CA, 2015

(b) Book Publication

1. Zhong, K., Maguire, R., Dang, V., et. al. "Practical Aspects of Processing and Applications for Nanocomposites," DESTech Publications. 2010

Dream no small dream; it lacks magic. Dream large. Then make the dream real.

– Donald Wills Douglas, Sr.