

“ANALYSIS OF RISK MANAGEMENT ACTIVITIES IN THE DESIGN, ENGINEERING, DEVELOPMENT PHASES OF MANUFACTURING ORGANIZATIONS”

MASTER’S THESIS REPORT

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AKNOWLEDGEMENTS

“The Master’s thesis represents the final step of my Masters in Management of Technology in the faculty of Technology, Policy, Management of TU Delft Netherlands. The past two years of my Masters has been a steep learning curve. The thesis has staged the perfect platform and has prepared me to take a step into the industry. My Masters has provided me a global exposure which gave me the perfect opportunity to interact with some of the sharpest minds. The application oriented studies in the various course work , the group projects has not only enhanced by analytical skills, but has definitely shaped me up as a true team player.

First of all I would take this opportunity to thank my mentor Dr. Wijnand Veeneman for his constant support, patience and trust in my capabilities. I thank him for guiding me in this project, and for always pointing out the correct path whenever I diverged from the focus of the project. It was an immense honour to have the opportunity to learn from Dr. Veeneman. I thank Dr. Hans de Bruijn, and Dr. Roland Ort, my chair and my first supervisor, for always being open to discussions, and their detailed feedback, which helped me to improve my work. I would also like to thank Dr. Casper Wassink and Dr. Herman Mooi, for giving me access to their respective organizations for data collection. Next I would like to thank my fellow class mates and my friends for their constant support and motivation.

Last but not the least , I would like to thank my parents, Mr. Subrata Bhaumik, and Mrs Sumana Bhaumik, for being beside me through thick and thin all along my life. I sincerely dedicate this piece of work to them.”

*Regards,
Satyaki Bhaumik.*

EXECUTIVE SUMMARY

New Product or System development in a manufacturing industry is realized through the culminated efforts of different functional units, namely the Research and Development unit, the Supply Chain unit, the Design and Engineering Team, and finally the Manufacturing and Assembly units. The Design, Engineering and Development phase is a critical part of the entire product development lifecycle since it's a process in which conceptualized ideas of the Research and Development unit or the Technological centers are given shape in the form of the first blue prints, which is further developed into the physical structure itself.

The technical complexity of realizing a new technology, the interfaces and interdependencies amongst the different functional silos of the organization and the complexity of dealing with external suppliers and vendors leads to risks in the process of product development. These risks hamper the project in terms of quality of the product or system to be achieved, cost management and the time management of the project. Therefore it is necessary to adopt and practice certain important risk management activities which helps to be prepared to face such risks.

Study of literature helped to realize that it is known what risk management is, and why it should be applied. However there is a gap of knowledge of how and what are the most effective and necessary risk management activities that should be adopted and practiced. An explorative multiple case study amongst three well established manufacturing organizations was carried out to study what are the best risk management activities practiced and adopted to manage risks on grounds of technological complexities, complexities and interfaces amongst the different functional silos in the organization and the risks which arose while dealing with the suppliers and vendors.

The literature was used to develop the research protocol based on the risk management lifecycle. The protocol helped to build constructive questions which was used to investigate two past executed projects from each of the organizations chosen in the sample. The cases studied had realized at least the first prototype or the concept design successfully. Theory of consolidation was used to narrow down to twenty seven risk management activities. The next step in the research was to establish the most effective combinations of risk management activities.

Using the concepts of fuzzy sets qualitative comparative analysis, the independent risk management activities were dealt as input conditions and the project outcomes in the context of quality of the product developed, the cost management of the project and the time management of the project was dealt as the dependent variable. The fsQCA tool was used to carry out the analysis by framing fuzzy data sets of the different conditions catering to technological risks, internal organizational risks and the external organization in the form of suppliers and vendors.

The fsQCA analysis using the set and subset theory, analyzed the maximum consistency and coverage of the different combinations of the Risk management activities. This helped to conclude on the most important risk management activities on grounds of technical risks, internal organizational risks and the external organizational risks. The qualitative judgement of the cases helped to identify certain risk management activities which is essential to be practiced in order to make the combinations of the risk activities identified by fsQCA successful. The combination of the fsQCA analysis and the qualitative judgement helped to build up the Technological Risk activity model, the Internal organizational risk activity model and the External organizational risk activity model. These mentioned risk activity model are the main deliverables of the research on managerial terms. The fsQCA and the qualitative judgement further helps to establish relations between the independent risk activities and the dependent project outcomes which can be defined as the contribution to science. The added advantages and the contributions of the risk activities on the dependent project outcomes have also been discussed in the research.

The study of the past executed projects help to conclude that risk management as followed in the literature is more algorithmic in nature with pre-defined steps, whereas risk management in actual practice

is more aligned in towards a project management approach. The risk management framework followed in the organization is highly influenced by the driver of the project which could be quality, cost or time management of the project. The author deduces that larger the size of the organization, the more structured and streamlined is the risk management framework. Smaller the size of the organization, more informal is the risk management. In such organizations the risk management is almost carried out from the perspective of project management.

Through the research it is realized that there are no perfect risk management activities, since even after taking immense precautions and adopting a vigorous risk management framework, the project can eventually meet some un conceived risks, which might completely hamper the process of execution. Therefore the prescription model recommended in the research, would enable the organization to be well equipped to face and counter the risks that evolve in the process of product development. The risk management activities as prescribed through the model should be primarily disciplined or institutionalized in the manufacturing processes.

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RESEARCH PROBLEM

In this chapter the researcher, provides a brief description of how an efficient process management and project management helps in a smoother execution of a new system development project. The chapter builds up the research problem and the project objective. The key research sub questions and main questions are constructed.

1.1 Topic Background

Organisations provide either a system(product), or a solution or a service to the market. Be it a system or a service or a solution that the organisation offer to their clients, the organisation needs to constantly adapt to the changing needs of the market. The needs of the client have become dynamic in nature. The rapid advancement in science and technology has enhanced the bar of expectations of the clients. (Jifeng.M, Gang.P, & Maclachlan.L.D, 2009). The customers expect the organisations to deliver systems with more incremental or radical features, systems which are more precise, yet faster than the previous existing system. Organisations need to constantly innovate in order to secure their position in the market. The organisations either aim at the mass market or specific niches. They plan the advancements of the product plans accordingly. (Wang.J, Lin.W, & Huang.Y, 2010)

Innovation is defined as the application of new creative solutions that meets new requirements, inarticulate needs, or existing market needs. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010) Innovation is the source of economic growth and a key source of new employment opportunities as well as potential for realizing environmental benefits. As a result of innovation, a new system development is the process by which an organisation uses its resources and capabilities to create a new product or improve an existing one. Product or System development is seen as “among the essential process for success, survival, renewal of organisations”. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010)

The engineering, design and development phase is a crucial phase in the entire life cycle of a product or system development. The Engineering and Design phase acts as the corridor and interface between the conceptualized idea and the first physical structure of the new prototype. Risks arise in the process of design, engineering and development. In fact risks and uncertainties are generated in the complete process of innovation of new system development. Risks are generated right from the conceptualization of the idea to the commercialization of the system. (Salomo.S, Weise.J, & Gemunden.G.H, 2007) Risks can generate in the context of the market uncertainties, the technological complexities and the organizational complexities. (Jifeng.M, Gang.P, & Maclachlan.L.D, 2009) Risks in the design, engineering and developmental stage also arise due to the complexities faced with the suppliers and vendors who can be viewed as the external market. A product or a system is finally realized due to the synchronised, coordinated and culminated efforts of the different functional units of the organisation. (Schmidt.B.J, Montoya-Weiss.M.M, & Massey.P.A, Fall 2001) Managing the different inter-organisational complexities within the different organisations are important from the perspective of achieving a successful new prototype of the product or system. (R.Fabac, 2010)

It is important from the perspective of the organisation that risks are managed well. Proper risk analysis lets an organisation achieve an understanding of the relative severity of the risks. Risks are

associated with every stage gates of the product developmental process. Well-co-ordinated process management amongst all the functional units of the organisation makes the execution and the operational process a lot smoother. (Salomo.S, Weise.J, & Gemunden.G.H, 2007) Risk management is important while framing the basic scopes and objectives of the project. The initial process management and project planning makes the operational phase a lot smoother. Risks further generate in the execution and operational phases, which are further managed by means of efficient risk management activities. The project and process management structure of an entire new product development cycle is visualized below. (Salomo.S, Weise.J, & Gemunden.G.H, 2007)

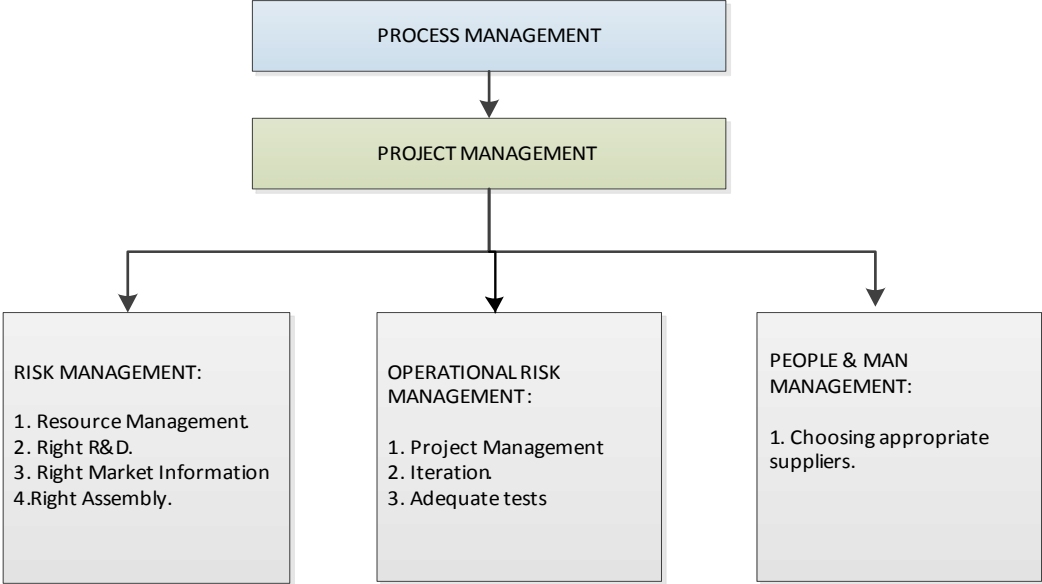


Figure 1 : Illustration of the Effects of the Process management and Project Management (S.Salomo 2007)

Fig 1. Depicts that initial project planning takes place by means of process management amongst all the actors. The risk management in the different contexts of the projects are carried out by means of project and process management. Different organisations have different risk management activities or approaches to risks. Organisations either have formalized risk management activities or they have informal risk management activities. The way risks are managed further enables the project to shape up in a specific way. In other words the risk management strategies have a direct influence on the project outcomes. Literature has made it evident that the industry knows what risk management is, and why it should be applied.(Hillson.D & Simon.P, The Atom) However there are no specific mentioned risk activity that must be necessarily adopted and practiced by the organizations to get a better project outcome.

1.2 Definitions of Key Terms

In this section we define some of the key terms that are used in the report. We clarify the definitions of Risks, Risk Management, “Design, Engineering and Developmental phase”, Risk Management Strategies, Complexities, Interfaces, Contexts, and Project Outcomes. The following are the definitions of the above terms. The detailed explanation of the terms are found in (Appendix, chp1, 1.2)

Risks: Risks can be defined as any uncertainty that if it occurs would have either a positive or a negative effect on the achievements of one or more objects of a project. . (PMBOK), (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010), (D.Hillson & P.Simon)

Cause: The cause describes existing conditions that might give rise to risks. (D.Hillson & P.Simon)

Effects: The effect of an event arises in the future (that is it is not a current problem). However its existence depends on whether the related risk occurs. (D.Hillson & P.Simon)

Risk Management: Risk management is the process of identifying the uncertainties of future events, and plan out activities which mitigates the possible negative impacts (threats) or take advantage of them if viewed to have a positive impact (opportunity). (Gidel.T, Gautier.R, & R., February 2005)

Design, Engineering, Developmental phase: It is defined to be an important phase since it acts as a corridor and interface between the conceptualized theoretical solution and the physical structure of the prototype. (PMBOK)

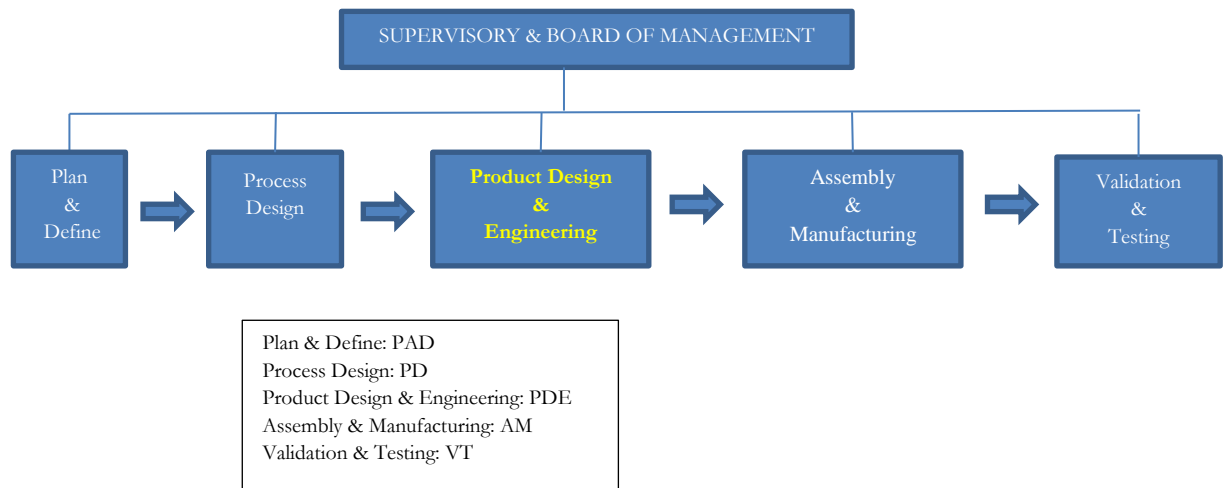


Figure 2: Stage gates of New Product Development

Risk Management Activities: Risk management activities can be defined to be the methodology, practiced or tools used in order to manage the risks identified in the organization. (Jifeng.M, Gang.P, & Maclachlan.L.D, 2009)

Complexities: Complexity in the context of this research applies to the problems , that might arise due to the interfaces and interdependencies amongst the actors involved in the network of new system development. (M.Hobbey, 1998)

Interfaces: Interface can be defined to be the point where two systems, subjects, organizations, meet and interact with another system or person. (R.Fabac, 2010) (M.Hobbey, 1998)

Contexts: Contexts can be defined to be the boundaries, the source of risk or the aspects of the risk management.

Project Outcomes: Project outcome in the context of this report refers to the result or the way consequences shape up in terms of the various stage gates of a project.

1.3 Research Problem Statement

Literature and theory propose, various risk management frameworks. (Hillson.D & Simon.P, The Atom).Risk management activities as mentioned in the literature, are generally in the nature of algorithmic steps, which follows certain preconceived steps. Literature does not specify the necessity to adopt certain

specific risk management activities in accordance to certain contexts to achieve a better project outcome. Improper application of certain risk management activities may lead to more complexities in the project outcome. (D.Hillson & P.Simon) Unnecessary risk activities may even stifle innovation in the process of new system or product development. Analysis of practical risk management approaches enables the researcher to find out the difference between the proposed theory and industrial practices. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010),(Appn,Chp1, 1.3)

It is quite clear what risk management is. The problem is not a lack of understanding the why, who, or when of risk management. The lack of effectiveness comes from not knowing how to manage or carry out risk management activities. The problem lies in not knowing the right risk activity for a certain situation. (D.Hillson & P.Simon). It is important to analyze how the risk management is carried out and how it is beneficial to the project outcome. It is essential to establish a causal relation between the independent risk management activities and the dependent project outcome, so that companies perceive the distinct benefits of carrying out risk management activities in the process of product development. The perception of risk management in real life projects will also give an opportunity to improve the existing risk management tool or algorithms. (Appn,Chp1, 1.3) The figure below illustrates the Problem Statement.

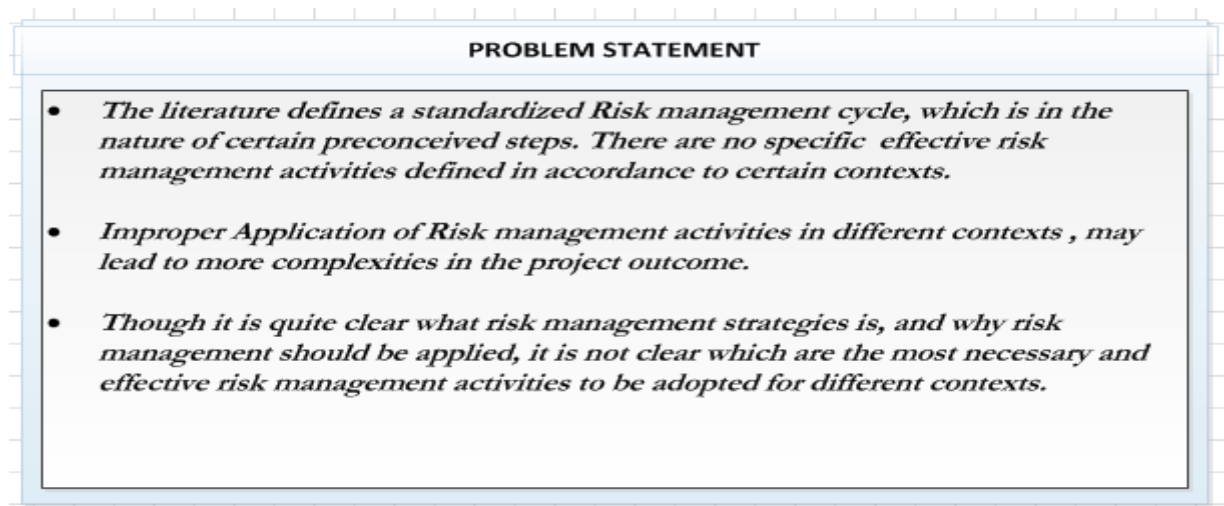


Figure 3: Problem Statement of the Project.

1.4 Research Objectives

The primary objective of this research is to analyse the most effective risk management activities that should be adopted by the industries in the different contexts. The research also aims to establish a causal relation between the independent risk management activities and the dependant project outcomes by analysing how the risk management activities influence the project outcomes. The research will be carried out by means of an explorative case study analysis in the manufacturing organisations. The main aim would be to study the various risk management activities and approaches of the organisations in the context of Technology and Internal and External Organisation structures. This would help to make recommendations to the organizations on how certain risk management activities are effective in specific contexts and circumstances related to technology and internal and external organization structure

An initial review of the literature to study the normative risk management framework, and then an exposure of the various risk management activities of the industries will further help to realize the

differences in the risk management activities in practice are from the proposed normative risk management framework in the literature.

The primary objective of this research is three fold and is clearly specified in the figure (4) below.

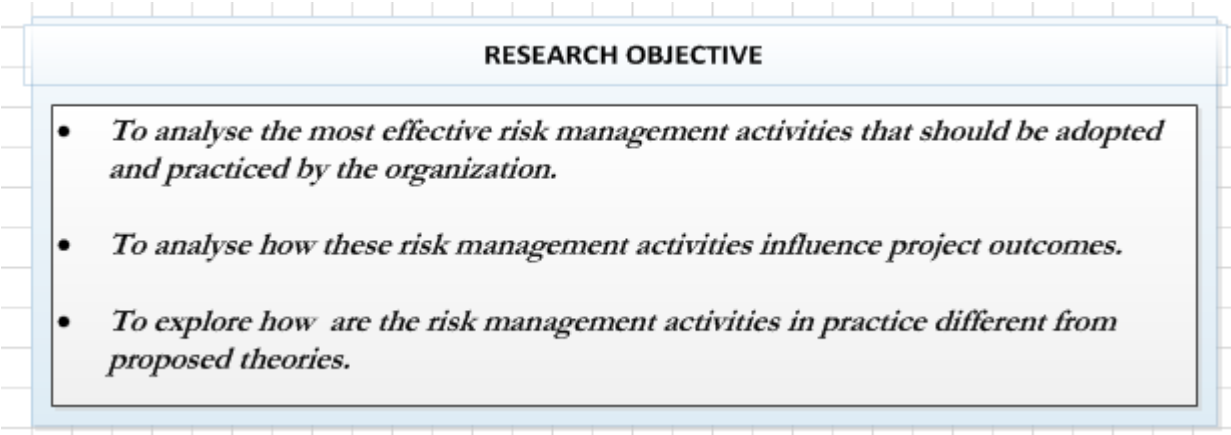


Figure 4: Research Objective of the Project

1.5 Research Framework and Questions

The chart below (fig 5) illustrates the different phases of my research and delineates the various research sub questions which need to be answered to answer the main research question:

What are the most effective risk management activities that should be practiced during the design, engineering and development phases for new system development in manufacturing organizations?

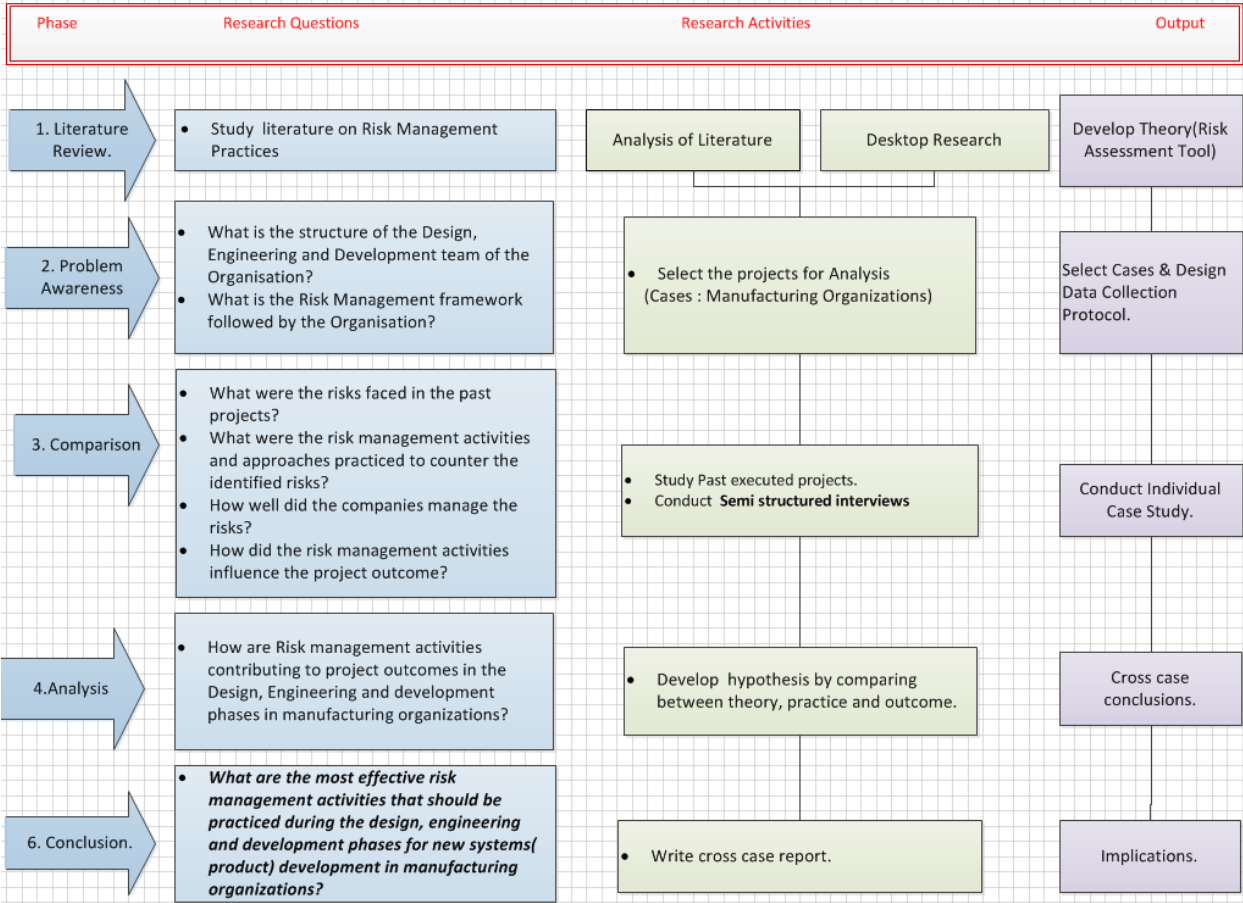


Figure 5: Research Framework consisting of Research Sub Questions and Research Question

Case selection and development of Research Sub Questions:

In order to analyze the projects in which the prototype has been realized it is essential to analyze the structure of the design, engineering and development team of the organization. It is important to visualize the different interfaces and complexities of the team structure with respect to the rest of the organization. The context of organizational structure in risk management is important since the complexities of organizational structures can create major hindrances in the progress of project outcome. The first research sub question is constructed as , *“What is the structure of the Design, Engineering, and Development team of the Manufacturing Organization?”*

In the context of my research it is crucial to have a basic knowledge of the risk management framework being followed by the company. The second research sub question *‘what is the risk management framework followed by the organization?’* gives clarity whether the organization pursues a formalized

risk management framework (more structured and algorithmic) or an informal risk management framework (more inclined towards project management)

Once we choose the projects that we analyze in the companies, it is important to determine the various risks that were identified, and the risks that were not identified by the design and engineering team by virtue of semi-structured in depth interviews. The third research sub question ‘*what were the risks faced in the past executed projects?*’ gives the above necessary information. The next step is to study how these risks were managed. The fourth research sub question deals with the risk management activities and approaches adopted by organizations to manage the risks, “*What were the risk management activities and approaches practiced to manage the identified risks*” . The study of the different risk management activities adopted by companies would help to analyze what are the different risk management activities in practice and how different are these practices from theory. Analysis of the above research sub question would automatically help me in the analysis of the next research sub question “*How different are the risk management activities in practice from the risk management framework and methods proposed in theory?*”

The analysis of the various risk management activities in the different projects would help to realize “*how well did the companies manage the risks with their implemented risk management activities*”

The cross case analysis of the different projects helps to analyze and understand how the risk management activities helped to achieve a better outcome in the project. The research sub question is constructed as “*How risk management activities contributes or influences project outcomes in the design, Engineering and development phases in manufacturing organizations*”.

Analysis of the individual risk activities, the way they influence the project and the cross case analysis would help to realize, the most effective risk management activities, that should be practiced. This answers the main research question, “*What are the most effective risk management activities that should be practiced during the design, engineering and development phases for new systems(product) development in manufacturing organizations?*”

1.6 Research Significance and Contributions

The significance of the research can be seen in the perspective of the practical social relevance and the academic relevance.

Practical Relevance:

Risks can be related to the instable market conditions, the related technology which is being implemented, risks related to manufacturing, and even the uncertainties of commercializing a given product. In our research we limit our investigation only to the design and engineering phase of the entire system (product) development life cycle. A system development life cycle has a number of actors who are involved in the entire process. The suppliers and vendors are responsible for supplying the various necessary parts of the system which needs to be realized. Integrating all these subsystems together has a lot of technical complexity associated. The different functional silos, the R&D teams, the marketing units, the design and engineering teams, the assembly teams, the testing units have vital roles to play in the entire product development cycle. The final success of the product is realized due to the culminated and coordinated functioning of the different functional silos. The different functional teams coordinate with each other through a predetermined project management structure. Risk management is seen as a mediating role for the entire process of project management. Risk management in the context of technology, internal organization structure and external organization would make the execution of the project much smoother.

Different organizations have different risk management activities. There is no predetermined set structure that the companies follow. However a better understanding of which risk management activities

should be implemented in certain contexts and situation would tend to incorporate a certain structure in how Risk management should be implemented. Moreover efficient risk management would ensure that the projects are executed in the stipulated time period. Proper risk management also ensures that the project is executed within the predetermined budget. Quality, cost and time are the three vital factors in the perspective of project outcome. A proper risk management methodology ensures proper process management and synchronization between the network of suppliers, vendors, and manufacturers and clients. The causal relations and hypothesis derived from the research can be applied to the other manufacturing industries apart from the industries taken into consideration.

Academic Relevance :

As mentioned above there are already proposed Risk management techniques and theories, more in the form of set defined steps. In practicality industries need to deviate from theories. This is a necessity in order to cater to unforeseen circumstances. A comparison of how the industries deviate from proposed theories would enable to suggest on improvements that should be brought about to the theoretical framework or the risk management models. To increase the external validity of the research, the researcher tries to generalize the causal relations between the risk management activities and the project outcomes.

1.7 Report Structure

The research is realized through the next proceeding chapters. The following points illustrates out the report structure:

- **CHAPTER2:** The research designed is charted out.
- **CHAPTER3:** The literature review and research protocol is achieved.
- **CHAPTER4:** Case Descriptions (Risks faced in the project are described)
- **CHAPTER5:** Case analysis (Risk management activities adopted to manage the risks are discussed)
- **CHAPTER6:** Cross case Analysis (Theory of consolidation to arrive to 27 Risk management activities. The technological risk activity model, the internal organizational risk activity model and the external organizational risk activity model is realized)
- **CHAPTER7:** Conclusions on risk management activities are made and recommendations to the Manufacturing industries are made.
- **CHAPTER8:** Discussions and Reflections on the research.

The diagram below shows the entire structure and flow of the report.

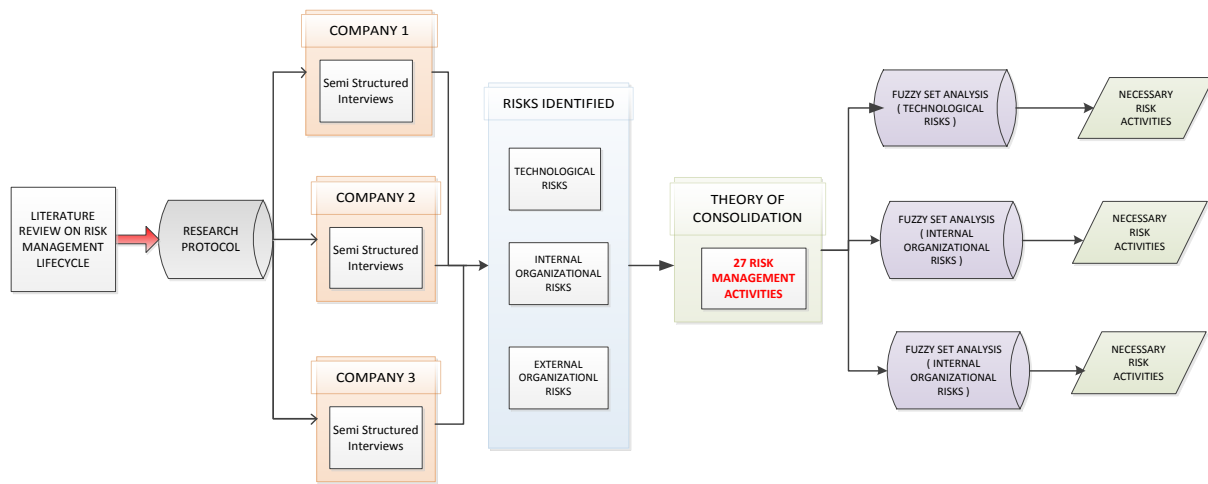


Figure 6: Research Structure

The first part of the report consists of the theoretical concepts and the literature review. The literature review helped to construct the research protocol on risk management lifecycle, and how a company evolves into adapting certain risk activities for identified risks. The research protocol has been used for semi structured interviews on past executed projects for three manufacturing organizations. Projects were the prototype has been developed or at least till the concept design has been realized have been studied.

The interviews helped to realize the risks they faced in the context of Technology, Internal Organization and the External Organization in the form of the suppliers and vendors. The interviews also helped to study the different risk management activities which has been adopted to manage the risks faced. Using the theory of consolidation, similar risk management activities have been constructed, categorized and clubbed together. Hence 27 different risk management activities have been identified.

The 27 risk management activities have been further segregated as Technological risk management activities, Internal organizational risk management activities and the External Organizational risk management activities. A risk activity which has been recognized for technological risks, could also be catering to internal organization risks or the risks related to suppliers and vendors. The fuzzy data sets of technological risk activity, internal organizational risk management activity and the external organizational risk management activity was created.

The fuzzy data sets were used for the fsQCA tool to carry out the analysis. fsQCA helped to identify the necessary risk management activities which should be adopted to manage the technological, internal organizational, and the external organizational risks, to influence the quality, cost and time of the project.

NOTE: KEY POINTS OF CHAPTER 1

- A short background on how process management and project management is involved in New Product development.
- Definition of Key terms like Risks, Causes, Effects, Risk management activities, Complexities, Interfaces, Contexts, Project outcomes.
- The key problem statement of the Research has been defined. The problem being that there are no effective risk management activities defined in accordance to certain contexts.
- The main research objective, “ to analyse the most effective risk management activities in the design, engineering and development phases” is constructed.

- The research framework consisting of the research sub questions and the and the research questions are defined.
 - The academic relevance and the practical social relevance is addressed.
 - The research structure and the report structure is defined.
-

RESEARCH DESIGN

The second chapter elaborates on the research technical design. It illustrates how, where and when the research is being carried out in order to answer the research sub questions. The chapter explains the research methodology implemented in order to carry out the research. The data collection process and the research analysis techniques are also elaborated in the chapter.

2.1 Research Strategy

The objectives of the research are to explore and understand the necessary risk management activities which needs to be adopted by organizations. The research also aims to realize how these independent risk management activities influence and contribute to the dependant project outcomes. The research is explorative in nature. A qualitative analysis is employed to get a better insight of the research topic. The research strategy chosen for the thesis is an explorative multiple case study approach.

The reason to consider a multiple case studies is to follow a replication design. Replications would help to generalize on the necessary risk management activities which should be adopted. It would further help to establish the causal relations between the independent risk management activities and the dependent project outcomes. This would lead to the original finding being robust.. The framework (fig 7) below illustrates out the basic structure of a multiple case study methodology, which the researcher has followed in the research. (Robert.K.Yin)

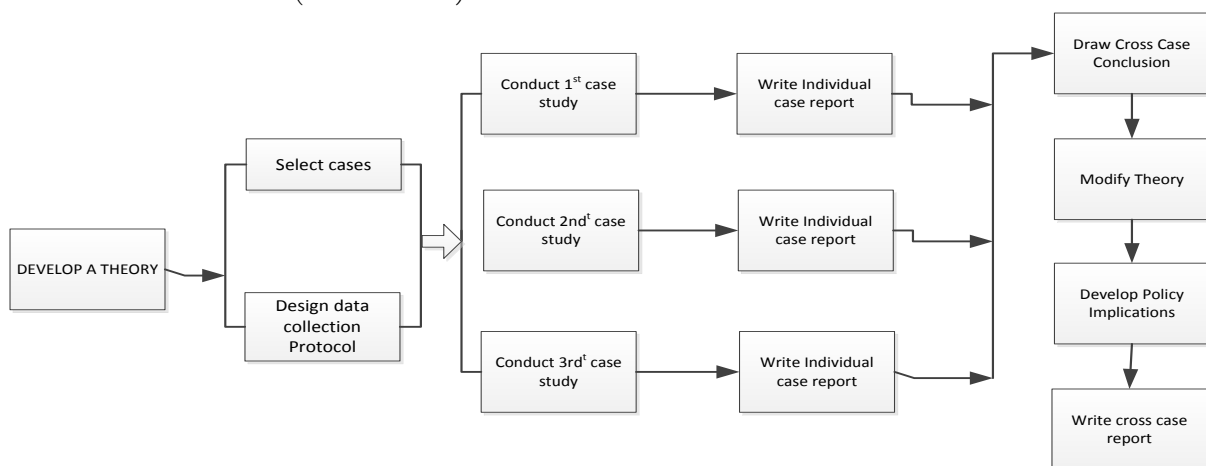


Figure 7: Illustration of Multiple Case Study Method

The existing literature helps us to realize the normative Risk Management Cycle. The Risk Management Cycle illustrates the various theories and tools related to the steps of Risk management. The researcher develops the risk protocol from proposed risk management techniques and the ATOM structure proposed by Hilson and Simon. The next stage is to select the cases which will be studied. Executed projects in which the prototype has been realized, from three manufacturing organizations were selected for the case study. The next step is to design the data collection protocol. The researcher conducts semi structured in-depth interviews. After the data collection is carried out, the different case are studied in

order to analyze the different projects. The interviews are coded and the individual case reports are written. The next step is critical since the cross case analysis helps to realize how the different risk activities helps to influence the project outcomes. This helps in concluding on the most effective risk activities that must be adopted and practiced.

Depending on the causal relations developed, conclusions and recommendations are made.

2.2 Research Material

Scientific literature in the form of scientific articles and journals were used as a source of knowledge. Various popular journals pertaining to subjects like: Risks related to New Product Development, Risks related to Innovation processes, Risks associated to Supply Chain Systems, Complexities of Organizational structures and Hierarchies, Project Risk Management methodologies from the International Journal of Project Management, Journal on process Management were referred. In the process of literature review I also referred to books on Risk management like the “Active Threat and Opportunity Management” methodology, popularly known as the ATOM by Simon and Hilson.

Literature helped to realize the entire Risk management Cycle. It helped to realize all the major steps in the Risk management process. Specific Risk Identification and Risk assessment tools were also studied from the literature. The Normative Risk Management methods helped to build up the research protocol or the research framework to study how the risks in the Design, Engineering and Developmental phase are actually managed in practice in the Industry.

The research protocol further helped to design the question for the semi structured in-depth interviews. The Funnel approach was employed while designing the questions of the interview. The interviews started with generic questions of the aims of the projects. The questions slowly streamlined to the precise contexts of the various risks related to the Technological context and the contexts of the internal and the external organisational structure. The questions aimed at deciphering what were the risk management activities and how they influenced the project outcomes.

2.3 Sample Selection and Research Analysis

In this section the researcher elaborates on the reasons for selecting a particular sample for the research and defines the various units and boundaries of the analysis. The organizations chosen for the research are high tech manufacturing organizations. The organizations range from medium size to leading large sized firms in the manufacturing domain. Three companies are chosen for the research. The researcher analyses two executed projects from each company.

Companies chosen for the research, manufactures systems which are realized due to highly technical solutions. They have critical engineering, design and development stages which is realized due to the culminated efforts of different functional silos and organizations. The final systems realized are dependent on the external suppliers and vendors who supplies components, software, or subsystems of the main system. Research done in the manufacturing industry would enable to find better causal relations. The conclusions drawn would have a definite pattern. The figure(8) illustrates the research methodology and the sample of analysis for the project.

MULTIPLE CASE STUDY FOR RISK ANALYSIS OF ENGINEERING FIRMS

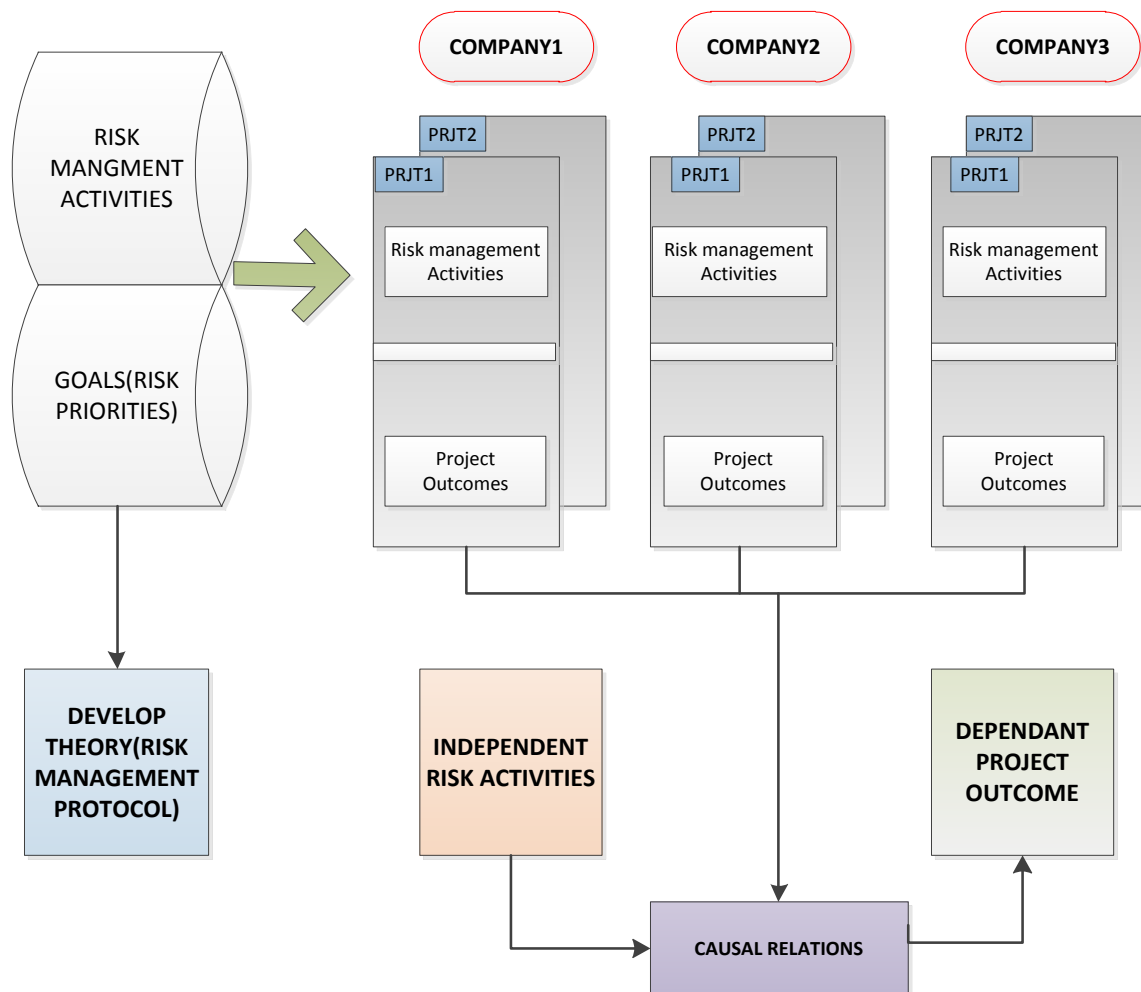


Figure 8: : Research Methodology

The companies chosen are of different sizes and magnitudes. A medium size organization has different complexities in terms of resources, technicalities and organization structures while an established giant organization has different complexities in different dimensions. The researcher aims to attain a different perspective of the different risk management activities which is being influenced by the firm size.

- Multiple case study research design would help to analyze the different risk management activities and approaches amongst the different organizations. As Yin has suggested that drawing conclusions from a single case study might prove to be vulnerable. The primary aim to carry out a multiple case study is to find replications of patterns or risk management activities related to the various contexts of Technology and Organizational structure Moreover a multiple case study would also increase the external validity of the research. Conclusions drawn from the research of various projects in the different organizations would enable the researcher to generalize the causal relations or the hypothesis to the other industries. The conclusions drawn from a multiple case study is more concrete and valid. (Robert.K.Yin)
- The unit of analysis will be on the level of a project, and the contexts of risk management activities are primarily on the grounds of technology and internal organizational structure and external structure.

- The researcher chooses two executed projects (preferably projects where the prototype has been realized). The analysis of different projects would enable to carry out a better causal relation of how risk management activities influence project outcome.
 - It is necessary to carry out structured in-depth interviews with experts of each project. The interviews are access to information regarding the risks that were identified and fired, the risks that were not identified, the various risk management activities and approaches of the organization, the various project outcomes due to the managed risks.
 - Literature review is primarily carried out to analyze how a risk assessment tool should be, which would enable to formulate questionnaires for a structured interview. The literature review would also help to compare how the risk management activities in practice in the industries differ from the risk management activities proposed in literature and theory.
-

2.4 Correlation and Research Analysis

The final aim of the thesis is to correlate how the independent risk activities influence the project outcomes in the context of technology and organizational structure. Hence the comparison and analysis has to be carried out amongst qualitative data gathered from the study of executed projects. Therefore qualitative comparative analysis using fuzzy sets(fsQCA) is a probable technique of qualitative analysis of macro social phenomena. It examines only a few cases at a time, but their analysis is both intensive and addresses many aspects of cases. (R.C.Charles, 2007)

fsQCA, is an analysis of sets of relations. Sets are groups of things. In formal set theory, sets are usually composed of numbers, or other sets. Sets can be subsets of larger sets. At times these sets are definitional, but sometimes they can be causal. In fsQCA , we transform our variables into sets. We then analyse what combinations of causal sets constitute a subset of the outcome. Regression gives us the magnitude and direction of effect of a variable. However in fsQCA , the focus is on what conditions leads to a given outcome. The advantages that fsQCA has over traditional correlational analysis like regression is:

- It makes correlation between relationships which are asymmetrical
- It has the advantage of equifinality where there are multiple paths or solutions to the same outcome.
- fsQCA, also has the advantage of causal complexity. fsQCA does not only measure independent effects , but it also measures combined effects. fsQCA finds combinations of causal measures that leads to the outcome.

Normal Boolean Algebra follows a method in which a case is either 'in 'or 'out 'of a set. Thus a conventional set is comparable to a binary variable with two values (that is either 1 or 0). A fuzzy set in comparison permits memberships in the intervals between 0 and 1. Hence it retains the two qualitative states of full membership and full non membership. In the research the independent risk activities can be treated as the membership functions which influence the project outcomes from a range of 0 to 1. There is an aspect of relativity and specificity. Relativity defines, how relatively has the condition being applied in a particular case in comparison to another case. Whereas specificity defines to what extent the condition is applied in the particular case. (R.C.Charles, 2007)

The cross case analysis makes use of the fsQCA tool. The set and the subset analysis of the fsQCA helps to identify the risk activities, which are the necessary and commonly used risk activities. This provides a strong base to analyze how the risk activities shape the project outcomes.

APPLICATION OF fsQCA IN THE RESEARCH

Fuzzy sets act as group of combinations or conditions that are necessary or lead to the outcome of a specific result. Fuzzy sets try to solve the problem of fitting cases into one of the two categories, membership or non-membership. Hence Fuzzy sets are extremely powerful since they allow researchers to calibrate partial membership in sets using values in the interval between zero which counts for non-membership and values of one which acts as full membership. The subset relationship is central to the analysis of causal complexity. The basic idea of subset relationships is to permit the scaling of membership scores. This allows an extent of partial membership. (R.C.Charles, 2007)

Membership signifies the extent or the degree to which a particular condition or a set is applicable or belongs to a particular case. The diagram below defines the two states of full membership and full non membership:

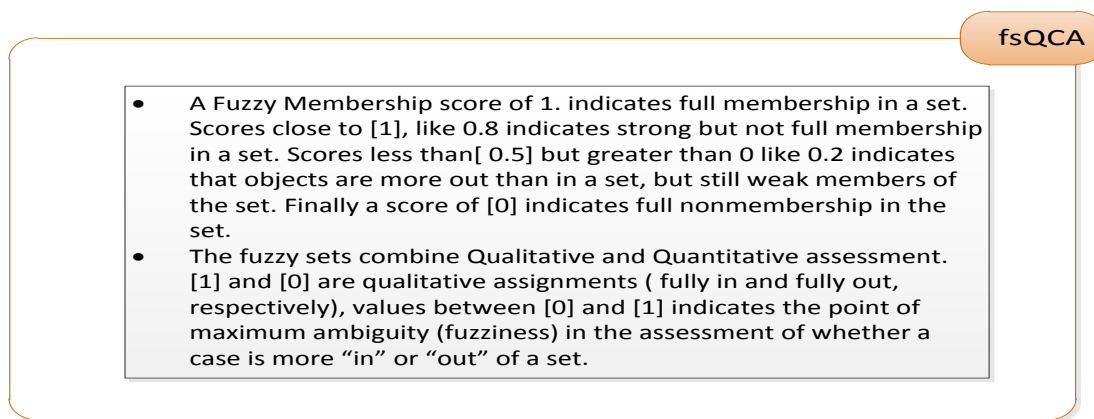


Figure 9: Concepts of fsQCA Membership(R.C. Charles, 2007)

The conditions (risk activities) are being qualitatively assessed, judged and then they are quantitatively evaluated. The aspect of relativity and specificity becomes important now. Fuzzy sets are not merely ranking cases relatively to each other (relativity) but fuzzy sets are also pinpointing qualitative states at the same time assessing varying degrees of membership between full inclusion and full exclusion. The set acts as a continuous variable that has been purposefully calibrated to define to indicate degrees of membership in a well-defined set. Such calibration is only possible through substantial judgement or knowledge of the situation which helps to define full non membership, full membership and cross over point.

Fuzzy Subsets: The fsQCA tool logically combines all the fuzzy membership functions. The combinations occur with logical OR functions or logical AND functions to generate possible combinations of conditions. Considering that there are k number of conditions the vector space consisting of the possible number of combinations are 2^k . Fuzzy sets Qualitative Comparative analysis helps to analyse the combinations of conditions which are necessary, consistent and sufficient for the result or outcome which is under consideration. The consistency of fuzzy subset relation in simple terms is a degree to which one set is contained within another. In order to be consistent the condition needs to be lower than the value of the outcome. A necessary condition is a condition that must be present for the outcome to occur. On the contrast a set theoretic coverage by contrast assesses the degree to which a cause and a causal combination “accounts for” instances of an outcome. The combination of coverage and consistency determines the sufficiency of conditions.(R.C.Charles, 2007)

2.5 Research Limitations

The limitations of the research are being presented here which is based on some assumptions and is framed by a number of constraints that affect the magnitude of its impact. The rationale is to identify and enlist these limitations, so as to declare understanding of their existence and thereby reduce their effect. The below table illustrates the limitations of this project and hence provides mitigation strategies:

LIMITATIONS	MITIGATION STRATEGIES
1. The research is only limited to the design, Engineering and the Development stage of the entire new product development cycle.	1. Consider the phase of business planning. Hence consider the market uncertainties which is a major context of the risks of new product development
2. Due to the Qualitative nature of the project, possibilities are there that the knowledge might not be generalizable to the other industry.	3. Select greater number of cases for analysis to achieve in depth knowledge for the hypothesis development.

Table 1: Research Limitations

NOTE: KEY POINTS OF CHAPTER 2.

- The research methodology implemented in the project is explained. The reasons for choosing a multiple case study method is elaborated.
 - The sample or the companies selected belongs to the manufacturing domain. Three companies are selected for the research. The researcher will study two projects for each company.
 - The fundamental concepts of fsQCA (fuzzy sets Qualitative Comparative Analysis is explained)
 - The limitations of the research are also charted out.
-
-

THEORETICAL FRAMEWORK

The main aim of this chapter is to study what are the existing theory on Risk Management. The researcher studies the proposed risk management tools which are applicable in the different phases of the Risk management lifecycle. The research protocol for studying the different past executed projects are developed. The research protocol is a detailed extension of the existing risk management cycles.

3.1 Literature Review

The literature helps us to realize that the Design , Engineering and Development stage is a very crucial stage in the entire lifecycle of the development of the prototype or the development of a new product. (Reim.W, Parida.V, & Lindstrom.J, 2013) The literature proves that the Design, Engineering and Development stages are dependent on a number of related actors. The interdependences on each other and lack of coordination leads to numerous uncertainties and hence risks. (A.M.Radhke, T.Tolio, M.M.Tseng, & M.Urgo, 2013)

The topic of the research can be fragmented into three major segments. The first part focusses on the spectrum of Risk Management activities. The second fragment speaks of the various contexts of risk management which in my research topic deals with technology, the internal organization structure and the external market of suppliers. The third fragment can be visualized as the spectrum of prototype development, which can be also defined as new product development.

Risks are usually borne due to certain factors and then the risks have a certain amount of impact. It is important to identify and control the risk factor within the time and the resource limits of the project, take actions to reduce the likelihood of a bad outcome and minimize adverse impacts. (Reim.W, Parida.V, & Lindstrom.J, 2013) A probable risk that arises in the process of developing a new prototype rises primarily due to technological complexities, market uncertainties, and organizational structures. (Jifeng.M, Gang.P, & Maclachlan.L.D, 2009) Risk management can also be carried out by measuring key performance factors, on the basis of certain indicators at the firm level, which can be further defined to be the firm's financial, customer, internal business process and learning and growth perspectives. (Wang.J, Lin.W, & Huang.Y, 2010) Drawing close relevance to the area of research, the literature suggests that risks evolve due to financial crises, constantly changing customer needs, process hindrances due to the organizational structures and the uncertainties which evolve due to the process of learning.

Literature further helps to realize that process management acts as a mediating agent for improving the efficiency of manufacturing a new prototype. (Salomo.S, Weise.J, & Gemunden.G.H, 2007)

- Business planning at the beginning of a project creates a basis for proficient project and risk planning.
- The proficiency of project planning, risk planning, and process management activities improves the innovation performance directly.
- The relationship between project planning and project execution success is bridged by means of process management.
- The strength of the above relationships is moderated by uncertainty as determined by the degree of technical complexities.

New Product development is a stage gate process. At the end of each stage there is a go and a no go decision which needs to be carried out. Collaboration of different individual experts in a team takes more effective decisions than individual expert. The Design, Engineering and Developmental phase of a new prototype is dependent on the individual design experts and engineers, but the success of the designs are highly dependent on the functional silos. (Gidel.T, Gautier.R, & R., February 2005), (Swink.M & Talluri.S, 2006) Market information, project management experience, balanced top management commitment, establishment of project goals and collaborative work environment, has a direct positive impact on the efficiency of project execution. (Gidel.T, Gautier.R, & R., February 2005), (Schmidt.B.J, Montoya-Weiss.M.M, & Massey.P.A, Fall 2001) The model below (fig 10) represents how the core concepts can be unified to create a conceptual model for the research.

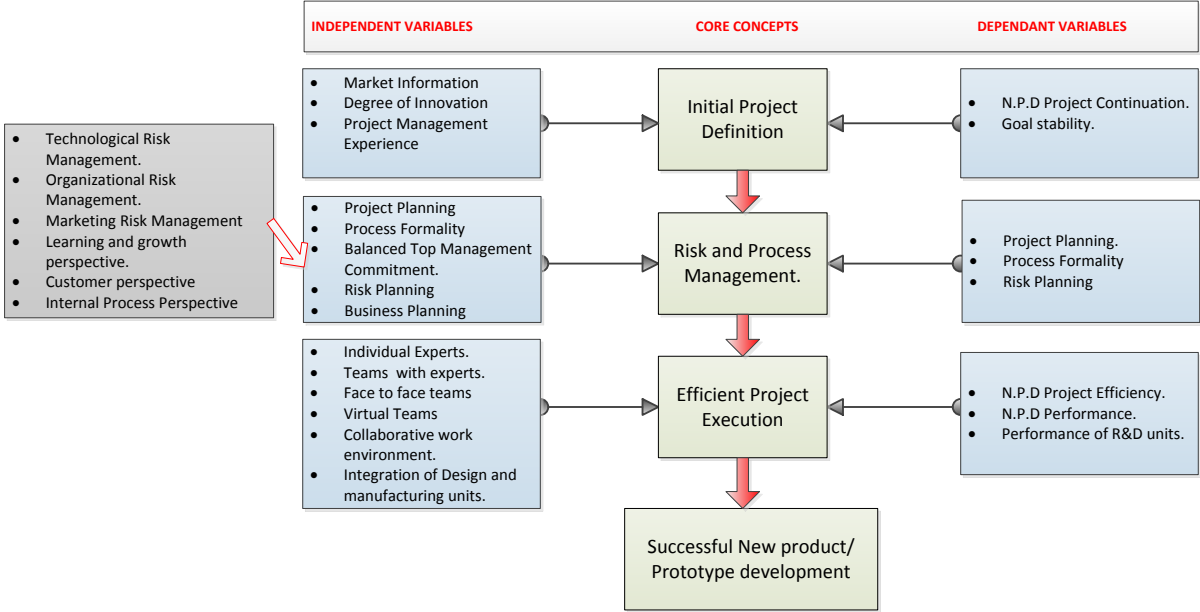


Figure 10: Relations of Core Concepts related to successful Prototype Development.

Depending on the market information an organization realizes the new features which need to be incorporated into the existing system. Degree of innovation refers to the complexity of the desired improvements which needs to be achieved. (Wang.J, Lin.W, & Huang.Y, 2010) A proper project management helps to stabilize the goals and finally decide if the project should be continued. This entire process can be defined to be the Initial Project Definition.

The different variables of project planning, process formality, involvement of top management business planning and risk mitigation activities can be broadly defined to be the Risk and Process Management. Risk and Process Management propels the execution of the project at a much faster rate and it increases the efficiency of the project. (Salomo.S, Weise.J, & Gemunden.G.H, 2007) In the third phase we realize that a collaborative working environment, with a cross-functional inclusion of the various working silos in a team, enhances the product development project efficiency. (Schmidt.B.J, Montoya-Weiss.M.M, & Massey.P.A, Fall 2001) This concept can be broadly defined as efficient project execution. Efficient and effective execution enables to achieve a successful prototype development. (Wang.J, Lin.W, & Huang.Y, 2010) Following the above model (fig 10) the primary focus of the research is based on how Risk management activities improve the project execution and therefore influences the project outcome.

3.2 Risk management Lifecycle (THE ATOM)

Risk is defined as any uncertainty that if it occurs would have a positive or a negative effect on the achievement of one or more objectives. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010) Embedding risk management within project management, leads some to consider it as just another” project management technique. (D.Hillson & P.Simon) To be fully effective risk management must be closely integrated into the overall project management process. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010) Risk management must be “built in” not “bolted on”. (D.Hillson & P.Simon) Initially project related decisions were made with an understanding of how the risks are involved, related to the scope of the project, the cost estimations and the budgets, the value of the project, the quality, resources and the control of execution. Organizations can view risks to be either a threat or an opportunity. (D.Hillson & P.Simon) It is quite practical that certain amount of risks is necessary to propel, a project in a positive direction to achieve successful results. (Hernandez.V.G.J, Noruzi.R.M, & Sariolghalam.N, May 2010) A certain percentage and degree of acceptance of risks are also necessary to achieve innovation. The projects should be given a risk based approach. Risk management processes must be integrated with other project management processes. Hence projects must use risk data and there should be a seamless interface of process boundaries. (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012). Figure 11, below illustrates how risks can be treated either as a threat or as an opportunity for the project.

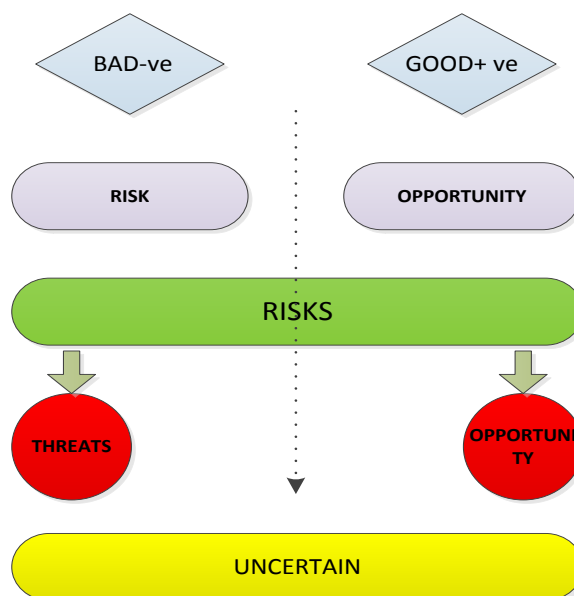


Figure 11: Opportunity and Threat approach to Risks.

A supportive organization structure, competent people, supporting infrastructures and a simple to use scalable and documented process enable and aid an organization to follow a structured and formal risk management approach. It is crucial for every organization to review their position on risk management against the two dimensions of importance and effectiveness. Organizations need to take appropriate actions to move up the scale of risk management. (D.Hillson & P.Simon)

Implementation of risk management brings about numerous generic benefits to the projects. Risk management leads to better sharing of information and knowledge between the different functional silos, better generation of alternatives, more meaningful assessment of contingencies, adhere to schedules and budgets, make proper cost benefit analysis, identifies and allocates responsibility to the best risk owner. From the perspective of the team members executing the project, proper implementation and practice of risk management, enhances the ability of the team members to asses risks. In the course of project management attention is paid on the real and most important issues. From the perspective of the

organization, risk management ensures that the company abides by corporate governance requirements, better execution of projects, provides greater potential for future business. It provides the company a better reputation as a result of fewer headline project failures, and hence better customer relations due to improved performance. (D.Hillson & P.Simon), (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012)

David Hillson and Peter Simon describe the “Active Threat and Opportunity Management” methodology, the ATOM structure, which is a generic risk assessment tool applicable to any type of project, for any size, and any industry. It explains how to tailor the generic risk process that meets the specific risk challenge. The following are the steps followed in the ATOM methodology of Risk Management. The same risk management lifecycle has also been found in the paper “ A Risk Management Ontology for Quality by Design based on a new development approach according to GAMP 5.0”. (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012)

- The first step in risk management process is to ensure that the objectives of the project are well defined and understood. It is important to unify all the actors of the project under the same consensus and goals. The initial act of process management amongst all the actors initiates the risk management for the project. The first step of the risk management cycle can be defined to be the **Risk Initiation** step. Risk Initiation helps to identify the main goals, periphery, and the boundaries of the project are realized. The initiation of the project usually starts by realizing the key factors governing the critical aspects of scope, cost management, time management, planning of interactions and certain rules and procedures that the organization follows. The detailed process of Risk Initiation is explained in the appendix. (Appn, Chp3, 3.2.1)
- It is important to identify the risks and uncertainties that might affect the project. The second phase can be defined as the **Risk Identification** stage. Literature identifies Brainstorming by experts, Delphi technique, and Root cause analysis, creating checklists, making system analysis, fault tree diagrams, Ishikawa cause and effect analysis, SWOT analysis being some of the effective tools for identifying Risks. The primary output of the Risk Identification process is the creation of the Risk Register. The Risk register lists out the cause of the risk, the event that might occur and the effect the event will have in future. Risk Identification forms the baseline for assessing and prioritizing the risks. The detailed process and tools used for Risk Identification is explained in the appendix. (Appn, Chp3, 3.2.2)
- Once the risk challenges have been identified, the risk management process must include a step for filtering, sorting or prioritizing the risks. The analysis helps us to realize the worst threats and best opportunities. The third stage can be defined to be the **Risk Assessment or Risk Prioritization** stage, in which the prioritization of the risks further helps us to assess the risk impacts on the projects. The impacts of the risks can be further analyzed using qualitative and quantitative risk analysis tools. The details of Risk prioritization throws light on the different Qualitative and Quantitative risk prioritization tools are discussed in the appendix. The detailed process of Risk assessment is explained in the appendix. (Appn, Chp3, 3.2.3)
- Once risk challenges have been identified and prioritized, the determination of the risk challenges faced by the project will be clearer. Hence the process moves from analysis to possible actions. A wide variety of actions and strategies are planned to manage the risks. Risks can be managed following the strategy of “RATA”, which is described as “a risk can be managed or tackled either by reducing the risk, or accepting the risk, or transferring the risk, or avoiding the risk”. Planned responses must be executed or implemented in order to change the risk exposure of the project. This phase of risk management can be defined to be the **Response Planning, or Risk Planning** stage where the risk management strategies are implemented. The detailed process of Risk planning is explained in the appendix. (Appn, Chp3, 3.2.4)
- The Key stakeholders should be informed about identified risks and their responses. This phase is known as the **Risk Review** stage, where the actions implemented and the decisions taken are reviewed by the different actors. Risks faced in every project are extremely dynamic and changing in

nature. Hence the risk process is iterative in nature. Finally there is a post project preview. In the near future the threats are minimized and the opportunities are captured in the most efficient and effective manner. The detailed process of risk review is explained in the appendix. (Appn, Chp3, 3.2.5)

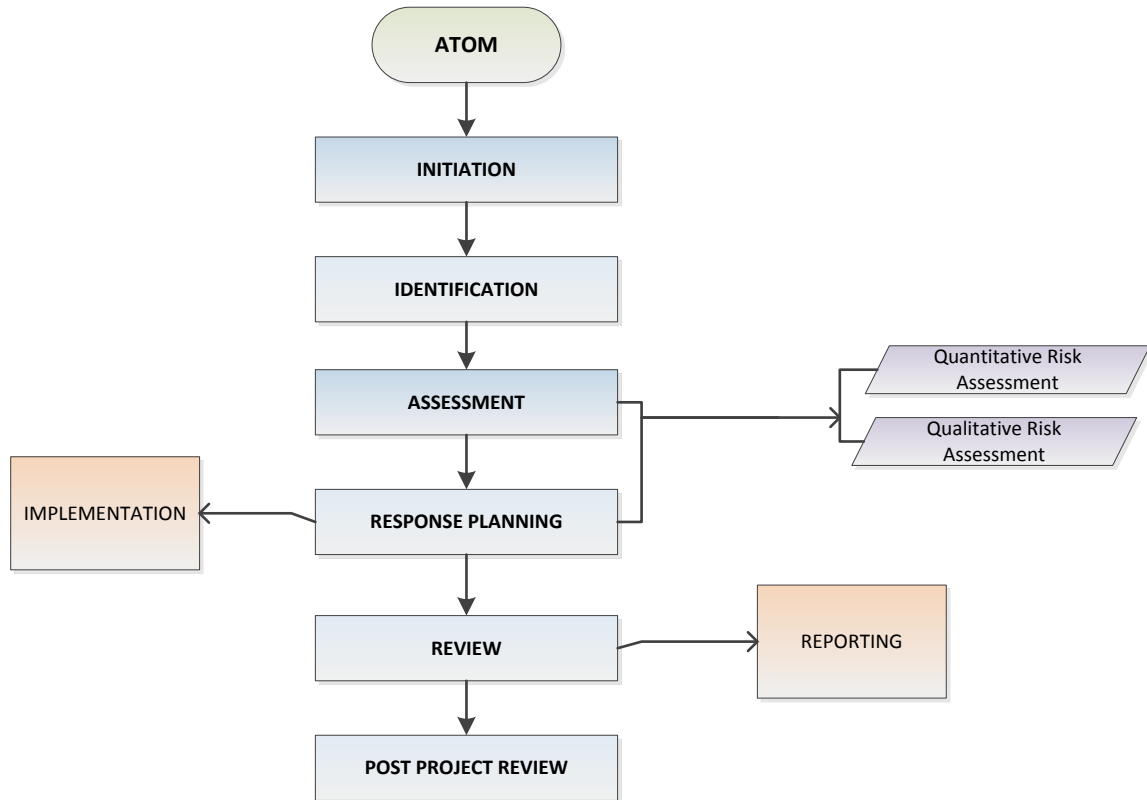


Figure 12: Schematic Diagram illustrating the Risk Management Cycle

The “ATOM” approach recognizes the undeniable need to carry out the risk management throughout the project lifecycle, from conceptualization to completion, from business justification to handover. The flowchart (fig 12) below illustrates the various steps of the “ATOM” methodology of risk management cycle.

The literature review helped to create a chart (, which lists out the different risk management tools as described by literature, applicable in the different phases of the Risk management cycle.

3.3 Contexts of Risk Management

Manufacturing and Engineering organizations who are primarily the technology providers and product manufacturers, manage risks in the context of Technology, Market, and Organizational structures. (Jifeng.M, Gang.P, & Maclachlan.L.D, 2009)The primary risk before a product is developed starts in analyzing the market feasibility of the product in the market. Hence a major risk analysis goes on during the business development phase. However since it is not viable to look into the risks of each and every stages of product development, the scope of our research is limited to the Engineering, Design, and Development phase. We define the boundaries of our context of risk management to Technology and the Internal and External Organization structure. We define the external organization as the network or market of suppliers and vendors.

The context of external market of suppliers is important since the final product or system is assembled due to the correct supply of subcomponents, and subsystems from the suppliers. (M.Giannakis & M.Louis, 2011) It is important that the subsystems are technically adaptable to each other which leads to the integration of a correct system. The context of technology is crucial since it deals with the technical complexities of design and engineering, which is the primary point of focus. The context of internal organization dealing with composition of the design and engineering team, hierarchy in organization structures, and information asymmetry between teams is also important since they have a direct impact in the project outcome of the Engineering, Design and Development phase. (M.Hobbey, 1998) Table 2. below charts out the various contexts in which risk management is carried out specifically in the Design, Engineering and Developmental stage. The context of market, customers, and competitors is not considered since the design and engineering phase starts from a point where the business strategies are already made. The table below charts out the various factors and circumstances which lead to risks in the context of technology, the internal organization structure and the external organization in the form of the suppliers, vendors.

TECHNOLOGY	INTERNAL ORGANISATION	EXTERNAL ORGANIZATION
1. Capability and Interpretation.	1. Composition of the design and engineering team.	1. Network and market support of suppliers.
2. Incorporation of New features.	2. Hierarchy in organization	2. Retention of suppliers
3. Complexity of Design.	3. Information Asymmetry	3. Recognition of the apt suppliers and vendors.
4. Maintaining the Quality and advantages of previous design.	4. Co-ordination between the board of management and the design, engineering and development teams.	
5. Biased on previous dominant design		
6. Tools, tackles and machinery to back up the design.		

Table 2: The different Contexts of Risk management

We realize that risks arise in the design and engineering phase of the entire product development cycle in the context of Technology, which also consists of the infrastructure support provided by the organization. Risks in the defined phase also rise due to the context of organizational structure which includes the team structures responsible for carrying out the design and engineering, the individual competency of the various team members. A detailed explanation of the critical factors of risks in a project for new product development is discussed in the appendix. The conceptual model for the research is illustrated in Figure 13.

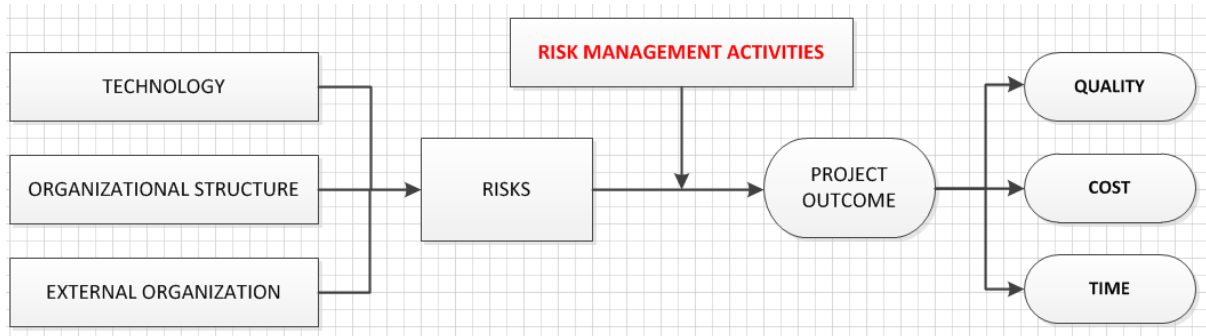


Figure 13: Conceptual Model of my Research.

The above model can be explained in the sense that Risks in the design, engineering and developmental stage generally originate from the technological and internal and external organizational complexities. The identified risks are then managed by means of specific risk management activities. The independent risk management activities shapes and influences the project outcomes, in terms of key project drivers like cost, time and quality of the project.

With every generation the complexity of producing integrated products with more functionality increases. Risks are generated in the process of design, engineering and development. Companies abide by either a formalized risk management framework or they follow informal risk management procedures. In order to establish the causal relation between the independent risk management activities and the dependent project outcomes, the research will aim to conduct a study on how the different risk management activities and approaches may have different impacts on project outcomes. The analysis of the correlation will further enable to generalize the risk management framework and hence improve the proposed theories.

3.4 Research Protocol

The main aim of this thesis is to analyse which are the necessary risk management activities that must be adopted in the design, engineering and the development stages of a manufacturing project that aims to develop a prototype which might be completely radical or have incremental features. The research protocol is developed, following the structure of the risk management life cycle, as suggested by the literature. Though the main aim is to study the risk management activities, adopted in a project and the way these approaches help to shape the project outcome, it is essential to traverse through the entire risk management life cycle of Risk Identification, Risk Prioritization or Assessment, Risk Planning, and Risk Review in order to realize and understand the essence, the reason, and the importance of applying a particular risk management activity. In order to understand the value and the outcome of a particular adopted activity it is essential to gather knowledge of what were the risks that cropped up, what were the tools applied and how did the approach benefit the project in terms of its output.

Before the research dives into the technicalities of the project it is important that the researcher garner knowledge on the composition of the design, engineering and the development team. The composition of the project execution team is extremely important from the perspective of a project. The efficient working of a functional unit calls for a team with the right balance of veteran and experience engineers, project managers, and also new talented engineers. The need of tacit knowledge is extremely crucial for propelling the team ahead. A project execution team always runs the risk of mortality, where experienced engineers quite the job.

Risk identification is an important phase of the Risk management lifecycle. Following the principals of process management, stronger and more detailed the process management at the beginning

of a project, smoother is the execution of the project. Stronger the risk identification at the beginning of the project, more efficient is the project execution. As discussed in the latter segment, the most critical aspects of a project can be defined to be the scope, the budget, the time and the schedule, the complexity of the project on technical grounds, and the organizational processes. The root causes of most of the risks that arise in a project are due to the above mentioned critical factors. Risk identification is necessary to conceptualize and foresee the probable risks that might emerge in the process of the project. Literature suggests that Critical path Method, Brainstorming, Failure Mode Effects Analysis, Responsibility Assessment Matrix, Delfhi technique, Ishikawa Diagram, Work Breakdown Structure, Variance and Trend Analysis are some of the probable tools that are used for Risk Identification process. To realize the risk management activities applied in the practical executed projects in the industry it is important to know, how the projects teams actually carried out the risk identification process and if they indeed use the tools mentioned in the literature.

Once the risks have been identified it is important to study how the organizations assess and prioritize their risks. It is crucial to study if they prioritize their risks, depending on the project drivers, or the risk impacts or the some other criteria's. Once we gain knowledge on the risk prioritization methodology of the organization, we can now study the main research question of how they managed the identified risks, by critically analysing the risk management activities. It is important to study what are the day to day management practices and the constant decision making processes amongst the project execution team, with an aim to reduce or manage the identified risks. We finally come down to the final stage of the risk management lifecycle which is the risk review process. It is important to learn how the organizations monitors and analyses the result s of the implemented plan.

The complete study of the Risk management lifecycle with the main stress on the risk management activities would help to analyse how the Independent risk management strategies have helped to influence and shape the dependant project outcomes. The chart below illustrates the complete Research framework and protocol. The protocol (fig 14) acts as the pivotal skeleton or framework for carrying out my research.

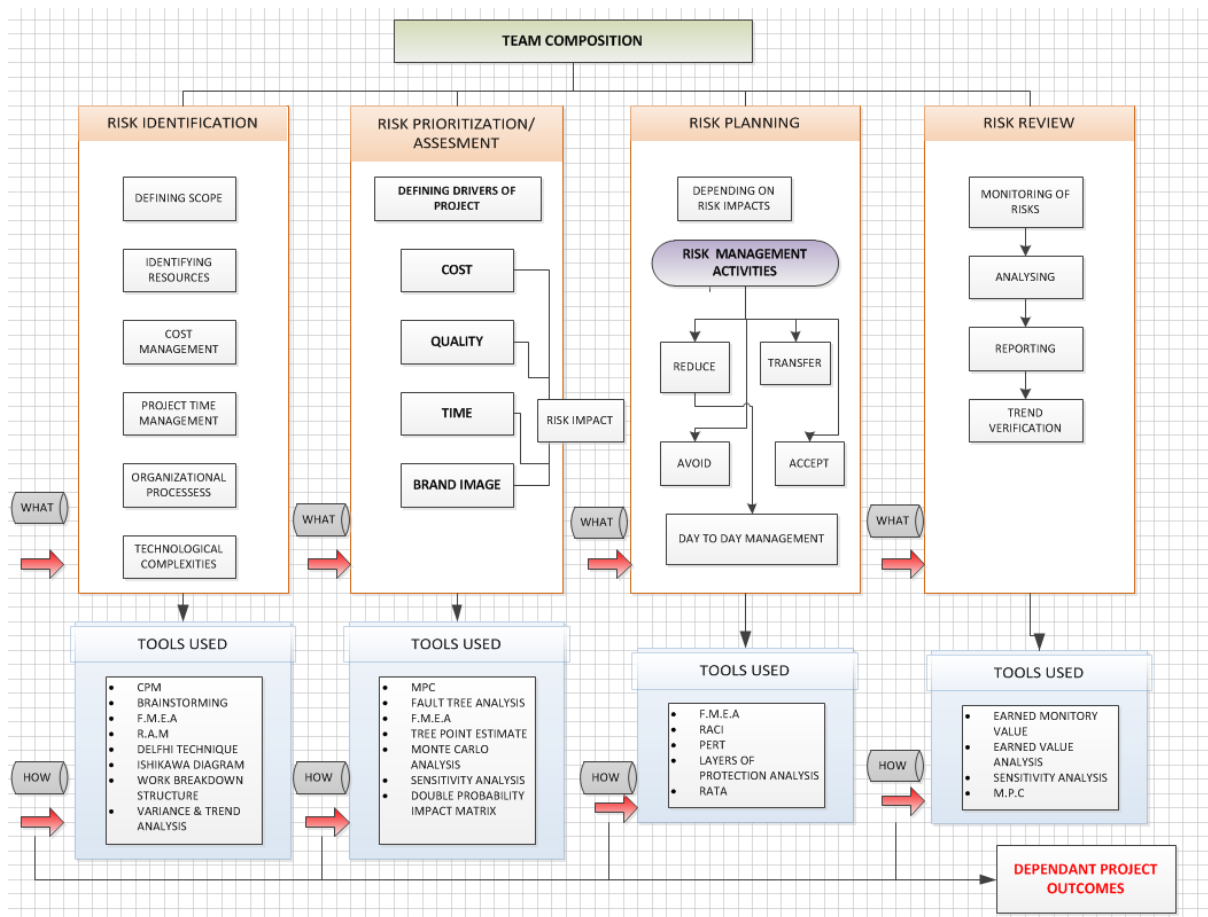


Figure 14: Research protocol for the case studies

The questions for the semi structured interviews are constructed from this protocol.

NOTE: KEY POINTS OF CHAPTER 3.

- In this chapter we have tried to recognize the risk management cycle as prescribed in the theory. The critical aspects of Risk Identification, Risk Planning, and finally Risk Monitoring have been discussed in details.
 - The critical contexts of Technology, the Internal Organizational structure and the External Market in the form of suppliers and vendors, that affect a new product development are explained.
 - The study of the above aspects led to the formulation of the research protocol. The research protocol is used as the reference for the formulation of the questions for the semi- structured interviews dealing with the cases.
 - The literature and the theories has also led to develop a list consisting of all the risk management tools that are applied in practice in the different phases of risk management.
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CASE DESCRIPTION & ANALYSIS

This chapter concentrates on the study of the past executed projects related to product development, and identifies the different risks that the projects faced on grounds of technology, internal organizational structure and the external organization related to suppliers and vendors. The researcher further analyses the different risk management activities adopted by the organizations in order to manage these risks. Each case dealt, ends by highlighting the added value brought to the project outcomes by means of the risk management activities practiced.

4.1 Company A Description

Company A is a leading global service provider, who delivers technical assurance through non-destructive testing (NDT), inspection and certification to the capital intensive, high risk energy, utility and the infrastructure industries in the world. The upstream and downstream oil and gas sector, the nuclear energy industries are the primary sectors that A focusses at. They have industry leading experience and expertise in project management for pipelines. The primary activities of A are as follows:

- Company A provides asset integrity assurance through the provision of specialized services using latest technologies.
- Regular detailed visual and mechanized electronic and radiographic inspection of pipelines for the upstream and downstream oil and gas operators and service companies.
- Company A is the global leader of the non-destructive testing. At the forefront of the development of new techniques and customized solutions, A has pioneered the use of a large array of non-destructive investigation methods, which includes magnetic flux leakage, radiographic and ultrasonic
- In order to cope with the above functionalities and to provide the best quality service, A has been developing new technologies and products in-house for more than 75 years. The product range involves different customized ultrasonic probes suitable for different environment and functionalities. A has a dedicated probe department capable of delivering custom made probes on short notice due to their expertise in design, testing and field deployment activities.

Why is company A an interesting organization for the research?

Company A is interesting in the context of the research for the following reasons:

- The development of the probes for specific non-destructive testing applications involves complex technologies and concepts of physics which are difficult to realize and give an appropriate physical shape. There are immense technical complexities which would be interesting to study. (Technical Complexities)

- Company A has a complex organizational structure, especially with their operational units, who acts as their internal clients; there are quite a lot of complexities which exists within the organization. A typical organization involved in manufacturing has numerous inter-functional dependencies, which is also the same for A as an organization. Therefore the organizational complexities would be interesting to study for company A, which is the second context of the risks management. (Complexities of Internal Organization)
- The third most important factor being the suppliers and the vendors. The products responsible for inspection and the non-destructive testing are unique products with specific technologies. However the realization of the final product is highly dependent on complex components which are delivered by suppliers and vendor. A faces a lot of complexities with regards to suppliers and the vendors which would also be interesting to study. It suffices the third context of risk management related to the external market of suppliers and vendors.

The projects studied in company A for this research is concentrating on the process of product development of two of their most successful projects “Rayscan Mk2”, and “Riser Inspection tool development” project. In the next section the objectives of the project, the description of the project teams and the different risks faced has been discussed.

4.1.1 “Rayscan MK2” project description.

The Rayscan MK2 project involves in the mechanical and the electrical implementations for the scanner development for pipeline inspection. The project focussed on an incremental innovation over the previous model. The objectives of the project, the description of the project team and the risks faced in the project have been discussed based on the interviews of the research scientist, and the project manager, of the project.

Objectives of the Project

The main objectives of the project are as follows:

- Up gradation of Rayscan MK1 pilot system to a full production system for further reproduction.
- Improved robustness to withstand harsh temperature conditions and corrosion.
- Improved detector performance with respect to sensitivity, image quality and endurance.
- Company A had to pilot five systems. Though this was not the first time that A was piloting a large number of systems, the project was challenging due to the size of the equipment, technical complexity and time frame.

Composition of the Product Development Team

The client of the Rayscan Mk2 project is the operational unit of Company A itself. The operational unit is responsible for the inspection and testing of the pipelines at the end client.

The project steering committee has the right to propose changes to the project scope. The steering committee is responsible for assigning resources to the project as well as choosing the suppliers and the sub-contractors. They are responsible for manoeuvring the project ahead. The technological centre provides resources and knowledge to the project teams. The project consultation team advises the project managers and the project steering committee. The technological centre as well as the project consultation units act like staff branches to the project manager and the steering committee. The project manager is responsible for organizing the project, communication within the team and communication to the steering committee and clients.

The project team is responsible for the project execution of product development. It includes specialists of the mechanical, electrical, and physics engineering teams. The lowest tier responsible for the supply of different mechanical and electrical subcomponents can be seen as the external organization of

suppliers and vendors. The developer of the software for the functioning of the system had an important role to play in the project. The project had suppliers and vendors responsible for the supply of various X-ray equipments. The diagram below shows the structure of the organizational hierarchy and the project team responsible for the development of Rayscan Mk2.

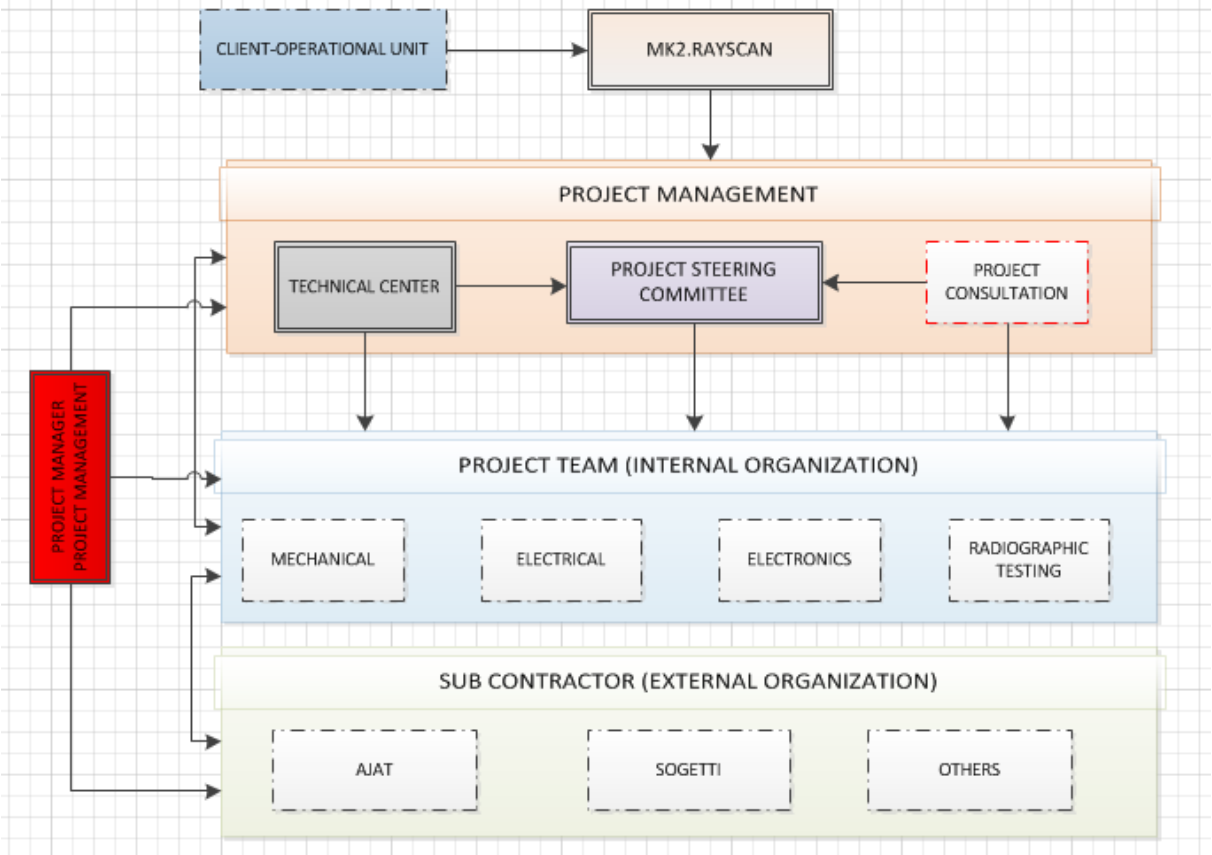


Figure 15: Team structure Rayscan Mk2.

4.1.1.1 Risks faced in the “Rayscan MK2” project.

Through the interviews the risks faced on the technological grounds, the internal organization structure and the external market in the form of the Suppliers and Vendors were recognised.

Technological Risks faced

The theoretical concepts of non- destructive testing and inspection are complicated. Integration of these concepts of physics along with the physical and the electrical components makes the whole product development of the MK2. Rayscan detector even more complicated. Most crucial mistake was a misunderstanding about the scope, requirements and scale of changes between project teams and stakeholders, client management. Since the first generation MK1 was a success it was expected from the client perspective that the changes to upscale to a production type (Rayscan MK2) would be limited. However from the view of the project engineers (technical) the requested improvements needed a complete overhaul of the design. The table (table 3) below charts out the major technological risks faced in the project. The detailed explanation of these technological risks are found in appendix.(appn, Chp4, 4.1)

S.NO	TECHNOLOGICAL RISKS	TAGS
1.	Perceived the project to be easy.	P1-R1
2.	Integration of the software developed by supplier, with the physical hardware system was a major risk.	P1-R2
3.	Integration of the X- ray equipment with the complete system was of high risk prone	P1-R3
4.	Time considered for the mechanical design and software implementations were highly insufficient	P1-R4
5.	Imperfect Concept/Engineering Design at the front end loading of the project.	P1-R5
6.	Integration of the entire system was extremely difficult since there were numerous sub-systems and each sub-system had high technical precision.	P1-R6
7.	Design and Testing of Individual components were done parallel to speed up the process.	P1-R7
8.	To realize the prime objective that the prototype should be more robust was itself the major technical risk	P1-R8

Table 3: Technological risks faced in Rayscan MK2.

Internal Organizational Risks faced

The most critical internal organization risk faced can be recognised to be the clash between the operational unit and the product development team. The biggest complexity in the project was the fact that the in-house operational unit was the very client of the product development team. An important factor was the large geographical distance between the project team and the end client. Company A did not have a definite manufacturing unit. Their maintenance department lacked dedicated resources. Company A had an immature production unit. Furthermore the project team was highly technically driven and lacked definite project management. Table 4. below charts out the risks related to internal organization and the explanation of why the below mentioned risks could have an impact is explained in the appendix. (appn, Chp4, 4.1)

S.NO	INTERNAL ORGANIZATION RISKS	TAG
1.	The project team was technically driven but lacked project management	R1-RA9
2.	Clashes between operational unit and the product development team.	R1-RA10
3.	Absence of a dedicated Assembly Unit	R1-RA11
4.	Definite lack of resources to arrange logistics.	R1-RA12
5.	Estimated costs were exceeding the determined budgets.	R1-RA13

Table 4: Internal Organizational risks faced in Rayscan MK2.

External Organizational Risks faced

The interactions with the software developers and the suppliers of the X- ray equipments were extremely complicated. In fact some of the risks faced due to suppliers and vendors can be identified in the technical risks faced in this project. The context of this risk is purely in the form of complicacies which creep up due to information asymmetry. The other risk which is the lack of resources of many aspects which were not identified initially (similarity with Internal Organization related risks). The table

below describes the risks related to suppliers and the vendors and their possible impacts are explained in the appendix. (appn , Chp 4, 4.1)

S.NO	EXTERNAL ORGANIZATION	TAG
1.	Definite lack of Resources of many aspects	R1-RA14
2.	Interactions with software developer was extremely complicated and risk prone	R2-RA15
3.	Interactions with the suppliers of the X-ray equipment was also risk prone.	R2-RA16

Table 5: : External Organizational risks faced in Rayscan MK2

4.1.1.2 Risks Management activities adopted (project Rayscan Mk2)

In this section we analyse the different risk management activities which were adopted by company A to counter or manage the risks they identified or faced in the process of the development of the second generation Rayscan MK2 scanner. As discussed above the major complexities faced in the project was due to the fact that the project was perceived to be easier on technical grounds. There was immense process management amongst all the important actors involved in the product development process. Intense team meetings, interactions, redesign of engineering/concept designs, closer proximity with the suppliers and vendors, intense risk workshops were some of the major risk management activities adopted by company A. The different Risk management activities are charted out below in three segments of technological risk management activities, internal organization risk management activities and external organization(Suppliers and vendors) related risk management activities.

Table 6. below charts out the different risk management activities adopted to counter technological risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P1-R1	Team meetings, interactions, updates with clients	P1-R1S1
2.	P1-R2	Deputation of a dedicated Project Engineer stationed with Suppliers	P1-R2S2
3.	P1-R3	Complete support from project Engineers on technical requirements and specifications.	P1-R3S3
4.	P1-R4	Re-Evaluation of critical path and Re- design of Project breakdown structure.	P1-R4S4
5.	P1-R5	Re- Design of the concept design or Re-design of Engineering	P1-R5S5
6.	P1-R6	Testing of Individual subsystems and the complete system as a whole.	P1-R6S6
7.	P1-R7	Parallel Design and Testing	P1-R7S7
8.	P1-R8	Testing conducted in artificial environment	P1-R8S8

Table 6: Technological risk management activities (Rayscan Mk2 project)

Table 7. charts out the different risk management activities adopted to counter internal organization related risks.

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P1-R9	Inclusion of a project manager	P1-R9S9
2.	P1-R10	Technical risk workshops and meetings with operational units	P1-R10S10
3.	P1-R11	Formed dedicated assembly units	P1-R11S11
4.	P1-R12	Taking back up resources from other projects.	P1-R12S12
5.	P1-R13	Detailed business plan reported to the management	P1-R13S13

Table 7: Internal organizational risk management activities (Rayscan Mk2 project)

Table 8. below charts out the different risk management activities adopted to counter external organizational (Suppliers and Vendors) related Risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P1-R14	Allocate more budget for execution purposes	P1-R14S14
2.	P1-R15	Ensure the correctness of specifications shared by means of stronger interactions and communications.	P1-R15S15
3.	P1-R16	Stronger technical assistance provided to the suppliers by sharing technical knowledge.	P1-R16S16

Table 8: External organizational risk management activities (Rayscan Mk2 project)

Influence of Risk Management activities

In this segment we analyse how the different adopted risk management activities influence the project outcome . The project outcomes as discussed in the literature have been defined to be Quality , Cost and Time. The researcher tries to analyse how these independent risk management activities have affected these dependant project outcomes(Quality, Cost and Time). The impact made by these independent risk management activities can be defined to be the value added to the project It is important to study how the different risk management activities adopted help to manage the different technological risks in terms of Quality, cost and time. The explanations are as follows:

- P1-R1S1: Team meetings, interactions and updates amongst all the actors of the project is the most basic risk management activity adopted when it was realized that the project was more technically complex than perceived. Team meetings, interactions and updates were process management mechanisms which helps all the actors involved in the product development cycle to come down to a common consensus, and hence realize the technical complexities. It tends to bring an all-round improvement on grounds of Quality, Cost and Time. It has positive effects on Quality, Cost and Time.
- P1-R2S2: Deputation of a dedicated project engineer with software developer was a tactical risk management activity adopted to manage the technical complexity of integrating the software developed with the physical device. A dedicated project engineer would not only ensure that the speed of development at the developers end would increase, but it would also ensure that the developer, developed the exact software as per technical requirements and specifications. It would speed up the process of development, enhance the quality of the software which is extremely

important in terms of the success of the proper functioning of the device. However deputation of a dedicated project engineers would also signify enhanced costs, therefore budget enhancements of the project. The activity has a positive effect as far as quality and time is concerned but it has a negative effect on budget.

- P1-R3S3: The fact that suppliers of the X- ray equipment lacked the cable testing skills, they also faced extreme difficulties in designing the appropriate supply cables depending on specifications. It was extremely critical that the project engineers shared their knowledge of their area of expertise with the suppliers. This definitely helped to enhance the quality of the project and also the time management since technical assistance helped to speed up the product development skills. It has a positive effect on the quality of the product and time management but has a neutral effect on the cost management of the project.
- P1-R4S4: As the project was initially conceived to be technically much easier, the time schedule and the cost budgets at the front end loading was not accurate. Hence re-evaluation of the critical path and the project breakdown structure was an immediate must which needed to be taken up. This has a direct effect on the improvement of process and quality management. It's a must when you realize that the project planning done initially is wrong. The new plan of action for the project obviously leads to more time and budget required for the project but it definitely stops the project from proceeding in the wrong direction. It has a positive effect on quality, it definitely improves the cost management of the project, it put the project out of time schedule but looking futuristically it improves the time management of the project.
- P1-R5S5: As discussed in the previous activity the re-design and re-engineering would stop the product being developed in the wrong direction. Though it increases the time spent and the budget of the project, it enhances the quality of the project by increasing the correctness of the design of the product. Having a futuristic look the project tends to have an advantage in trying to keep to the time schedule, because there is no technical hindrance at the end. It has a positive effect on quality, it is neutral to the cost management of the project, initially it puts the project out of time schedule but looking futuristically it improves the time management of the project.
- P1-R6S6: Since the system had numerous subsystems and components it is crucial that all the subsystems are tested on an individual level before the complete system is tested on a whole. This increased the correctness of the whole system and the quality of the system. Individual testing takes up more time, increases the budget, but it covers for the fact that it acts as a precaution for failure during complete system testing. Therefore Individual system testing has a positive effect on Quality, it has a negative effect on Cost management, initially it puts the project out of time schedule but looking futuristically it improves the time management of the project.
- P1-R7S7: Parallel design and testing, the risk itself can be viewed as an activity . Parallel working specially designing, engineering, purchasing, assembly and testing will tend to decrease the quality of the work. It definitely improves the time management of the work. Usually the activity is neutral or negative to costs since the idea is to already start on a activity while full requirements for the activity are not completely clear. It's almost equivalent to taking a risk halfway that the activity needs to be altered or redone.
- P1-R8S8: Testing being conducted in an artificial environment was the activity adopted to counter the identified risk to make the prototype more robust for extreme temperatures with improved sensitivity and hardness. The activity would ensure that the product would actually be able to survive hazardous conditions and hence increase the quality of the system. However creating the artificial environment meant that there were increased costs and budgets. This decrease the cost management of the task, initially it puts the project out of time schedule but looking futuristically it improves the time management of the project.

The table below summarizes the influence of the different risk management activities to counter technological risks on the project in terms of Quality, Cost and Time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P1-R1S1	I (+ve)	I(+ve)	I(+ve)
2.	P1-R2S2	I (+ve)	D(-ve)	I(+ve)
3.	P1-R3S3	I (+ve)	N	I (+ve)
4.	P1-R4S4	I (+ve)	I(+ve)	I(+ve)/D(-ve)
5.	P1-R5S5	I(+ve)	N	I(+ve)/D(-ve)
6.	P1-R6S6	I(+ve)	D(-ve)	I(+ve)/D(-ve)
7.	P1-R7S7	D(-ve)	N/D (+ve)	I(+ve)
8.	P1-R8S8	I(+ve)	D(-ve)	I(+ve)/D(-ve)

Table 9: Influence of the technological risk activities on quality, cost, time.

The researcher studies how the different risk management activities adopted help to manage the different Internal Organization risks in terms of quality, cost and time. The explanations are as follows:

- P1-R9S9: Inclusion of a project manager definitely brought in more project management in terms of cost management and time management of the project. Apart from the fact that project was technically driven, the project managers has a positive effect in terms of time and budget of the project.
- P1-R10S10: The fact that the product development team was not being able to keep up to the expectations of the operational team, technical risk workshops and interactions with the operations team helped to make the operations team aware of the complexities of the project. The activity has a neutral effect on both the quality and the cost management of the project. It rather helps to bring about a better understanding between the actors for the reasons of exceeding project deadlines. Therefore we can say that the activity had a positive effect on the time management of the project.
- P1-R11S11: The absence of a dedicated assembly team was major deficit from the point of view of the organization structure. The maintenance unit was expected to assemble and integrate the entire system. Dedicated functional units were developed. This was more of a lesson learnt and was applied for other projects. Individual assembly units with more technical expertise in assembly of subsystems to realize the final product, ensures that the final system is more technically correct, and therefore improved quality. It also has a positive effect on cost management and time management of the project since technical experts will reduce extra costs and extra time required during the assembly and the integration of the system.
- P1-R12S12: The lack of resources faced during the project was managed by taking back up resources from the other project. Back up resources from other projects might tend to depreciate the quality of the product. It has a positive effect on the time management since it helps to keep the project on track. The activity has a neutral effect on the cost management of the project though.
- P1-R13S13: When the complexities of the project were realized, the new project schedule demanded more monetary resources. Hence strategically a business plan was written to the management explaining the definite positives out of the project for the organization. It was a tactical ploy to manage the risk of having no monetary resources to proceed in the project. The activity did not have any effect on improving the quality but the activity definitely helped in getting extra funds for the project to continue and hence it had a positive impact on the cost management and the time management of the project.

The table below summarizes the influence of the different risk management activities to counter the internal organization related risks on the project in terms of quality, cost and time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P1-R9S9	N	I(+ve)	I(+ve)
2.	P1-R10S10	N	N	I(+ve)
3.	P1-R11S11	I (+ve)	I(+ve)	I (+ve)
4.	P1-R12S12	D(-ve)	N	I(+ve)
5.	P1-R13S13	N	I(+ve)	I(+ve)

Table 10: Influence of the internal organizational risk activities on quality, cost, time.

Next the researcher studies how the different risk management activities adopted helped to manage the different internal organization risks in terms of quality, cost and time. The explanations are as follows:

- P1-R14S14: The fact that the lack of certain resources are not conceived initially, it acts as major risk, since it can stop proceedings. It is more of a lesson learnt for company A. A presently allocates more budget for project execution. Allocating more budget for the execution purpose is a cost management structure, which will tend to improve the time management during execution. Project management is the most complex part of the entire product life cycle. It had a neutral effect in terms of quality though.
- P1_R15S15: As discussed in the earlier section the interactions with the software developer were managed by deputing a dedicated project engineer of the organization. Deputation of a dedicated project engineer leads to cost enhancement of the project but improves the quality of the product and also the time management of the project. The presence of a project engineer meant the process of communication was a lot more smoother with the software developer.
- P1-R16S16: Stronger technical assistance provided to the suppliers by means of interactions, sharing of knowledge would not only improve the quality of the product but also develop stronger relations with the suppliers and the vendors. Technical assistance surrendered would also ensure faster product development of the subsystem. The cost management of the project remains unaffected.

The table below summarizes the influence of the different risk management activities to counter the external organization related risks on the project in terms of quality, cost and time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P1-R14S14	N	I(+ve)	I(+ve)
2.	P1-R15S15	I (+ve)	D(-ve)	I(+ve)
3.	P1-R16S16	I (+ve)	N	I (+ve)

Table 11: Influence of the internal organizational risk activities on quality, cost, time.

4.1.1.3 Risks Management framework followed

The risk management framework followed by the organization is informal. Company A does not have any formal, defined risk management framework. The risk management was more of the form of project management. The risks were countered more on the merit. The most commonly used risk management activity tools used are as follows:

- The use of risk registers, where the identified risks were documented considering their risk impacts. Depending on the impact the risks are prioritized and the risk management activities are planned.
- Technical risk workshops were further regularised in weekly schedule.
- The critical path of the project was identified at the frontend loading of the project.

4.1.1.4 Effectiveness of Risk management activities adopted

The project on the whole was extremely successful since the primary aim of achieving a more robust device capable of enduring tougher environmental conditions was achieved.

- In the product development process the quality of the product was given prime importance over the cost management and the time management of the project. The technical expertise of the engineers in the field of the pipeline inspection and non-destructive testing acted as important asset which helped to deal with numerous technical risks. The project was technically driven from the very beginning. The system was successfully integrated and intensive testing was carried out for the successful functioning of the product.
- The cost management of the project was handled quite efficiently. The business plan submitted to the management helped to harness additional budget resources which helped in the proper integration of the software . This helped the project to propel ahead.
- The time management in this project was the weakest. Since the technical complexity of the project was mis-interpreted, the front end loading of the project in terms of choosing the correct critical path and the project breakdown structure was itself wrong. The project was brought back on track by means of stronger project and process management.

The above analysis helps us conclude the fact that the risk management activities adopted helped to attain certain added values. The added values can also be seen in terms of technical developments , internal organization developments and the developments in the external network. Figure 16. below charts out the most important value addition of the risk management carried out in the project.

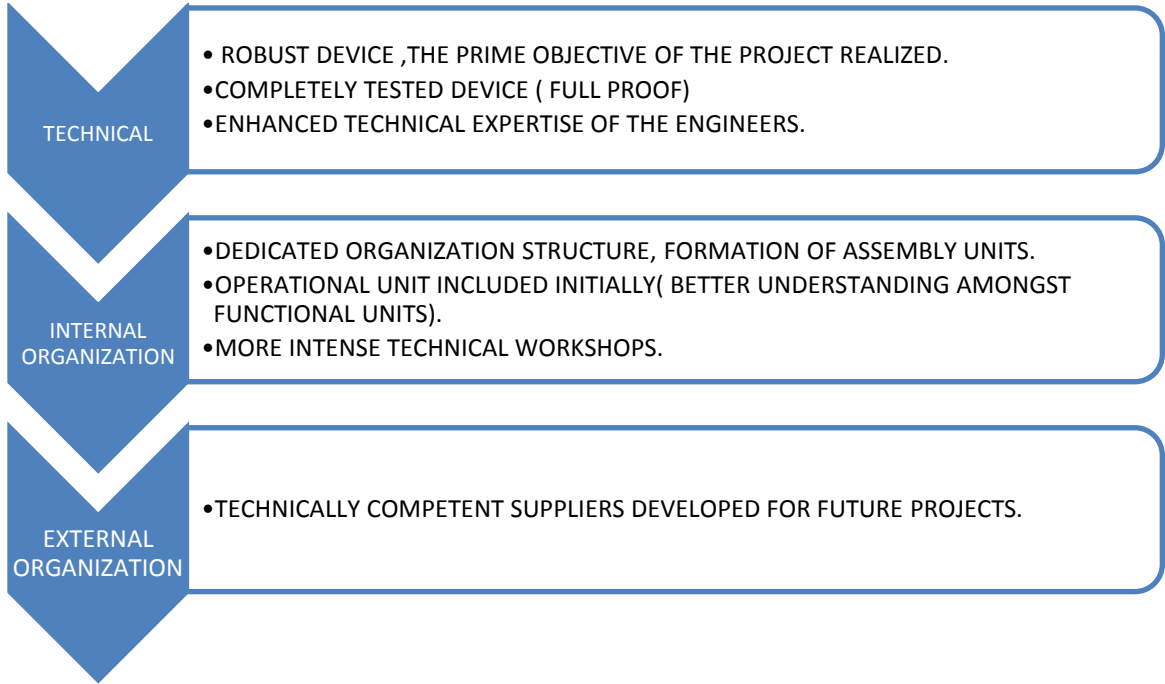


Figure 16: Added value of Risk management

4.1.2 “Riser Inspection Tool development” project description.

The main objective of the “Riser Inspection Tool” development project is to develop and manufacture an inline inspection tool to inspect risers and specially the welds of the riser which connects the platforms to the bottom of the sea.

Objectives of the Project

The following were the primary objectives of the project:

- The main objective of the project was to detect and size fatigue cracks in welds. The complexity being that the fatigue cracks may allow ultrasonic waves to pass through it and hence the cracks remain unnoticed.
- From a client’s perspective, the objective of the project was to save the costs since a possible shutdown of the riser would signify that there would be loss of millions of Euros. The advantage of a proper inspection methodology would signify that the lifetime of the riser can be extended.
- The inspection methodology would signify a real time sensing of the welds with a real time data visualization and analysis. Furthermore the real time sensing of the welds would also mean that it is possible to get an actual idea of the weld deformation, which is needed for data analysis as well.
- Hence the main aim was to provide or develop an inspection tool with an algorithm that is able to accurately detect and sizes fatigue cracks.
- The inspection tool needed to function under high pressure (due to depths of 1000- 2000m beneath the sea level) and at high temperature of operation.

Composition of the Product Development Team

The team was balanced optimally to carry out the project and find a dedicated solution. The team had the right combination of technical and project management expertise. The project demanded to think of different options and solutions . The project needed to make the correct choices to make an impact on the quality and cost of the solution. The steering committee consisted of a team from the technology center, project manager representing the client, Operational manager from the Pipeline Inspection Department. The project manager from company A was primarily responsible for supervising the project and updating the steering committee on the results, budget and planning. The steering committee was primarily responsible for monitoring the progress of the product development and decisions regarding planning and budget.

The second tier consisted of all the project engineers responsible for the main project execution, that is the design, engineering and the integration of all the subsystems.

The lowest tier depicts the external organization that is the suppliers and the vendors. The suppliers and the vendors are responsible for the supply of the all the subsystems of the complete device.

Figure 17. below shows the structure of the organizational hierarchy and the project team responsible for “Riser Inspection tool” development product.

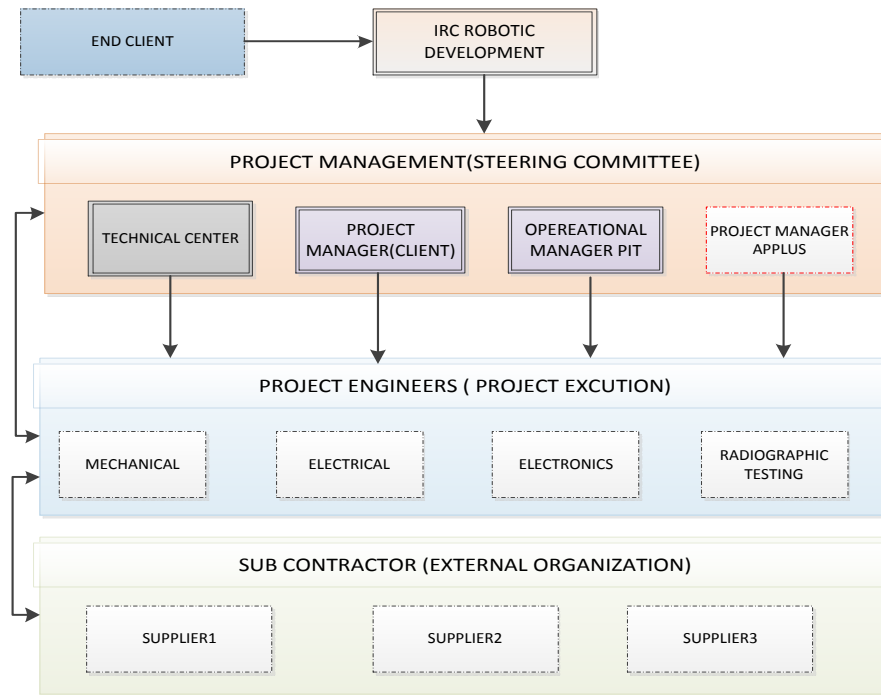


Figure 17: Team Structure of “Riser Inspection Tool” development project

4.1.2.1 Risks faced in the “Riser Inspection Tool” development project.

Semi structured in-depth interviews with the project manager and the technical head helped to identify the various risks faced on the technological grounds, the internal organization structure and the external market in the form of the suppliers and vendors.

Technological Risks faced

The main complexity from an inspection point of view was the fact that different theories of physics (diffraction & reflection) related to different inspection techniques like (Time of Flight Diffraction, Phased Array, Pulse Echo and Creeping Waves) were needed to be combined to find the optimum inspection solution. As previously mentioned, the complexity was due to the nature of the cracks, which needed to be inspected in the welds of the risers. The cracks exhibit a transparent behavior to ultrasonic waves. The integration of the hardware, the software with the different concepts of physics leads to the main technical complexity.

Furthermore huge amounts of data are needed to be analyzed while it was important to compare different techniques and come up with the best possible solution with minimum requirements. Table 12. below charts out the different risks faced on technological grounds. The detailed explanation of how these risks could have an impact is explained in the appendix. (appn, chp4, 4.2)

S.NO	TECHNOLOGICAL RISKS	TAGS
1.	Theoretical complexity due to combination of different concepts of physics	P2-R1
2.	Risk of not realizing a product capable of accurate positioning and sizing of cracks	P2-R2
3.	Risk of not being capable of Integrating the theoretical concepts with the Electrical and Mechanical components	P2-R3

4.	Risks of failure while Integrating the software along with the mechanical structure.	P2-R4
5.	Risks of failure during integration of the different subsystems to achieve the final device.	P2-R5
6.	Risk of mal-function of the device in high temperature and pressure.	P2-R6
7.	Risk of making wrong technical choices.	P2-R7

Table 12: Technological risks faced in “Riser Inspection Tool” development project.

Internal Organizational Risks faced

The team responsible for carrying out the product development was quite stable. The team had the right balance of technical expertise and project management. There was not any major clash with the board of management. However criticality and complexities of the keeping up to the expectations of the clients was the most important factor. At times risks arose when there was certain amount of overdependence on other functional units. Table 13. below charts out the different risks faced on organizational factors. Detailed explanation of the below mentioned risks are explained in the appendix.(appn, chp4, 4.2)

S.NO	INTERNAL ORGANIZATIONAL RISKS	TAGS
1.	Risks due to conflict of interest with end client.	P2-R8
2.	Risks due to broader expectations of the client	P2-R9
3.	Risk of not keeping to time schedule due to delay in approval from client end.	P2-R10
4.	Risks of failing to abide by the time limits due to increase in scope of the project.	P2-R11
5.	Risks of not having the right resources in the appropriate time from other functional units	P2-R12

Table 13: Internal organizational risks faced in “Riser Inspection Tool” development project.

External Organizational Risks faced

In the perspective of this project , company A had a very short time to the market.. The risk of the suppliers not being able to delivers the subcomponents within the short lead times always remained. Table 14. below charts out the different risks faced with suppliers and vendors. Detailed explanation of the below mentioned risks are explained in the appendix. (appn, chp 4, 4.2)

S.NO	EXTERNAL ORGANIZATION RISKS	TAGS
1.	Risk of not being able to arrange resources on time	P2-R13
2.	Risk of suppliers not being able to deliver on time.	P2-R14

Table 14: External organizational risks faced in “Riser Inspection Tool” development project.

4.1.2.2 Risks Management activities adopted (Riser Inspection Tool development project)

In this section the researcher analyses the different risk management activities which were adopted by company A to counter or manage the risks they identified or faced in the process of the

development of the “Riser Inspection Tool” development project. As discussed previously the major complexities faced in the project was due to the fact that the solution being developed for the project was extremely complex. It was also complicated to manage the expectations of the clients. Company A tried to manage the risks by resorting to a strategy of showing the cost benefit of the project to the end client. Since the project was technically so challenging in nature a dedicated system architect was assigned for the integration of all the subsystems together. Moreover they had adopted a milestone based payment system which was extremely important since it was unsure if the suppliers would be able to realize the complexities of the subsystems.

Table 15. below charts out the different risk management activities adopted to counter Technological Risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P2-R1, P2-R3, P2-R4	Brainstorming different solutions.	P2-RS1
2.	P2-R1, P2-R6, P2-R2	Technical expertise of experts(Delphi method)	P2-RS2
3.	P2-R4, P2-R5	Involvement of a system architect	P2-RS3
4.	P2-R6	Prototyping and achieving sample simulations	P2-RS4
5.	P2-R3, P2-R5	Involve engineers from the very beginning of the concept design.	P2-RS5
6.	P2-R7	Have a strong Project critical path.	P2-RS6
7.	P2-R7	Have a stronger front end loading.	P2-RS7
8.	P2-R7	Important to be pragmatic in approach.(Well defined scope)	P2-RS8

Table 15: Technological Risk management activities adopted in “ Riser Inspection Tool” development project.

Table 16. below charts out the different risk management activities adopted to counter the Internal organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	STRATEGY TAG
1.	P2-R8	Show the client the net present value of the project.	P2-RS9
2.	P2-R9	Stronger communications with the project managers to realize the exact specifications.	P2-RS10
3.	P2-R9	Provide alternate possible applications.	P2-RS11
4.	P2-R10	Extremely proactive and pragmatic in their approach.	P2-RS12
5.	P2-R10	Allocate resources on time.	P2-RS13
6.	P2-R10	Adapt the time schedule immediately if the scope and the plan is changed.	P2-RS14
7.	P2-R10	Alternatives and back up options to stick to deadlines.	P2-RS15
8.	P2-R11	Check the budget and the time schedule after every milestone on perspective of the complete project.	P2-RS16
9.	P2-R11	Experts from the operation committee were involved in the steering committee	P2-RS17

Table 16: Internal Organizational Risk management activities adopted in “ Riser Inspection Tool” development.

Table 17. below charts out the different risk management activities adopted to counter the External organization related risks related to suppliers and vendors:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P2-R14	Make the suppliers realize the complexity of the project	P2-RS18
2.	P2-R14	Involve the suppliers from the beginning of the project	P2-RS19
3.	P2-R14	Communicate the right requirements to the suppliers	P2-RS20

Table 17: External Organizational Risk management activities adopted in “Riser Inspection Tool” development.

Influence of Risk Management activities

In this segment the researcher analyses how the different adopted risk management activities influence the project outcomes. The independent risk management activities have affected the dependant project outcomes(Quality, Cost and Time) in specific ways. The impact made by these independent risk management activities can be defined to be the value added to the project.

At first the researcher explains how the different risk management activities adopted help to manage the different technological risks in terms of quality, cost and time. The explanations are as follows:

- P2-RS1: Brainstorming different solutions helps to arrive to the best possible solution, with minimum complexities. Brainstorming helps to improve quality, cost and time.
- P2-RS2: Technical expertise was extremely important to achieve the complexity of the technical device. Technical expertise helped to improve the quality of the product. The technical expertise also helped to achieve solutions faster and hence improved time management.
- P2-RS3: The expertise of a system architect helped to attain a faster integration of all the subsystems. It improved the quality of the product overall. Moreover system architect also helped in defining the correct technical specifications of the subsystems. Correct technical specifications also improves the cost management of the system.
- P2-RS4: Prototyping and achieving sample simulations helped to realize if the combinations of the concepts along with the physical device of the system actually helped to achieve the desired functionalities. It improved the overall quality of the system as it validated if the choice of the theoretical concepts were correct. This also helped the time management and cost management of the project since it stops the project from proceeding in the wrong direction.
- P2-RS5: Involving engineers and the operational team from the very beginning helped the engineers to understand the technical complexity which further enabled in a smoother integration. It has a positive effect on the technical viability of the device. It also helped the project to gain pace on executional terms. The activity had a neutral effect on the cost management of the project.
- P2-RS6: The critical path chosen for the execution of the project during the front end loading was done with a pragmatic approach. This helped to chart out a viable project execution time line.
- P2-RS7: A stronger process management at the beginning of the project(stronger front end loading) helped to chart out a logical work breakdown structure and correct project critical path. This enabled to have a smoother time management and cost management of the project.

Table 19. below charts out the effect of the different technological risk management activities on quality, cost and time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P2-RS1	I (+ve)	I (+ve)	I (+ve)
2.	P2-RS2	I (+ve)	N	I (+ve)
3.	P2-RS3	I (+ve)	I (+ve)	I (+ve)
4.	P2-RS4	I (+ve)	I(+ve)/D(-ve)	I (+ve)
5.	P2-RS5	I (+ve)	I (+ve)	I (+ve)
6.	P2-RS6	N	I (+ve)	I (+ve)
7.	P1-RS7	N	I (+ve)	I (+ve)

Table 18: Influence of the technological risk activities on quality, cost, time.

The researcher explains how the different risk management activities adopted help to manage the different internal organizational risks in terms of quality, cost and time. The explanations are as follows:

- P2-RS9: Company A adopted the strategy to show the client a strong cost benefit analysis, proving that the net present value of creating an inspection procedure had a higher net present value rather than repairing the whole riser. Convincing the client on the return of investments initiated the process and made the process much faster. It had a strong impact on the cost management of the project.
- P2-RS10: Stronger and more specific communications on the different specifications brought more clarity on technical grounds. This improved the time management of the project.
- P2-RS11: Proving alternate applications using the same solutions with different technical combinations made the whole project appealing and cost effective for the clients.
- P2-RS12: The project dynamics were extremely fast paced, especially since the scope of the project was always expanding. Proactive and pragmatic approach from company A's end helped to face the constant changes, and improve the time management of the project. Pro activeness from company A helped to counter the complexity of not attaining the approval from the client end on time.
- P2-RS13: Allocation of the resources within the time schedule in consideration helped to achieve project deadlines on time even when the approval from the client end was delayed.
- P2-R14: Adapting the time and scope of the project with immediate changes in the scope of the project helped to attain a better time management and cost management of the project. It also helped to manage the delays from the client end.
- P2-R15: Stronger back up options in terms of resources helped to mitigate the risk of not having the adequate resources specially when the scope and plan of the project were changed. It helped to manage the delays in approvals from the client end.
- P2-RS16: The fact that the budget and the time schedule of the project was checked after every milestone and project stage gates on perspective of the milestone achieved as well as the entire project helped to achieve the correct time and cost management of the project.
- P2-RS17: Experts from the operations team were involved so that they had the correct technical knowhow of the assembly of the system. Moreover their past experiences during inspection and testing at the client end helped to attain a better design. This enabled to improve the quality of the system, and would also help in future operational functions specially during the usage of the device at client ends.

Table 19. below charts out the effect of the different internal organizational risk management activities on terms of Quality, Cost and Time:

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P2-RS9	N	I(+ve)	I (+ve)
2.	P2-RS10	I (+ve)	N	I (+ve)
3.	P2-RS11	N	I (+ve)	I (+ve)
4.	P2-RS12	N	I(+ve)	I (+ve)

5.	P2-RS13	N	I (+ve)	I (+ve)
6.	P2-RS14	N	I (+ve)	I (+ve)
7.	P2-RS15	N	I (+ve)	I (+ve)
8.	P2-RS16	N	I(+ve)	I(+ve)
9	P2-RS17	I(+ve)	N	I(+ve)

Table 19: Influence of the internal organizational risk activities on quality, cost, time.

Now the researcher explains how the different risk management activities adopted helped to manage the different External organizational risks(risks related to suppliers and vendors) in terms of quality, cost and time:

- P2-RS18/P2-RS19: It was important that the suppliers were involved from the very beginning of the project. This helped the suppliers to realize the urgency of keeping to the lead time of project deliverables and also realize the technical complexity of the entire system. Suppliers being involved from an early stage helped to design the subsystems to be technically compatible to each other as well as the entire system. This helped to improve the quality of the product as well as the time management of the project.
- P2-RS20: Communicating the necessary requirements and specifications to the suppliers helped the suppliers design the subcomponents/ subsystems in a more technically correct manner. This helped to manage the Quality of the product as well as the Time management of the project.

Table 20. below charts out the effect of the different risk management activities on Quality, Cost and Time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P2-RS18	I (+ve)	N	I (+ve)
2.	P2-RS19	I (+ve)	N	I (+ve)
3.	P2-RS20	I (+ve)	N	I (+ve)

Table 20: Influence of the external organizational risk activities on quality, cost, time.

4.1.2.3 Risks Management framework followed

The Risk Management followed in the project was a lot more formal, organized and pre-planned. The fact that the operational unit , the engineers and the suppliers were involved from the very beginning of the project proved that lessons learnt from the previous executed projects were actually implemented. It is realized that company A had a stronger process management adopted for the entire project. The diagram (fig) below helps to visualize that the risk management activities were adopted more to develop a product within the scheduled budget and time frame. It was important for Company A to execute the project for the client and penetrate the market. The Project developed :

- An intense risk matrix tool to identify all the risks.
- Company A tried to develop a tool kit with different risk management activities. The right solutions were adopted for the identified risks.
- A very strong project critical path was developed at the front end. Constant updation of the time and budget schedule with the changes in the scope of the project were implemented.

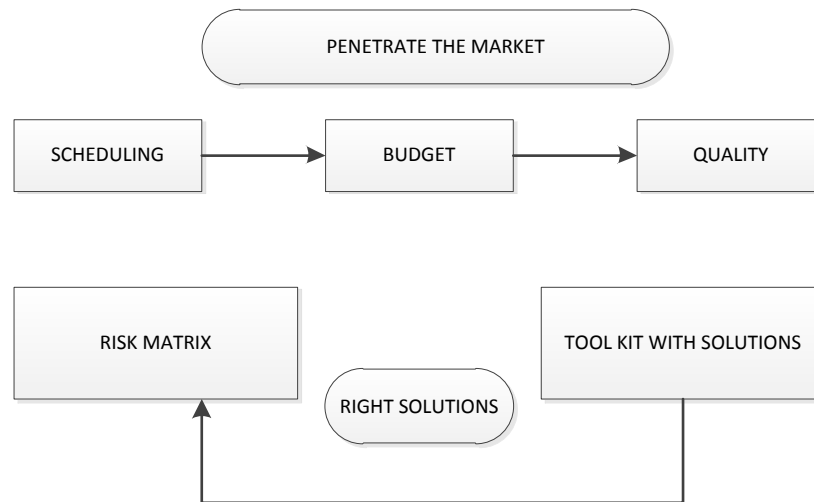


Figure 18: Risk management framework adopted for “Inspection Riser Tool” development project

4.1.2.4 Effectiveness of Risk management activities adopted

The project was successful since a feasible and optimum inspection solution for the welds of the risers was achieved. The prototype still needs amendments on technical grounds to attain technical precision.

- Inspection procedures were developed. The hardware feasibility was achieved. The hardware development, validation and development are still to be done. A two year development period is envisaged.
- The operational unit, the engineers, the suppliers, and vendors having been involved right from the beginning of the concept design helped in the correctness of the technicalities of the subsystems. This also helped in the time management during the integration and assembly of the entire product.
- The strategic ploy of showing the end client a strong cost benefit analysis of developing a product rather for inspection means helped to convince the client faster. This helped in the time management of the entire project.

The above analysis helped us to realize that there were certain added values which emerged out of the risk management activities on technical grounds, on internal organization structure levels, as well as with suppliers and vendors.

The figure 19. In the next page illustrates the added value of the risk management adopted.

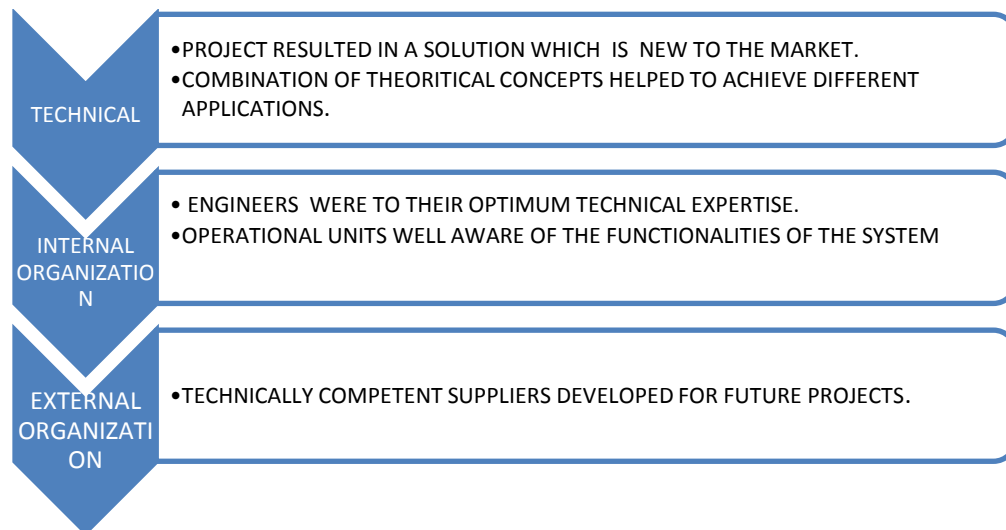


Figure 19: Added value of risk management

4.2 Company B Description

Company B is the world's leading provider of lithography systems for the semiconductor industry. They manufacture complex machines that are critical to the production of integrated circuits or chips. Company B's largest business focuses is on lithography systems for 200-300 millimetre diameter wafers. Their business activities involve customized solutions for compound semiconductors, software enhanced lithography and commercialization of extreme ultra violet lithography systems.

Reasons why Company B is an interesting company for Research?

Company B is interesting in the context of the research for the following reasons:

- The development of the lithography systems involves a complex technology. Complex machine designing skills, engineering skills based on strong concepts and theories involved in developing the lithography systems. This makes B interesting to study from the perspectives of technological complexities.
- The main system manufactured by B contains tens and thousands of parts. Nearly all of them are manufactured by outside suppliers. The researcher gets the opportunity to study the risks and complexities which were faced with the supplier . The engineers of company B focus on what they do the best that is design the system and integrate the different modules into a finely tuned machine. The system is dependent on a
- Company B has a complex organization structure with a very strong board of management, different business segments, different business operation units and dedicated business support units responsible for the business development like marketing. There is a certain amount of interdependence on each of the functional units in order to realize the final product . Therefore a lot of complexities and risks arise within the internal organization, which is the other context of study in the thesis.

4.2.1 Tooling Packaging and Hoist development (project description)

Products create value only when it is ultimately used by the customer. It is important that it reaches the customer end first. The company B lithography systems are large. They cannot be shipped in one piece. They need to be dismantled intelligently so that reassembly into one complete unit is kept as simple as possible. Producers and their customers often set highly specific requirements for disassembly, shipping and reassembly. The primary concern is with costs, speed, efficiency, space, user convenience. The researcher studies how the tooling, development and hoist development projects are executed with an aim to deliver the lithography systems at the client end in an undamaged condition.

Objectives of the Project

The main aim and objectives of the project were as follows:

- To deliver tooling, shipping, transport, hoist, lifting and packaging solutions for safe transit of the lithography machines from the manufacturing units to the end client.
- The environment in which the tool performs is always different. The uncertainty of the environment in which the tooling functions is completely new.
- The main objective is to realize a product which is safe enough.

Composition of the Product Development Team

Figure 20 in the next page. shows the structure of the organizational hierarchy and the project team responsible for the development of the tooling, packaging and the hoist development solutions. The product development team is headed by the project lead. The chief architect is responsible for developing the technical feasibility of the solutions. The second tier for project management reporting to the project lead and the project architect are the individual team leads responsible for heading the individual hoist development, individual transport development, and the packaging development.

The project execution team consists of mechanical engineers responsible for the manufacturing. The project execution team under the guidance and management of the group leads interacts with all the suppliers and the vendors.

Company B has a balanced product development team. The team had the right balance between managerial and technical expertise. Moreover throughout the project the team was consistent and balanced.

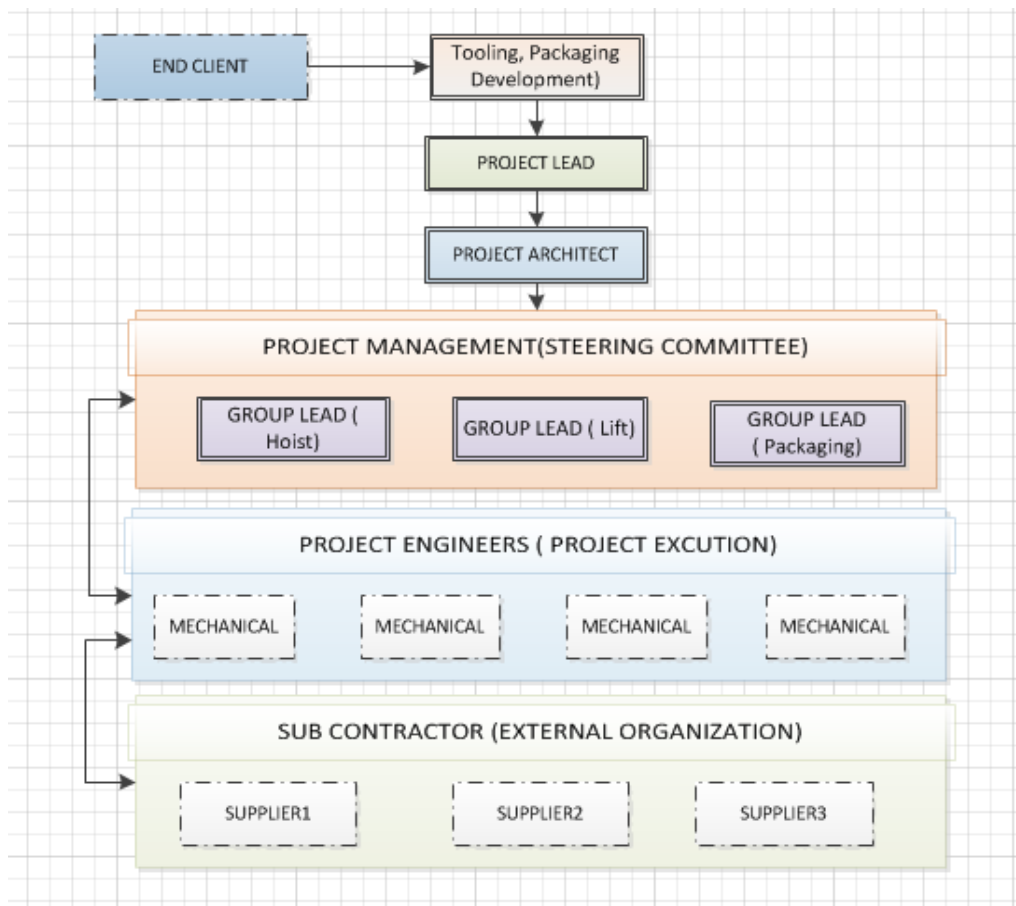


Figure 20: Team Structure of “ Tooling Packing and Hoist” development project

4.2.1.1 Risks faced in the “Tooling Packaging & Hoist” development projects.

The biggest complexity in the tooling, packaging and the hoist development process is about the fact that the need of the shipping tool has a lower priority. The need arises at the last phase of shipping the lithography machine to the client side. The tooling solution is more of a logistic means, which is not given prime importance during design of the main lithography system. The importance of involving the tooling team at the early stages of designing the lithography systems is not realized. The tooling system should be developed in accordance to the design of the main system.

Technological Risks faced

A tooling or packaging solution becomes extremely difficult to realize when the product or the system to be shipped has already been designed. It leaves no room for technical innovation. The tooling system has to be designed in accordance to the system to be shipped. Table 21. below charts out the different risks faced on technological grounds. The detailed explanation of the technological risks are found in appendix(appn, chp4, 4.3)

S.NO	TECHNOLOGICAL RISKS	TAGS
1.	The tooling system has too many subsystems.	P3-RS1.
2.	The design of the tooling system is already dependant on the main system.	P3-RS2.

3.	Risk of having to redesign the entire tooling and packaging system.	P3-RS3.
4.	Risks of failing to realize the scope of the project.	P3-RS4.
5.	It is always a risk of not realizing the clean room compatibility.	P3-RS5

Table 21: Technological risks faced in “Tooling Packaging & Handling ” development project.

Internal Organizational Risks faced

The tooling and the packaging unit though an extremely important and critical unit in terms of logistics, it is always considered as a secondary system. It is given less importance than the main lithography system in the organization. Table 22. below charts out the various risks related to the Internal organization. The detailed explanation of the internal organizational risks are found in appendix (appn, chp4, 4.3)

S.NO	INTERNAL ORGANIZATION RISKS	TAGS
1.	The risk of inadequate resources.	P3-RS6
2.	The risk of not being able to keep up to the expectations of the production unit.	P3-RS7
3.	The risk of budgets being resource driven and not value driven.	P3-RS8

Table 22: Internal organizational risks faced in “Tooling Packaging & Hoist ” development project.

External Organizational Risks faced

The suppliers need to be technically adept to comply with the tooling development of the packaging industry. At times the suppliers and the vendors were determined initially by the top management. Table 23. below charts out the major risk faced with the suppliers and the vendors. The detailed explanation of the external organizational risks are found in appendix (appn, chp4, 4.3)

S.NO	EXTERNAL ORGANIZATION RISKS	TAGS
1.	Risk of the Suppliers and the vendors not being technically adept and skilful.	P3-RS9

Table 23: External organizational risks faced in “Tooling Packaging & Hoist ” development project.

4.2.1.2 Risks Management activities adopted (Tooling, Packaging and Hoist development)

In this section the researcher analyses the different risk management activities which were adopted by company B to counter or manage the risks identified or faced in the process of the development of the Tool, packaging and hoist development systems.

Company B has a more formalized risk management approach to their projects. They maintained a regularized risk register in which all the probable risks were documented. The risk analysis was carried out in two levels. Risk analysis is initially done on the product and then risk analysis is carried out on the whole project. Company B follows a two-step risk analysis approach.

Table 24. below charts out the different Risk Management activities adopted to counter Technological Risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P3-R1	Parallel teams were formed.	P3-RS1
2.	P3-R2, P3-R3	Re- think and Re-do the concept of the tool	P3-RS2
3.	P3-R2	Regular interaction amongst cross functional units.	P3-RS3
4.	P3-R3	Risk analysis done on the product by means of a Failure Mode Effects Analysis	P3-RS4
5.	P3-R3	Make sure that the tools used for manufacturing purposes were certified.	P3-RS5
6.	P3-R4	Make a risk register mainly from the perspective of the project.	P3-RS6
7.	P3-R3	Involve the suppliers from the concept design stage.	P3-RS7

Table 24: Technological Risk management activities adopted in “Tooling Packaging & Hoist ” development project.

Table 25. charts out the different risk management strategies adopted to counter the Internal Organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITIES	ACTIVITY TAG
1.	P3-R6, P3-R8	Escalations to the higher management.	P3-RS8
2.	P3-R7	Focus on the issue by means of regular meetings amongst the various cross functional units.	P3-RS9

Table 25: Internal organizational Risk management activities adopted in “Tooling Packaging & Hoist ” development project.

Table 26. below charts out the different risk management strategies adopted to counter the External Organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITIES	ACTIVITY TAG
1.		Closer contact with the suppliers even in the term of distance.	P3-RS10
2.		Extremely specific instructions needed to be given to the suppliers.	P3-RS11
3.		Clarification with other companies on the past performance of the suppliers.	P3-RS12
4.		Involve the suppliers at the very design phase of the project.	P3-RS7

Table 26: External organizational Risk management activities adopted in “Tooling Packaging & Hoist ” development project.

Influence of Risk Management activities

In this segment the researcher explains how the different risk management activities adopted helped to influence the project outcomes. The researcher analyses how these independent risk management activities have affected these dependant project outcome. The impact made by these independent risk management activities can be defined to be the value added to the project.

At first the researcher studies how the different risk management activities adopted helped to manage the different technological risks in terms of quality, cost and time. The explanations are as follows:

- **P3-RS1:** As the tooling system has numerous subsystems, it was a strategic move to make parallel teams. Teams were formed depending upon the expertise of the team members. This helped to improve the quality of the system as well as the time management of the system.
- **P3-RS2:** Since the design of the tooling and packaging system is completely dependent on the design of the main lithography system, the only way to attain perfection in the design is to rethink and redo the design as per necessities of the main system. This also helped to attain the perfect layout and the space in which the product needs to be accommodated and compressed. The quality and the technical perfections of the system are definitely improved. On the perspective of the time and cost management, initially redesigning the entire system puts the project out of the time schedule and budget. However looking at the project from a futuristic perspective it stops the project from proceeding in a wrong direction.
- **P3-RS3:** Since the tooling system comes into the project at the very last stage the risk of unclarity in the project scope always exists. Strong process management in the form of constant interactions amongst all the functional units and specially the production unit helped to gain clarity in terms of scope of the project. Clarity in the scope of the project helps to attain a better time and quality management of the project.
- **P3-RS4:** Company B followed a strong Failure Mode Effects analysis on the whole product (That is the tooling system being developed). A strong FMEA helps to attain the correct concept design of the system. F.M.E.A helped company B to achieve a stronger technical clarity of the system. It helps to improve the Quality of the product. It also helps to improve the cost and budget management in the sense that it stops the project from proceeding in the wrong direction.
- **P3-RS5:** Making sure of the tools used for manufacturing are certified to be in good condition, made sure that there was no failure of machinery during the assembly and the integration of the entire system. Certification of the tools and machinery ensured that the time and budget of the assembly was maintained as per schedule.
- **P3-RS6:** Risk register was maintained by company B specifically to cater and manage the risks on the project level. The F.M.E.A helped to analyse the risks on the product particularly, and the risks related to the project management was conceived by means of a strong risk register. The risk analysis on a project level helped to attain a better cost and time management for the project.
- **P3-RS7:** Involving the suppliers from the concept design stage would not only help the suppliers attain a better understanding of the technical complexities of the entire system. It would also ensure that they design the subsystems accurately so that the subsystems or the subcomponents are technically compatible to each other and to the entire system. Involving the suppliers from an initial stage helps to improve the technical quality of the entire system and also the time management of the entire project.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P3-RS1	I (+ve)	I (+ve)	I (+ve)
2.	P3-RS2	I (+ve)	D(-ve)/I(+ve)	D(-ve)/I(+ve)
3.	P3-RS3	N	I (+ve)	I (+ve)
4.	P3-RS4	I(+ve)	I(+ve)	I (+ve)
5.	P3-RS6	N	I (+ve)	I (+ve)
6.	P3-RS7	I (+ve)	N	I (+ve)

Table 27: Influence of the technological risk activities on quality, cost, time.

The researcher next explains how the different risk management activities adopted help to manage the different Internal organizational risks in terms of quality, cost and time. The explanations are as follows:

- **P3-RS8:** Company B tackles the risk of inadequate resources and also lack of budgets by means of direct escalations to the higher management. Direct escalations to the higher management helps in the decision making at a much faster and quicker pace. The strategy of making tactical escalations helps to enhance the time management and the cost management of the project. It also helps to arrange the budget or resources to keep the project propel ahead in future.
- **P3-RS9:** The tooling design unit always had a clash with the operational unit since the operational unit was always expecting the tooling development unit to deliver their tooling systems at the earliest not realizing the complexity and drawback of involving them at the very last stage of shipments. The expectations of the operational units could be catered to only by means of regular meetings amongst the cross functional units.

The table below charts out the effect of the different risk management activities on the quality, cost and time of the project.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P3-RS8	N	I (+ve)	I (+ve)
2.	P3-RS9	N	I(+ve)	I(+ve)

Table 28: : Influence of the internal organizational risk activities on quality, cost, time.

The influence of the different risk management activities adopted to manage the different external organizational related risks in terms of quality, cost and time. The explanations are as follows:

- **P3-RS10:** Closer contact with the suppliers even in terms of physical distance helped to ensure stronger communications. Project engineers actually flew down to the destination of the suppliers, to ensure that a face to face interaction would ensure that specifications were shared correctly and also the development of the subsystems took place in accordance to the technical requirements of the main system. Having a closer proximity with the suppliers and the vendors helped to improve the quality of the system as well as the time management of the system. The deputation of engineers increased the budget of the project though.
- **P3-RS11:** Clear streamlined specifications given to the suppliers from company B's end helps to reduce the uncertainty on grounds of technical requirements from the suppliers for the subsystems. This helps to increase the quality of the entire system, as the subsystems are more technically compatible to the main system. The other fact being that clearer and streamlined specifications also increase the suppliers understanding and therefore the time schedule of the entire development.
- **P3-RS12:** Clarifying with the other companies on the past performance of the suppliers helped company B to be sure of their choice of suppliers and vendors for the sub systems and the sub components. It helped company B to have more technically capable suppliers. This risk activity helped in choosing suppliers who would be able to deliver products within the scheduled time, budget and quality.

The table below shows the effect of the risk management activities on the quality, cost and time of the project involved with the development of the tooling system.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P3-RS10	I (+ve)	D(-ve)	I (+ve)
2.	P3-RS11	I(+ve)	N	I(+ve)
3.	P3-RS12	I (+ve)	I (+ve)	I (+ve)

Table 29: Influence of the internal organizational risk activities on quality, cost, time.

4.2.1.3 Risks Management framework followed

Company B follows a formalized risk management framework for the project. B is a structured and well established organization. Company B has a more predetermined, institutionalized, and practiced risk management framework. The two tier risk management activity followed by B, as illustrated in the figure below (risk management on the product and then on the project) helps not only in the quality and the time management of the product or system development but also on the cost and the time management of the system. The risk management tools most commonly used by company b for the project are as follows

- B practiced a vigorous Failure Mode Effects analysis on the technical viability of the tooling system.
- Documentation of all the risks identified in a rigorous risk register.
- Issues related to organizational factors are generally escalated to the higher management.

Figure 21 in the next page illustrates the risk management framework adopted by the company to execute the project.

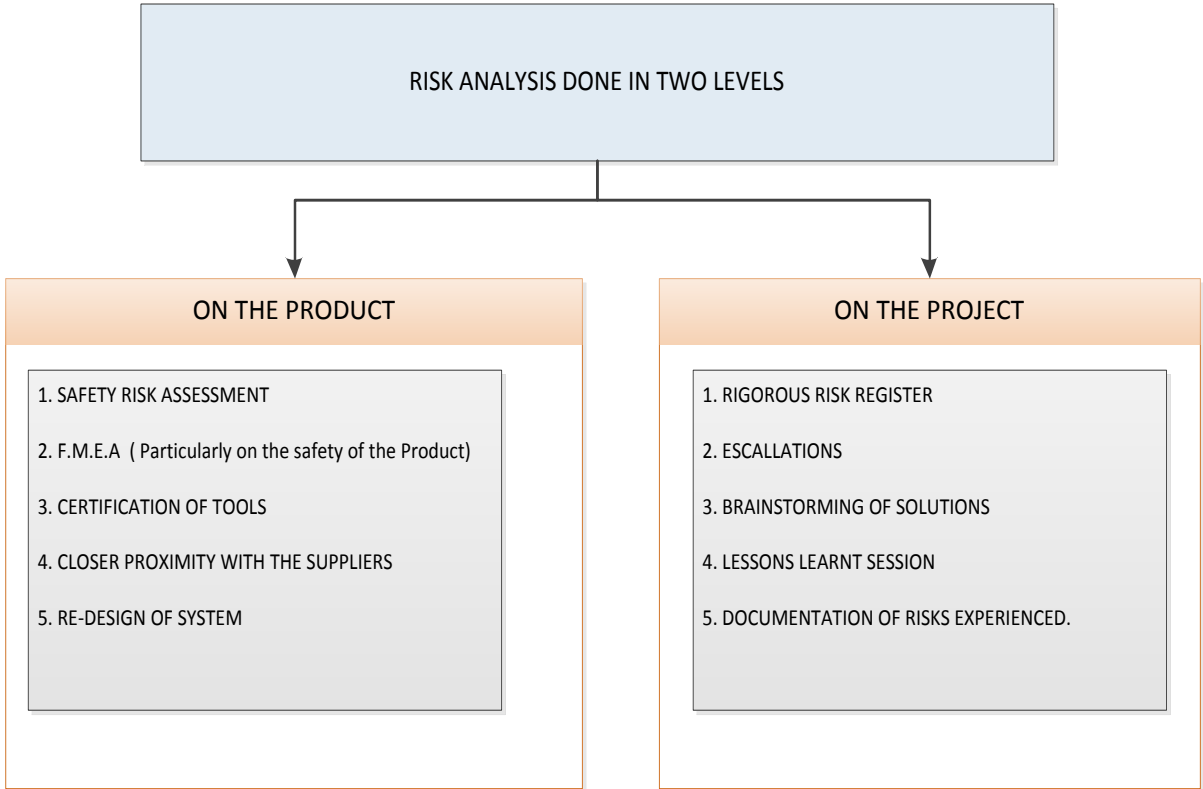


Figure 21: Risk management framework adopted by B for” Tooling, handling & Hoist” development project.

4.2.1.4 Effectiveness of Risk management activities adopted

The tooling and packaging unit deals with the product development of the tools responsible for the safety of the main product. The team cannot proceed without conducting a risk management of the entire system. The risk analysis of the entire system is done on two levels, the product or the system and also on the project. The primary value addition of the risk management activities are as follows :

- The Failure Mode Effects Analysis provides a vivid picture of the technical risks of the system being developed. F.M.E.A along with constant brainstorming and discussions with the other cross functional silos, specially the production unit helped to proceed the project in the right direction on technical grounds.
- The system is primarily developed for logistic purpose; the brand image of the company is at stake to deliver the main lithography systems in the correct shape. Damage of the lithography systems would mean loss of monetary value . Risk analysis gives more of a sense of gut feeling to get on to the road. The risk analysis in the perspective of the project is more of a sense of urgency and assurance. The risk analysis carried out rather gives a futuristic look and it helps to prepare further actions.

The above analysis helped us to realize that there were certain added values which emerged out of the risk management activities on technical grounds, on internal organization structure levels, as well as with suppliers and vendors.

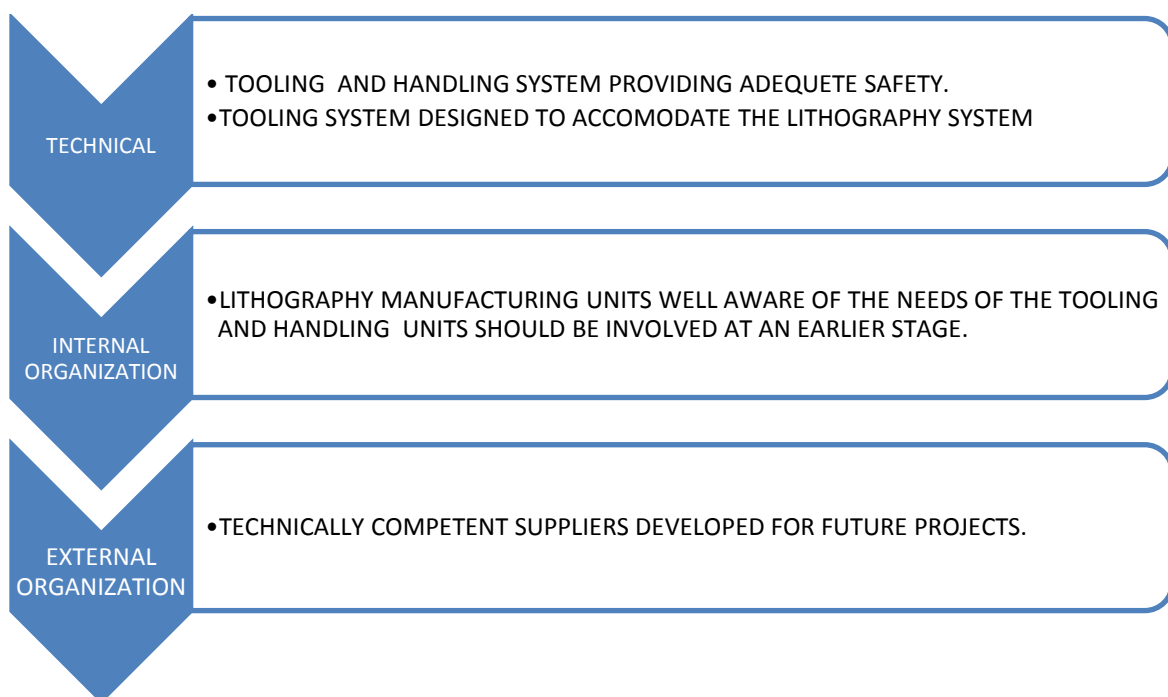


Figure 22: Added value of risk management

4.2.2 QXT 450mm Machine Design (Project description)

Company B aimed to develop a new lithography system. The aim was to design the system in a tenure of one year. The project aimed at an incremental innovation. The project team desired to manufacture a new air mount system for the lithography systems.

Objectives of the Project

The primary objectives of the project were as follows:

- The main focus of the project was on the design and the manufacturing of the air mount of the QXT machine. The scope of the project was rather an incremental innovation for the air mount. The project aimed at large scale production.

- The air mount of the system needed to have a low pass filter having a lower frequency and better isolation for the entire system.

Composition of the Product Development Team

The diagram below illustrates the structure of the product development team. The team was headed by the project lead . The team lead was assisted by the chief design architect.

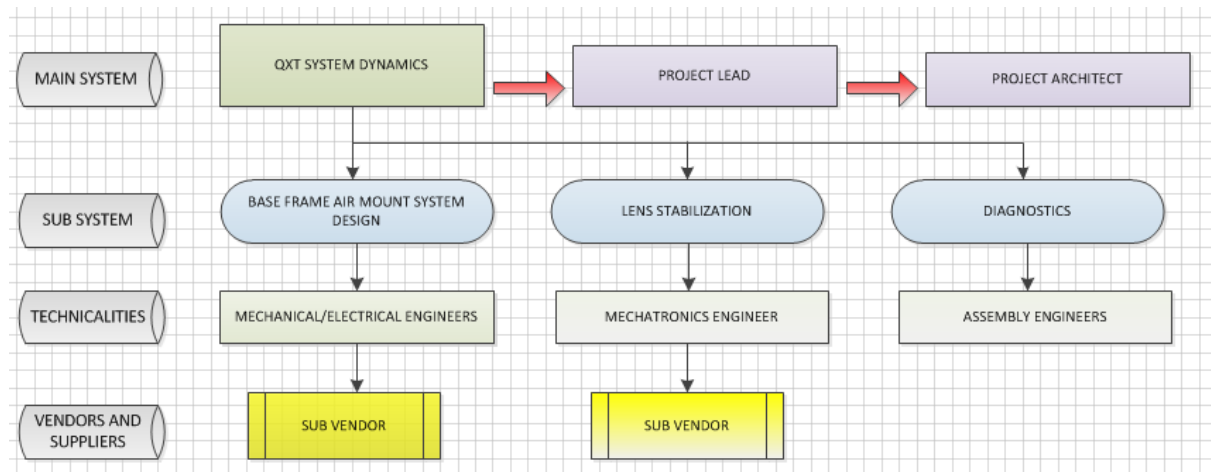


Figure 23: Team Structure for Machine Design project

The functionalities for the project were shared depending on the expertise of the project engineers. The main system was the entire QXT dynamics system. The different subsystems of the complete system were the base frame or the air mount design unit, the lens stabilization unit and the final assembly unit . the assembly unit was responsible for the integration and the diagnostics of the entire system. Mechanical and Electrical engineers were responsible for designing the base frame and the isolation system. Mechatronics engineers were responsible for the lens stabilization units. The suppliers and the vendors played an extremely crucial role in realizing the project. The developers of the air mount systems played an important role in the dynamics of the project.

4.2.2.1 Risks faced in the Machine Design project

The biggest complexity faced in the QXT system design project was the complexities in the interaction with the suppliers. Interfacing and aligning the working procedures of the suppliers in phase with the working procedures of company B was the biggest challenge and risks faced. In the following section we study the technological risks, the external organization related risks, the risks related to the suppliers and the vendors. The risks were identified through the interview conducted on this project with the project lead and the technical architect of the project.

Technological Risks faced

Realizing the complete hardware was the technical challenge. The complete system had numerous subcomponents. Successful interfacing of all the subcomponents was a big risk. The technical adaptability of the subsystems with each other and the main system was always an existing risk. The table 30. below charts out the various technological risks faced in the project. The detailed analysis of the below mentioned risks are explained in the appendix (appn, chp4, 4.4)

S.NO	TECHNOLOGICAL RISKS	TAGS
1.	Risk of interfacing numerous subsystems.	P4-R1
2.	Risk of failing to realize the complexities of the hardware.	P4-R2
3.	Interdependence amongst the different technical units or teams	P4-R3
4.	Risk of falling out of Time schedule and cost budget	P4-R4

Table 30: Technological Risks faced in the Machine Design project.

Internal Organizational Risks faced

Complicated situations and risks arose due to the fact that the management had made prior selection of the suppliers without realizing the knowledge gap of the suppliers. The management had failed to judge the technical competence of the suppliers correctly. The table 31. below illustrates out the different risks faced on grounds of the internal organization. The detailed analysis of the below mentioned risks are explained in the appendix (appn, chp4, 4.4)

S.NO	INTERNAL ORGANIZATIONAL RISKS	TAGS
1.	Simultaneous projects were handled.	P4-R5
2.	Risk of running out of budget	P4-R6
3.	Risk of prior selection of the suppliers	P4-R7

Table 31: : Internal Organizational Risks faced in the Machine Design project

External Organizational Risks faced

Interfacing with the external suppliers and the developers of the air mount system was the biggest challenge for company b in the project. The air mount system developers possessed definite technical skills, technical expertise and experience in design and manufacturing. They lacked a definite process in which the sub system should be developed. The developers viewed the tasks to be more series which meant that the project tended to fall out of the time schedule. Table 32. below charts out the various risks related to the external organization, the suppliers and the vendors. The detailed analysis of the below mentioned risks are explained in the appendix (appn, chp4, 4.4)

S.NO	EXTERNAL ORGANIZATIONAL RISKS	TAGS
1.	Major Cultural differences faced with IDE.	P4-R8
2.	Suppliers lacked project management skills.	P4-R9
3.	Each individual in the supplier end was loaded with different tasks.	P4-R10

Table 32: External Organizational Risks faced in the Machine Design project

4.2.2.2 Risks Management activities adopted (QXT Machine Design project)

The researcher identified the various risks faced in the development of the company B, QXT machine design project. In further conversation with the group lead and the chief architect the various risk management activities adopted to manage the risks faced were adopted. The project group in company B

tried to streamline the air mount system developer’s process of working as much as possible. Considering that the vendor was willing to learn company B tried to align the process of work between the two bodies. The typical process or stage gates followed to realize the prototype was detailed specifications, designs, investigations, concept designs and then detailed designs.

The biggest risk faced in the project was the fact that both the air mount system developer and company B were black boxes to each other. The organizations were unknown to each other’s process of working. In order to achieve a technically feasible prototype, and execute the project within the stipulated project time and budget, intense process management between the developers(vendor) and company B had to be carried out.

Table 33. below charts out the different Risk Management activities adopted to counter the Technological Risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P4-R1	Strong technical discussions and interactions carried out within the inter functional silos.	P4-RS1
2.	P4-R2	Strong Failure Mode Effects analysis is carried out on the product designs.	P4-RS2
3.	P4-R3	Proper Knowledge management by imbibing in knowledge from different bodies.	P4-RS3
4.	P4-R4	Aligning vendor and sub vendor’s process of working in line with organization.	P4-RS4

Table 33: Technological Risk management activities adopted in “ Machine Design project”

Table 34.charts out the different risk management activities adopted to counter the Internal Organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P4-R5	Deputation of dedicated engineers	P4-RS5
2.	P4-R6	Company followed the milestone based payment system.	P4-RS6
3.	P4-R7	Complete technical support and detailed specification.	P4-RS7

Table 34: Internal organizational Risk management activities adopted in “ Machine Design Project”

Table 35. charts out the different risk management strategies adopted to counter the External (Suppliers and Vendors) Organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	P4-R8	Stronger communications with vendors and suppliers	P4-RS8
2.	P4-R9	Company tried to frame the tasks more parallel than series.	P4-RS9
3.	P4-R9/10	A strong risk register was followed.	P4-RS10
4.	P4-R10	.Suppliers and vendors were forced to increase their resources.	P4-RS11

Table 35: External Organizational Risk management activities adopted in “Machine Design Project”

Influence of Risk Management activities

The researcher analyses how the different adopted risk management activities influence the project outcome. The researcher studies how these independent risk management activities have affected the dependant project outcomes in terms of quality, cost and time. The impact made by these independent risk management activities can be defined to be the value added to the project.

At first the researcher studies how the different risk management activities adopted helped to manage the different technological risks in terms of quality, cost and time. The explanations are as follows:

- **P4-RS1:** The risk of interfacing the different subsystems together was countered by means of strong technical discussions amongst all the functional silos and the suppliers. Brainstorming and technical discussions helped to erase doubts on technical grounds. Hence interactions helped to increase the quality, as well as the time management of the system.
- **P4-RS2:** Failure Mode Effects Analysis was carried out on the system designs or after realizing the first steps of concept design. F.M.E.A helped to realize the technical feasibility of the QXT machine. It also showed the possible reasons for failure. An F.M.E.A carried out on the concept design improved the quality of the system. The possible risks were erased out by means of constant repeated re-designs. F.M.E.A and the redesigns helped to put the project out of time schedule and predetermined budgets. Looking at the project futuristically it helped the project from proceeding in a wrong direction.
- **P4-RS3 :** Since the mechatronics department failed to receive adequate amount of technical inputs from the electrical department, proper knowledge management was maintained by means of imbibing knowledge from external sources and bodies. This rather helped to initiate the project further ahead. This increased the project budget.
- **P4-RS4:** Aligning the supplier and vendors process of working by means of stronger process management helped to bring in more structure and project management to the prototype designing phase. This rather helped in improving the time management and the cost management of the project.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P4-RS1	I (+ve)	N	I (+ve)
2.	P4-RS2	I (+ve)	D(-ve)/ I(+ve)	D(-ve)/ I(+ve)
3.	P4-RS3	I (+ve)	D(-ve)	I (+ve)
4.	P4-RS4	N	I (+ve)	I (+ve)

Table 36: Influence of the Technological risk activities on quality, cost, time.

Next the researcher studies how the different risk management activities adopted helped to manage the different Internal organizational risks in terms of quality, cost and time. The explanations are as follows:

- **P4-RS5:** Though there were simultaneous projects being executed, dedicated project engineers ensured that the focus on the project was retained. Dedicated project engineers ensured that the time management of the project was under control.
- **P4-RS6:** Company B fixed up a milestone based payment system for the project. Once Cost estimates were made the specifications and the scope of the project were send to the air mount system developer. Once the air mount system developers made the designs, the deliverables and the designs were reviewed. A strong review was also done on the number of hours spent on the project. Payments were made as per deliverables. This ensured a strong control on the cost management of the project. It was taken care that budget was spent wisely after achieving determined stage gates of project. This also maintained a certain amount of pressure on the

suppliers to ensure that the project deliverables and deadlines were met by providing quality designs. This risk management activity not only ensured a better cost management scheme but it also ensured that the project was executed on time and the designs maintained a certain level of quality.

- **P4-R7:** Technical support from company B to air mount system developers helped the vendor not only to realize the designs faster but it also helped to enhance the quality of the project. At times the designers from air mount developers also came down to carry out the technical drawings with company B.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P4-RS5	N	N	I (+ve)
2.	P4-RS6	I (+ve)	I (+ve)	I (+ve)
3.	P4-RS7	I (+ve)	N	I (+ve)

Table 37: Influence of the Internal Organizational risk activities on quality, cost, time.

The researcher studies how the different risk management activities adopted help to manage the different External Organizational risks in terms of quality, cost and time. The explanations are as follows:

- **P4-R8:** Stronger communications with the air mount system developer helped to create a better understanding within both the organizations. A better understanding helps to propel the project faster. Therefore better time management of the project.
- **P4-R9:** The fact that the air mount system developer lacked proper project management and developmental skills, company B tried to streamline their process of working. Company B tried to frame the tasks rather parallel where tasks were employed depending upon the expertise of the project engineers. This helped to execute the designs faster within the stipulated time period and also have a better cost management.
- **P4-R10:** Since both company B and the air mount system developers were almost like black boxes to each other, B maintained a strong risk register where both the parties and the suppliers documented the risks they perceived. The impact and the possible chances of the risks were also prioritized. Both parties ensured immediate action and updation of the risk list.
- **P4-R11:** The project manager of the air mount system developers had ensured that the team had adequate resources by recruiting more people into their team. The same individual was not burdened with different tasks. This ensured that engineers were allocated tasks as per their technical abilities and the quality of the designs was maintained. It also ensured that the project would proceed in a faster pace and hence a better time management of the project, though more engineers meant that the budget was getting higher. The table below charts out the effects of the different external organizational risk management activities on quality, cost and time.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	P4-RS8	N	N	I (+ve)
2.	P4-RS9	I (+ve)	I (+ve)	I (+ve)
3.	P4-RS10	I (+ve)	D(-ve)	I (+ve)

Table 38: Influence of the External Organizational risk activities on quality, cost, time.

4.2.2.3 Risk Management Framework followed

In the QXT , 450mm machine design process, company B followed a formal risk management framework. They tried to align their working process along with their suppliers and vendors by means of a stronger process management mechanism. Their main aim was to attain a perfect concept design of the

machine. The technical expertise was present but there was strong lack in project management skills from the vendor’s end. Company B tried to reduce the technical risks by means of a strong Failure Mode Effects analysis and have a better control over the project by means of a stronger risk register. The diagram below shows the two step approach to risk management by company B.

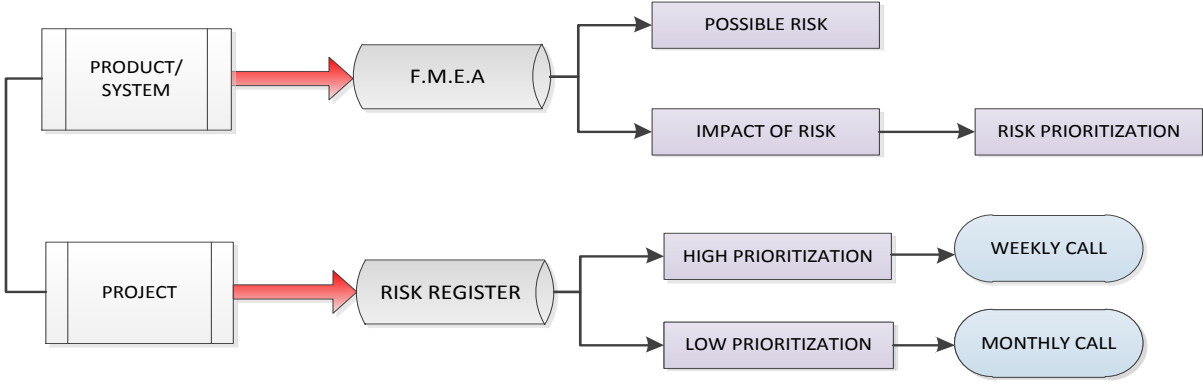


Figure 24: Risk Management Framework followed by company B for “Machine Design Project”.

4.2.2.4 Effectiveness of Risk Management activities adopted.

The risk management activities helped to attain a successful concept diagram of the QXT , machine design system. Repeated redesigns of the system and the interactions with the suppliers and the vendors were extremely complicated. The project was out of time schedule and budget. Strong process management with the suppliers and vendors in terms of constant communications, interactions, technical assistance helped in creating much stronger relations. Company B developed the air mount system developer as a dependable supplier for future projects. The added values of the risk management strategies are charted out in the diagram below.

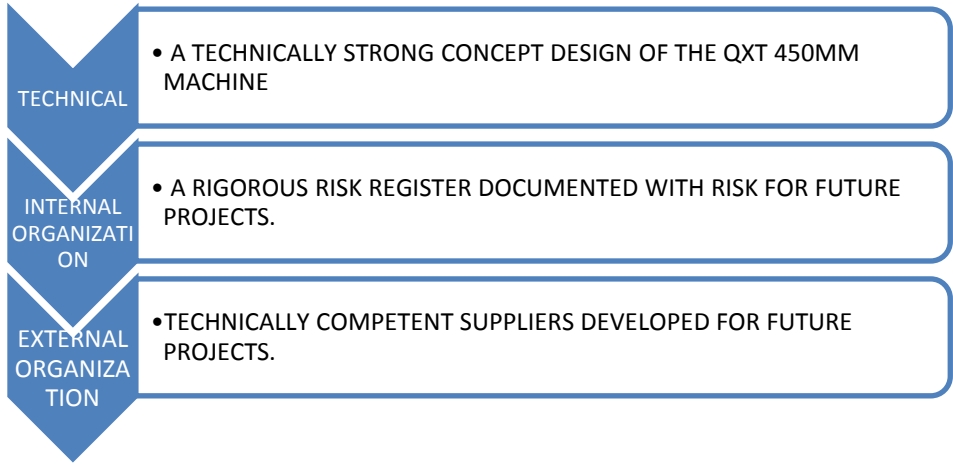


Figure 25: Added value of risk management

4.3 Company C Description

Company C is a global diversified technology and industrial leader serving customers in more than 150 countries. Company C creates quality products, services and solutions to optimize energy, and

operational efficiencies for buildings, lead acid automotive batteries for hybrid and electric vehicles, and interior systems for automobiles. The four main sectors that company C caters to are as follows:

- Building Efficiencies: C is the leading manufacturers of equipment, controls and services for heating, ventilating, air-conditioning, refrigeration and security systems.
- Global Work Place Solutions: C is the leading provider of facilities, corporate real estate and energy management for many of the world's largest companies.
- Power Solutions: C is the leading manufacturers of lead acid batteries and advanced batteries for start and stop, hybrid and electric batteries.
- Automotive Interiors: C is the global leader in the automotive seating, overhead systems, floor consoles, door panels and instrument panels

Reasons why C is an interesting company for the research?

The projects of C that have been studied for the thesis are related to the manufacturing of automotive seating. The following are the main reasons for choosing company C.

- Company C caters to niche clients and OEMs like BMW, Audi, GM motors. The complexities of dealing with high end clients for whom quality is an important aspect, makes C an interesting company to study.
- The organizational chart of company C in the following chapter makes it evident that the final automotive seating system is realized due to the collaboration and co-ordination of number of functional silos. The work is segregated amongst dedicated functional silos as per specializations. The complexities that rise due to the dynamics and interdependencies within the different functional silos are interesting to study.
- The automotive interiors specially the seating arrangements involve complex engineering and manufacturing skills. The niche segment clients always demand for innovative solutions. The risk management activities adopted to meet the expectations of the clients are important from the context of the research.

Objectives of the Project

Since both the projects studied by the researcher have similar dimensions in terms of risks faced and the risk management activities practiced, the researcher has dealt both the projects together. Objectives of both projects undertaken by company C is discussed in the following section:

- The project was executed for OEM, BMW /5 Series, with annual volumes of 258 thousand seats per year. The project started in 2012 and will continue for 5 years till 2016. The project kicked off in 2011 followed by 8 months of development. The project is interesting since JC had different dynamics with the different suppliers for components like metals, trim covers and foam. The system had to be developed from scratch. The main goal was to reduce the weight of the seating framework than a general system weighed. Hence JC came up with an innovative solution to use natural kind of fibre foams to reduce the carbon footprint. The biggest challenge was to come up with an innovative solution to reduce the weight of the system.
- The other project was with client GM motors. The project series was named GM J300. The project was extremely tough since the project had to be realized in three months. The end client demanded an extremely innovative solution with high frequency welding vinyl fabrics. The project was extremely risk prone since the project had time constraints, budget constraints and if company C did not end up having a successful prototype then the development costs were sunk costs.

Since both the projects were related to the automotive seat manufacturing, C faced similar kind of risks for both the projects. C has extremely formalized risk management activities. They had the same product

development team structure for both projects. The case descriptions for the risks faced and the risk management activities adopted for both the projects are the same.

Composition of the Product Development Team

Company C has a general management team headed by the program manager who is responsible for the entire time management and cost management of the project.

The seating systems are realized due to the cross functional collaboration of the different functional teams as shown in the figure 26.. C has a development team which is responsible for conceptualizing the innovative solution for the end clients. They have an inherent engineering team which is responsible for designing the conceptualized ideas. The purchase team is responsible for buying the technically apt subsystems or components for the main system. The purchase team is solely responsible for interacting with the suppliers and the vendors. The manufacturing team is responsible for the assembly and integration of all the subsystems and the subcomponents to realize the main system. The product validation team is responsible for testing the robustness of the system developed. They test if the end system is in line with what the end client or OEM demands.

The project execution is carried out by the different project engineers as mentioned in the third tier of the diagram below. The product engineer is responsible for the product tear down and realizes all the necessary components required for developing the system. The project buyer is responsible for the purchase and procurement of all the components. The manufacturing engineer is responsible for the integration and assembly of the main system. The Quality engineer is responsible for the product validation phase. The diagram below gives a detailed explanation of the hierarchy and the organization structure responsible for the product or system development.

The supplier structure of company C is complicated. At times some of the suppliers are dictated by OEM or the end clients themselves. In that case C has less control on the end clients. If company C has direct interaction with the end clients they tend to have more control. They share the required technical specifications with the end clients. Moreover if the organization feels that they have technical expertise of a subsystem, then they manufacture it in-house. However if they lack the technical expertise of the subsystem then they directly outsource it to the suppliers.

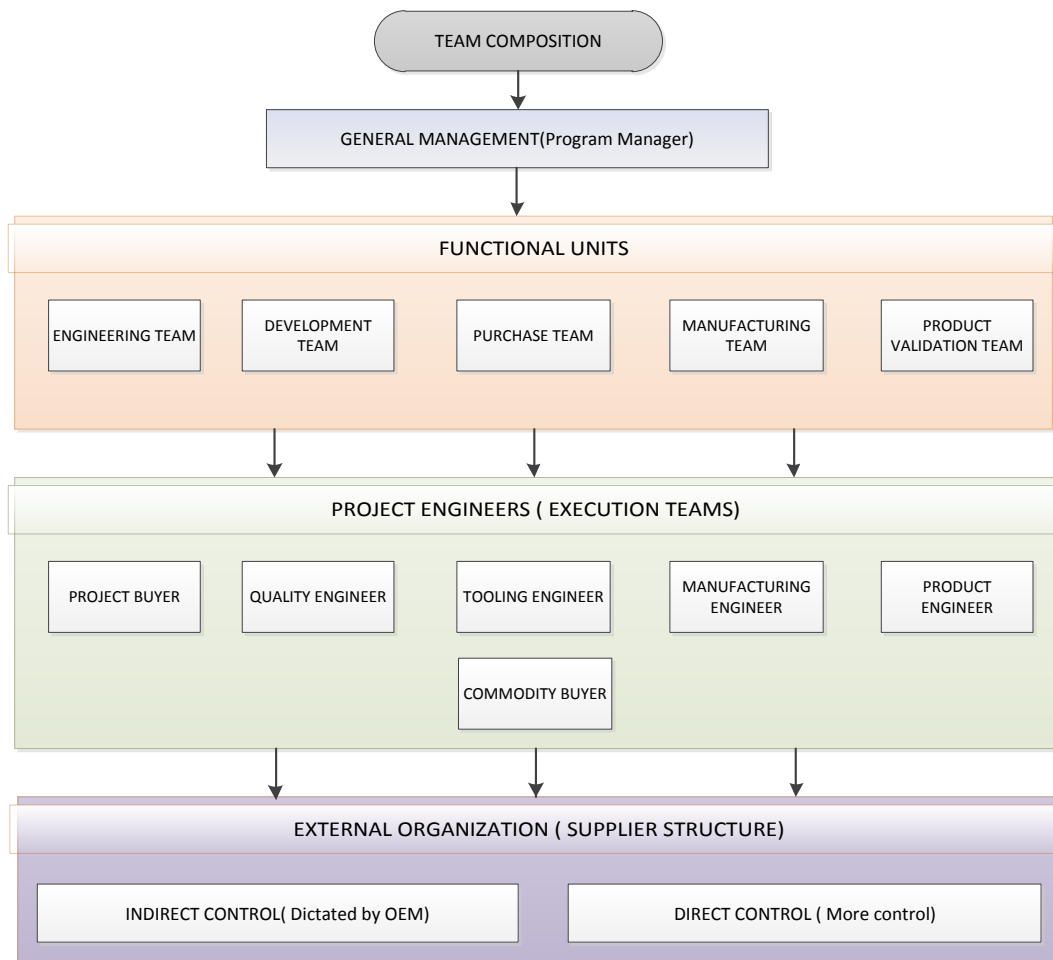


Figure 26: Product development team composition for seat arrangement manufacturing projects.

4.3.1 Risks faced in “Automotive Seat Manufacturing” projects

In the automobile industry, in order to win the project or the tender, the concept design or the solution for the seating arrangement system needs to be submitted to the client. Both projects executed by company C met the complexity of having to present a solution which needed to realize or implement new technologies. The technical development team and the engineering team always faced the risk of not being able to present a solution to the end client meeting their expectations. The researcher identified the risks faced in both the projects by interviewing the project manager and the purchase manager.

Technological Risks faced

At times the product designed by company C needs to be technically adjusted within the space allocated for the car by the OEM. The engineers and the product development team needs to work out the designs accordingly to meet the client needs. This leads to technical complexities and risks. Moreover the client demands solutions which are new to company C. The product development teams need to innovate a probable solution in a concise time frame. Table 39. below charts out the main technological complexities:

S.NO	TECHNOLOGICAL RISKS	TAGS
1.	Risk of realizing a concept design, which does not keep up to client expectations	P5/ P6-R1
2.	Risk of not realizing the engineering drawings or concept designs within stipulated periods.	P5/ P6-R2

3.	Risk of integrating numerous subsystems.	P5/P6-R3
4.	New testing methods can be extremely critical and complex.	P5/P6-R4

Table 39: Technological Risks faced in the “Automotive Seat Manufacturing” projects

Internal Organizational Risks faced

The organization chart of company C explains the fact that the organization structure of company C is extremely complicated. The job functionalities are streamlined and at times too specific. This leads to a certain amount of interdependence on each other to realize the final product. Co-ordinating with too many functional units at times leads to complicacies and causes of risks. Table 40 below charts out the different risks related to internal organization structure.

S.NO	INTERNAL ORGANIZATION RISKS	TAGS
1.	Co-ordinating with too many functional units leads to risks.	P5/P6-R5
2.	Risk of lack of Resources	P5/P6-R6
3.	Risk of exceeding the budget	P5/P6-R7

Table 40: Internal Organizational Risks faced in the “Automotive Seat Manufacturing” projects

External Organizational Risks faced

The supplier structure of company C is complex. The automotive seating system needed numerous components and subsystems. At times the second tier suppliers were dictated by the OEM themselves. This made the scenario tricky since company C did not have complete control over the suppliers apart from commercial terms. Table 41. below charts out the different risks faced on grounds of suppliers and vendors:

S.NO	EXTERNAL ORGANIZATION RISKS	TAGS
1.	The risk of bottlenecks from supplier ends.	P5/P6-R8
2.	At times the second tier suppliers were dictated by the OEM’s themselves	P5/P6-R9
3.	At times the suppliers lacked the technical capability of product realization.	P5/P6-R10

Table 41: External Organizational Risks faced in the “Automotive Seat Manufacturing” projects

4.3.2 Risks Management activities adopted (Automotive Seat Manufacturing projects)

Company C has an organized process management mechanism amongst all the functional units. The different teams generally met up on the starting of the week. The probable risks perceived and identified were discussed. The team decided on the plan of action to be implemented. At the end of the week the project proceedings were discussed again. The various technological risks, internal organizational risks and the external organizational risks were identified on discussions with the Project manager and the purchase manager of the automotive seating units of company C.

Table 42. below charts out the different risk management activities adopted to counter the Technological Risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	R1/R2/R3	Involvement of a subject material technical expert and dedicated engineering team	RS1
2.	R1/R3/R4	Strong discussions, interactions and brainstorming.	RS2
3.	R4	Roots cause analysis was done on the system.	RS3
4.	R1/R2	Failure Mode Effects analysis done on the product, then the process and then the concept design.	RS4

Table 42: Technological Risk management activities adopted by company C.

Table 43. below charts out the different risk management activities adopted to counter the Internal Organization risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	R5	Application of strong ICT software named PLUS & EPIC	RS5
2.	R6/R7	Dedicated team meetings scheduled along the week.	RS6
3.	R5/R6	A dedicated Responsibility Assessment Matrix is used.	RS7
4.	R6/R7	Escalations to the higher management	RS8

Table 43: Internal Organizational Risk management activities adopted by company

Table 44. below charts out the different risk management activities adopted to counter the External (Suppliers and Vendors) Organization related risks:

S.NO	RISK TAG	RISK MANAGEMENT ACTIVITY	ACTIVITY TAG
1.	R8	Buffer time is considered during the planning phase and especially during the front end loading	R9
2.	R9	Sales team directly deals with the suppliers dictated by the OEMs.	R10
3.	R10/R8	A dedicated software(Business Warehouse) consisting of all the details of the suppliers	R11
4.	R10	Suppliers were made to undergo a production part approval process (PPAP)	R12

Table 44: External organizational Risk management activities adopted by company C.

Influence of Risk Management activities

In this segment the researcher analyses how the different risk management activities adopted by company C helped to manage the various risks faced on technological grounds, internal organization structure and the external suppliers and vendors. The researcher studies how the different risk management activities helped to shape the project outcomes in terms of quality, cost and time.

At first the researcher studies how the different risk management activities adopted helped to manage the different technological risks in terms of quality, cost and time. The explanations are as follows:

- **RS1:** The subject material technical experts who work closely with the technical and R&D centre has a better perception of the viability of the concept designs. They have the expertise, to advice if the subsystems and the sub components which are being supplied by the suppliers would be technically adaptable to each other. A subject material technical experts helped company C in the better integration of the entire system. A subject material technical expert helps in the improvement of the quality of the entire system. They even help in realizing the solution faster. Hence better time management. Choosing the correct sub-components helps in aligning the cost management of the system as well.
- **RS2:** The ambiguities in the concept design and engineering was delineated in the project by means of strong process management amongst the entire cross functional units. Interactions, discussions and brainstorming with the technical experts helped to realize if the solution is catering to the needs of the end client. Interactions and discussions had a positive impact on quality, cost and time.
- **RS3:** A strong root cause analysis was done to realize the reasons for the project falling out of schedule and budget on technical grounds. A root cause analysis rather helps in the time and cost management on project management perspectives.
- **RS4:** A Failure Mode Effects(F.M.E.A) analysis was carried out in company C after the testing phase to realize the faults in the engineering. F.M.E.A helped to improve the quality of the concept design on technical grounds. F.M.E.A stops the product realization from proceeding in a wrong direction. Re-designs are the only way to mitigate the faults that arise from a failure mode effects analysis.

The table below charts out the effects of the different risk management strategies on Quality, cost and time:

S.NO	RISK TAG	QUALITY	COST	TIME
1.	RS1	I (+ve)	I (+ve)	I (+ve)
2.	RS2	I (+ve)	I (+ve)	I (+ve)
3.	RS3	N	I (+ve)	I (+ve)
4.	RS4	I (+ve)	D(-ve)/I(+ve)	D(-ve)/I(+ve)

Table 45: Influence of Technological risk management activities on quality, cost and time.

The researcher studies how the different risk management activities adopted helps to manage the different Internal organizational risks in terms of quality, cost and time. The explanations are as follows:

- **RS5:** The product launch System (PLUS) and Enterprise Program Information Collaboration (EPIC) software helped to gain a detailed idea of the various stage gates of the project. The Plus software is a project management tool where all the teams involved in the project has access to data of the project proceeding. The EPIC software aids the cross- functional team to share drawings, cost and data. It stops information asymmetry amongst the entire network. The data exchange amongst the cross functional units are a lot faster. These software primarily helped in the cost management and the time management of the project.
- **RS6:** A stronger process management by means of dedicated team meetings at the beginning of the week, where the agenda and the plan of actions are decided and then later on at the end of the week the results and the outcomes of the actions or the proceeding developments are discussed. This helps in a better understanding of the expectations amongst the cross functional silos. Stronger process management ensures faster project developments, better time and cost management.
- **RS7:** A detailed responsibility assessment matrix was a necessity for company C considering the fact that there are numerous functional silos associated with the product development. The

functionalities of the team were extremely streamlined. A detailed responsibility assessment matrix helped to gain a clear insight on the job segregation of individual teams and persons. A responsibility assessment matrix helped in a better time management of the entire project.

- **RS8:** Escalations to higher management is the fastest means of decision making. Escalations are normally practiced in company C since it is the fastest means of resource management or solutions to man power shortage. Budget is also a resource and in that case the crisis is always escalated to the higher management.

The table below charts out the effects of the different risk management activities on quality, cost and time:

S.NO	RISK TAG	QUALITY	COST	TIME
1.	RS5	N	I (+ve)	I (+ve)
2.	RS6	N	I (+ve)	I (+ve)
3.	RS7	N	I (+ve)	I (+ve)
4.	RS8	N	I (+ve)	I (+ve)

Table 46: Influence of Internal Organizational risk management activities on quality, cost and time.

Next we study how the different risk management strategies adopted help to manage the different External Organization related risks in terms of Quality, cost and time. The explanations are as follows:

- **RS9:** Buffer time was considered during the planning phase and mainly during the front end loading. The suppliers are informed to schedule the delivery date of the subsystems and the components couple of weeks prior to the integration of the main system. This ensured that even if the supplier faced a bottleneck, there was some cushion time in consideration for the suppliers to supply their deliverables. This ensured no delay in the process of manufacturing the seating arrangement system. Therefore a better time management of the project.
- **RS10:** In case the second tier suppliers were handled by the OEM, only the sales team directly dealt with the suppliers. The purchase and the technical department does not interact with the suppliers since they are not responsible on the technical grounds of that particular subsystem. This avoids complexity and the risk of confusion amongst the OEM, company C and the suppliers. This enables a better time and cost management with the suppliers.
- **RS11:** A strong application software (VONTIK) is used where all the company C strategic suppliers are needed to upload their balance sheets twice a year in order to ensure that they are not under financial depts.. This provides a strong visibility of the condition of the suppliers and hence it helps in the decision making process of choosing a particular supplier for the project. This helps in the time management and the cost management of the project.
- **RS12:** All suppliers (OEM directed and company C controlled) are made to undergo a production part approval process. Before going into a series production with the chosen supplier, the supplier is made to perform the Run at Rate production session. During this session the suppliers have to produce a predetermined quantity of the components within a specified time period to confirm the production cycle time. The quality of the subsystems produced during this session is tested if they abide by the specifications. If the suppliers are successful in the production part approval process, they are granted to go to the series phase of the project by company C. If the suppliers are unsuccessful, then the supplier needs to perform the session after time frame of two weeks with all improvements incorporated. This improves the quality of the main system, since the technical quality of the subsystem is already checked. On the other hand it also improves the time management of the project since the suppliers have the ability to supply the required quantities within the lead time.
- **RS13:** A dedicated risk management team is present which is responsible for interacting with the different suppliers and vendors. The risk management team is responsible for analysing if the

suppliers are technically capable enough to cope up with the dynamic needs and innovative solutions from the end client. They are also responsible to ensure that the suppliers have enough cash to withstand the economic downturn. The risk management team helps to select the most adept suppliers. This helps to improve the time management and the cost management of the project.

The table below makes an analysis of the effects of the External Organizational risk management activities on the quality, cost and time of the project.

S.NO	RISK TAG	QUALITY	COST	TIME
1.	RS9	N	I (+ve)	I (+ve)
2.	RS10	N	I (+ve)	I (+ve)
3.	RS11	I (+ve)	I (+ve)	I (+ve)
4.	RS12	I (+ve)	I (+ve)	I (+ve)

Table 47: Influence of External Organizational risk management activities on quality, cost and time.

4.3.3 Risks Management framework followed

Company C has a formalized risk management approach. Considering the complex and fragmented organization structure of C a formalized risk management scheme is quite understandable. Company C a strong use of ICT tools to ensure that they established a strong coordination amongst all the cross functional unit. The PLUS and The EPIC software helps the organization to have a strong time and budget management of the entire project. The diagram below helps to realize that all the cross functional units are aware of each other's responsibilities and the project proceedings through the software. This increases the efficiency of the project execution.

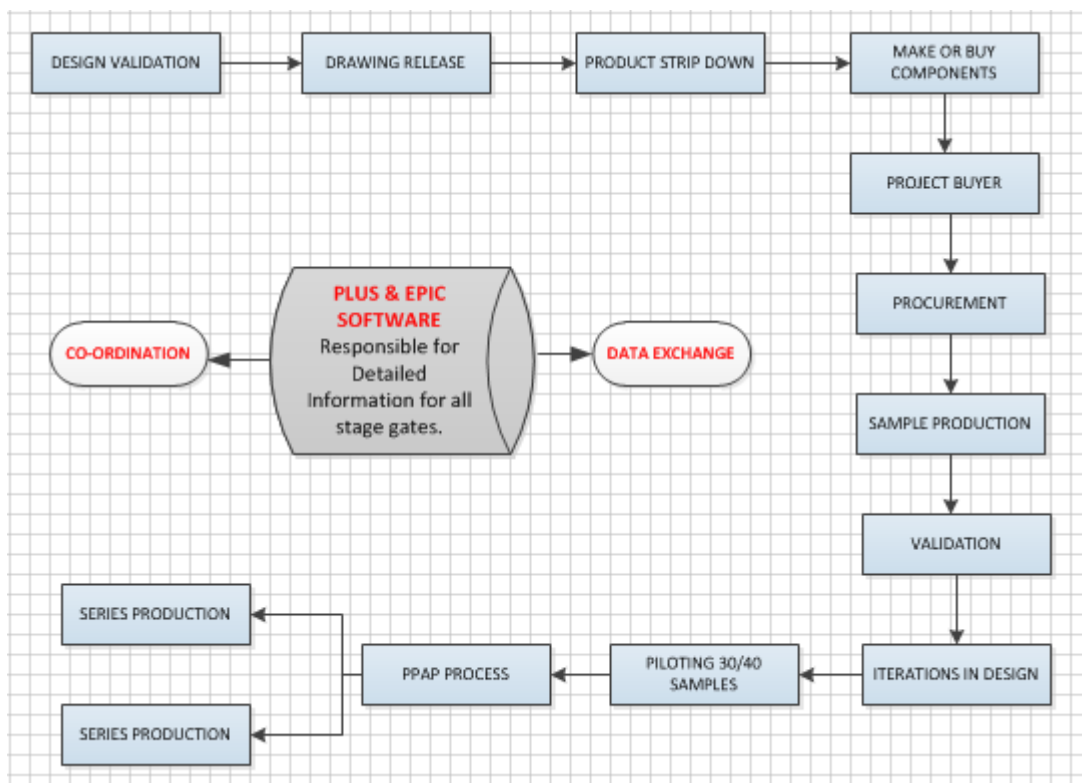


Figure 27: Strong Application of ICT by company C (PLUS and EPIC Software)

The root cause analysis is strongly used which helps company C to recognize the primary reasons for the project to fall out of budget and time schedule. C also uses the Failure Mode Effects analysis to have a strong clarity of the technical feasibility of the concept designs and the seating arrangement system they need to realize. It helps them to analyse if the solution would keep up to the client expectations.

Something worth noticing about company C is their supplier management activities. If C has the power to select their suppliers they deal with the suppliers on technical grounds. If the suppliers are dictated by the OEMs then company C does not get into the technical details of the subsystem with the suppliers. Only the sales team deals with the commercial aspects with the suppliers. Moreover if they realize that company C has the technical expertise of the subsystem, then the subsystem is manufactured in-house. If they realize that they lack the technical expertise then company C sources out the subsystem development to an outside supplier.

The figure 27 in the next page illustrates the risk management activities adopted by company C to manage the suppliers.

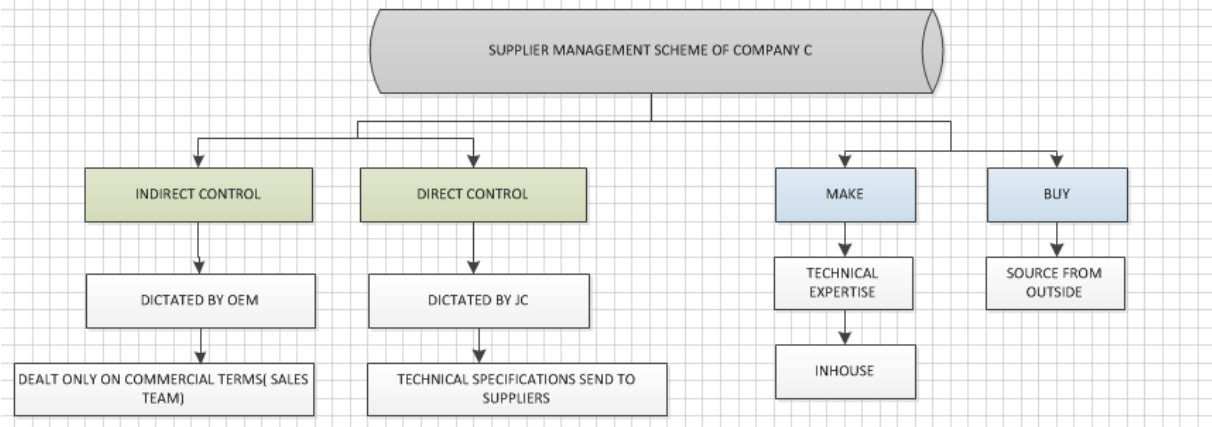


Figure 28: Risk management activities adopted by company C to manage Suppliers

4.3.4 Risks Management framework followed

The risk management activities helped the first project to execute successfully. The critical aspect of producing a seat arrangement system with a lighter metal framework (BMW /5 series project) was achieved successfully. On the contrary the project related to GM J300, they managed to develop the product. However the technological solution of achieving High Frequency welding on the vinyl leather seating was realized with strong support of the research and development unit. The final product could not be realized in Europe. We realize the added value of constantly involving the Research and Development units along with the engineering and the design units to realize the final solution. The fact that there are dedicated functional units, the work and responsibilities are extremely well distributed. Moreover a strong supplier management system has enabled to achieve a master database of suppliers which reveals the past performance of the suppliers and also the technical abilities. Figure 29.below highlights the main added values of the risk management system followed in Johnson Controls.

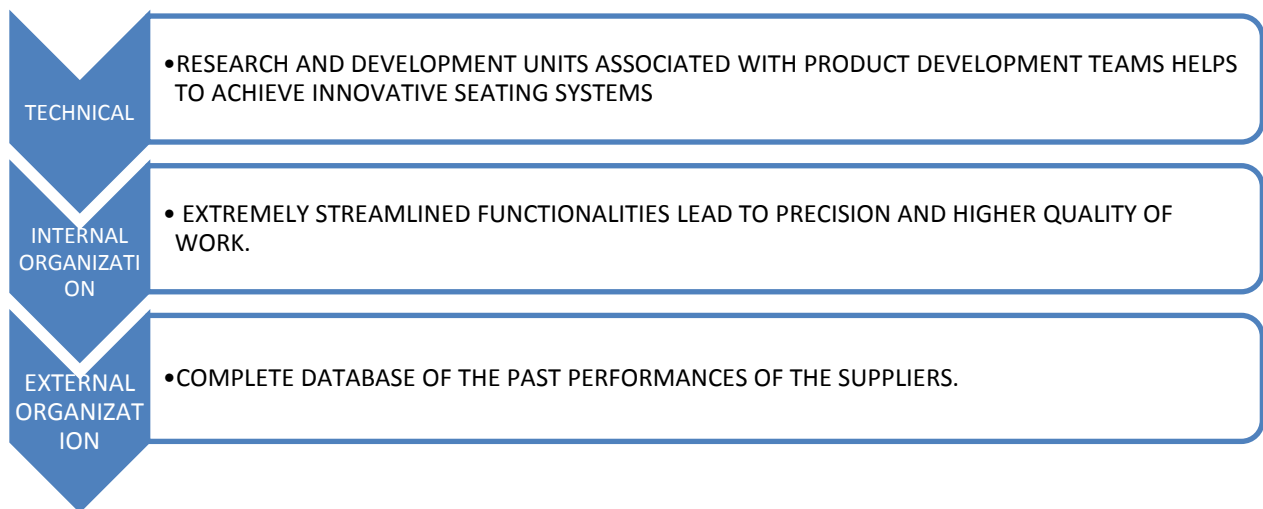


Figure 29: Added values of Risk management activities.

NOTE: KEY POINTS OF CHAPTER 4.

- The structure of the product development team of each of the past executed projects are studied. It is realized that the new system or product is realized due to the culminated efforts of different functional silos.
 - The various risks on technological grounds, the internal organizational complexities and the external organizational risks are identified.
 - The researcher analyses the different risk management activities adopted by the organizations in order to manage the different risks.
 - The researcher makes an analysis if the organization had managed the risks successfully. The added values of the risk management activities are identified. The added values of the risk activities are the effects of the independent risk activities which helps in shaping the project outcome. In the process it is identified if the organization has a formalized risk management framework (more structured) or an informal risk management framework (more inclined towards project management)
-

CROSS CASE ANALYSIS

The previous chapter was dedicated in identifying the various risks faced in the project. The researcher analysed the various risk management activities adopted by the organization to manage the risks on grounds of Technology, Internal Organizational structure, and the External suppliers and vendors. This chapter illustrates the cross case analysis of the past executed projects. A theory of consolidation is used to narrow down to twenty seven risk activities. The consolidated list of risk activities are further broken into three individual sets of Technological risk activities, the Internal organizational risk activities and the External organizational risk activities. The fuzzy data sets are fed into the fsQCA tool to obtain the combinations of the most effective risk activities.

5.1 Consolidated Risk Management Activities :

The cross case analysis has been designed based on the concepts of fuzzy set analysis as discussed in chapter 2. A fuzzy set analysis has a dependent variable which is the outcome. The outcome is dependent or influenced by certain conditions.

In the context of the thesis the different cases which are being tested are the projects of the different organizations which has been discussed. There are six different projects, the Rayscan MK2 project, the Riser Inspection Tool development project, the Tooling, Packaging, Hoist development project and the QXT machine development project, the BMW/5 series and GM J300, automotive interior seating development projects. There are six cases in consideration for the fsQCA application.

The outcome of the projects is being studied on grounds of quality, cost and time management of the project. Quality, cost and time are the dependent variables. The different risk management activities are being studied as the conditions which influence the project outcomes. The risk management activities identified in the different projects have been consolidated to 27 seven risk management activities. The various risk management activities have been constructed, clubbed on grounds of similarity. The different risk management activities recognized from the interviews, if qualitatively judged to have the same dimensions, with different names but they eventually have the same effects and influence, they have been consolidated under the same condition, as a particular risk management activity name. The process of consolidation has been demonstrated in the (Appn, chp5, 5.1). In the cross case analysis the researcher has recognized if the activities manage the Technological risks, or the Internal organizational risks or the External Organizational risks of the suppliers and vendors. The reasons how the activities help to manage Technological risks, Internal organizational and the External Organizational risks has been explained in (Appn, chp 5, 5.2). Table 48. below demonstrates the different risk management activities considered for the fuzzy sets, qualitative, comparative analysis.

TAG	RISK MANAGEMENT ACTIVITY	CONTEXT		
		TECHNOLOGY	INTERNAL ORG.	EXTERNAL ORGANIZATION
RA1.	Interactions and Discussions	TH	IO	EX
RA2.	Closer Supplier Proximity	TH		EX
RA3.	Technical Assistance	TH		EX
RA4.	Re-Evaluation.		IO	
RA5.	Re-Design.	TH	IO	
RA6.	System Testing.	TH	IO	
RA7.	Knowledge Management		IO	
RA8.	Risk Workshops.	TH		
RA9.	Task Specification.		IO	
RA10.	Parallel Activities		IO	
RA11.	Initial Involvement of Suppliers and vendors.	TH		EX
RA12.	Failure Mode Effects Analysis	TH	IO	
RA13.	Technical Expertise	TH	IO	
RA14.	Brainstorming	TH		
RA15.	Escalations		IO	
RA16.	Rigorous Use of a Risk Register	TH	IO	EX
RA17.	Milestone based payment system		IO	
RA18.	A System Architect	TH	IO	
RA19.	Back up Resources		IO	EX
RA20.	Application of ICT		IO	
RA21.	Wider product Application.	TH		
RA22.	Root cause Analysis	TH	IO	
RA23.	Smart delivery planning/ prior delivery of components.			EX
RA24.	Technically competent suppliers	TH		EX
RA25.	Production part Approval Process			EX
RA26.	Supplier Control.			EX
RA27.	Dedicated Risk Management Team			EX

Table 48: 27 Risk management activities obtained from the process of consolidation

TH: TH signifies that the particular risk management activity helps to manage technological risks.

IO: IO signifies that the particular risk management activity helps to manage internal organizational risks.

EX: EX signifies that the particular risk management activity helps to manage the risks related to suppliers and the vendors.

These risk management activities have been applied in the different projects to different extents. Through qualitative judgment we have quantitatively calibrated the extent of application of the different risk management activities for the different projects. The quantitative calibration has been done on a six point ordinal scale of (0, 0.2, 0.4, 0.6, 0.8,1). 0 signifies full non membership of that particular case(the project) for that particular condition(the risk management activity). On the contrary, 1 signifies complete membership. The gradation signifies the strength of usage or the extent of application of the risk management activity. The fuzzy data set created is added to the appendix (Appn, chp5, 5.3) for the reference. Three different fuzzy data sets have been created to analyze the most necessary and commonly used risk management activities on grounds of Technological risks, Internal organizational risks and the External Organizational Risks related to suppliers and vendors..

The quantitative calibration of the individual risk management activities signifies the specific extent of application of the activity for the project as well as how relatively has the risk management activity been applied in the project in comparison to the other projects. The dependent outcome of the

project in terms of quality, cost and time have also been calibrated. The calibration of quality, cost and time signifies how successful has the project been on grounds of quality management, cost management and time management. The fsQCA tool analyses the causal relation of the different risk management activities with respect to the dependent project outcomes to establish which are the most important risk management activities to manage technological risks, internal organizational risks, and external organizational risks related to the suppliers and vendors.

5.2 Technological Risk Management Activity (fuzzy data set)

Technological risk management activities are primarily aimed to negate and manage the risks that emerge due to the complexities and risks of the technology, the risks related to the technical adaptability of the subsystems, the difficulties faced in the process of integration, assembly and testing of the entire system.

The risk management activities that help to manage risks on technical grounds have been identified from amongst the 27 risk activities identified in the consolidated list of risk activities (Table:33) The reasons why they are chosen as an input for the fuzzy data set is mentioned in (appendix 11). The table below shows dedicatedly the risk management activities identified to manage technological risks. The dependant quality, cost and time of the cases(the projects) has been quantitatively calibrated by means of qualitative judgement. The relative and specific extent of application of the technological risk management activities in the different project cases has been charted out in the appendix (Appn, chp5, 5.4)) by means of quantitative calibration. Table 49. below charts out all the identified technological risk management activities , which acts as input conditions for fsQCA.

RISK TAG	RISK MANAGEMENT ACTIVITY
RA1	Interactions and Discussions.
RA2.	Closer supplier proximity
RA3.	Technical Assistances
RA5.	Technical Re-design
RA6.	System testing of the subsystem as well as subsystems.
RA11.	Initial involvement of suppliers and vendors.
RA12	Failure mode effects analysis after achieving the concept design.
RA13.	Technical expertise of the project team members.
RA14.	Brainstorming amongst technical experts.
RA16.	Rigorous use of a risk register.
RA18.	Involvement of a system architect for the entire assembly of the system.
RA21.	Wider application of the product or the technology.
RA22.	Application of Root cause analysis on the product and system level as well as the project.
RA24.	Choose technically competent suppliers.

Table 49: Input conditions for Technological Risk Management Activity (fuzzy data set)

5.3 Internal Organizational Risk Management Activity (fuzzy data set)

Internal organizational risk management activities are primarily aimed to negate the risks and the complexities that are born out of clashes between the board of management and the project execution group. These risk management activities are also aimed to manage the complexities that arise due to

interactions, lack of co-ordination and dependencies amongst the various functional units within the organization.

The risk management activities that help to manage risks on internal organizational grounds have been identified from amongst all the 27 risks activities mentioned in the consolidated list of risk activities (Table:33) . The reasons why they are chosen as an input for the fuzzy data set is mentioned in appendix (Appn, chp5, 5.2). The table below shows dedicatedly the risk management activities identified to manage internal organizational risks. The dependant quality management, cost management and time management of the cases(the projects) have been quantitatively calibrated by means of qualitative judgement. The relative and specific extent of application of the internal organizational risk management activities in the different project cases has been charted out in appendix (Appn, chp5, 5.4) by means of quantitative calibration. Table 50. below charts out all the identified internal organizational risk management activities , which acts as input conditions for fsQCA.

RISK TAG	RISK MANAGEMENT ACTIVITY
RA1	Interactions and Discussions.
RA4.	Re- evaluation of the project critical path.
RA5.	Concept redesign with all the involved functional units.
RA6.	System testing of the subsystem as well as subsystems.
RA7.	Knowledge management of the team
RA9.	Task specification amongst functional units and the team.
RA10	Parallel activities within the project group.
RA13.	Technical expertise of the project members.
RA15.	Escalations to the higher management.
RA16.	Rigorous use of a risk register.
RA17.	Milestone based payment system.
RA19.	Make sure that there is availability of back up resources.
RA20.	Make stronger use of ICT within the organization.
RA21.	Apply Root cause analysis on a project level.

Table 50: Input conditions for Internal Organizational Risk Management Activity (fuzzy data set)

5.4 External Organizational Risk Management Activity (fuzzy data set)

External organizational risk management activities are aimed to negate the risks that might arise due to the selection of not the most appropriate suppliers for the projects. The risk management activities help to choose suppliers that are technically competent. The suppliers may be new to the technology. The activities take care that their past executed projects with other companies are scrutinized. The primary aim of these risk management activities are to identify and choose suppliers who are technically competent, as well as suppliers who are capable to adapt to the dynamic needs of the clients as well as withstand economic downturns.

The risk management activities that help to manage risks on external organizational grounds have been identified from amongst all the 27 risks management activities mentioned in the consolidated list of risk activities (Table:33) . The reasons why they are chosen as an input for the fuzzy data set is mentioned in appendix (Appn,chp5,5.2). The dependant quality management, cost management and time management of the cases(the projects) have been quantitatively calibrated by means of qualitative judgement. The relative and specific extent of application of the external organizational risk management activities in the different project cases has been charted out (Appn,chp5,5.4) by means of quantitative calibration. Table (51) below charts out all the identified external organizational risk management activities, which acts as input conditions for fsQCA.

RISK TAG	RISK MANAGEMENT ACTIVITY
RA1.	Interactions and Discussions.
RA2.	Closer supplier proximity
RA3.	Technical assistance provided to the suppliers by the organization.
RA11	Initial involvement of suppliers and vendors.
RA16.	Rigorous use of a risk registers.
RA19.	Use of back up resources from other projects.
RA23.	Smart delivery planning and prior delivery of components.
RA24.	Technical competence of the suppliers.
RA25.	Product part approval process- Run at rate test.
RA26.	Supplier Control (Governance over the supplier)
RA27.	Dedicated risk management team(creation of a database of all suppliers, financial statements of suppliers, performance of past executed projects.)

Table 51: : Input conditions for External Organizational Risk Management Activity (fuzzy data set)

5.5 Results of fsQCA & Qualitative analysis

The fuzzy sets Qualitative Comparative analysis helps us to analyse the combination of risk management activities which have the maximum consistency and coverage for the desired outcome of the project in terms of quality, cost and time. We can conclude that if a combination of the risk management activities are consistent amongst all the projects and they also have the maximum coverage they are the most sufficient and necessary risk activities for the desired outcome.

The results from fsQCA identifies the most sufficient and commonly used risk management activities. The effectiveness of these risk management activities is realized if they are backed and support by other risk activities which can be stated by the qualitative judgement of the cases described in the previous chapters. The quantitative results of the fsQCA helps define the most sufficient conditions or risk activities whereas the qualitative judgement paves the route for the success of these risk activities. In the next segment the researcher builds up the models for the technological risk management activity, the internal organizational risk management activity and the external organizational risk management activity.

5.5.1 Technological Risk Management activity model:

The data set created for technological risk management activity (Appendix 2) was fed into the fsQCA tool. Since the number of conditions were high in ratio to the number of cases(Number of Cases 6, and Number of Conditions 15), the first level of fsQCA fetched the most complex solution of the combinations of risk activities.(Appendix 13) The combinations of risk management activities are elaborated in the (Appendix13). This ended in a rather broad scope of risk management activities from which strong conclusions could not be attained. Expert interviews were conducted with manufacturing organizations to arrive at the four most important Technological Risk Management activities affecting quality, cost, time. The table below charts out the most important factors as per expert interviews. These identified conditions were fed into the fsQCA tool for the second level of analysis.

TECHNOLOGICAL RISK MANAGEMENT ACTIVITIES	
Quality	Interactions, Re-design, F.M.E.A, Root cause Analysis
Cost	Interactions, Re-design, System testing, System Architect
Time	Initial, Involvement of Suppliers, Risk register, Closer Supplier Proximity, technical Assistance.

Table 52: Conditions Chosen on Expert Interview.

The results of the fsQCA (Appn, chp5, 5.5) help us make the following conclusions:

- The combination of intensive Interactions along with Re-Designing has the maximum consistency and coverage to enhance quality in terms of technological risk management activities. Redesigns are further backed and supplemented by means of F.M.E.A and Root Cause analysis.
- The combination of intensive Interactions along with Re-Designing has the maximum consistency and coverage to enhance Cost management in terms of technological risk management activities. Redesign is further backed by means of strong system testing of the system.
- The combination of a rigorous Risk Register followed in the organization along with Initial involvement of suppliers and vendors are necessary in terms of time management of the project. Time management of the product development is further managed by means of providing technical assistance to the suppliers.

The process of making the above deductions are shown in the fsQCA results (set and subset analysis. (Appn,chp5,5.5)The diagram below illustrates the model proposed by fsQCA for Technological Risk management activities to improve the Quality of the product or the system, the cost management of the project and the time management of the project.

Quality of a product relies completely on how sound and correct is the product on technological grounds. The risks of realizing product which has technical deficiencies can be evaded by means of re-designs and re-doing the engineering. Though Re-designs tend to put the project out of time schedule and the cost budget, futuristically looking, it stops the development of a faulty product. Root cause analysis and a strong F.M.E.A help to realize the faults in the concept designs and the engineering. These tools help to realize the corrections which need to be implemented in the concept designs. Re-designs also help in the cost management of the project since realizing a technically faulty product would prove to have complete sunk costs of the entire budget. System testing at the subsystem level and the complete system helps to realize if the product being developed is able to achieve the desired objective and scope of the project. In order to propel the development of the product on technical grounds it is important that the suppliers and the vendors are involved at an early stage of the project. This helps the suppliers to realize the technical complexity of the project. The suppliers are able to conceptualize the technical adaptability of the subsystems better incoherence with the main system. Certain amount of technical assistance rendered to the suppliers from the main organization helps to resolve technical complexities of the subcomponents and finally the assembly of the main system.

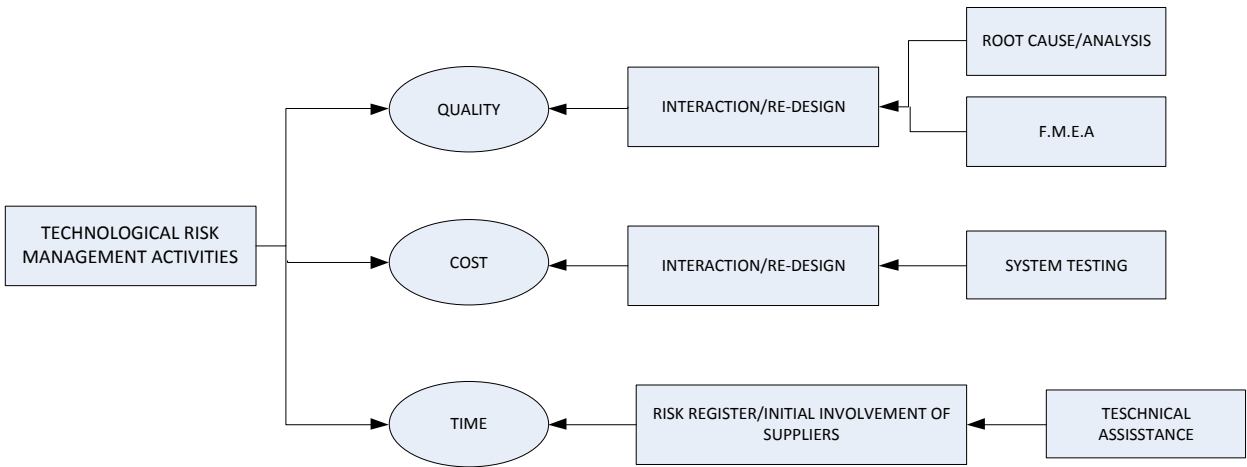


Figure 30: Most important risk activities for Technological Risks. (Results fsQCA)

The above figure illustrates the technological risk management activities as obtained from the fsQCA results. The figure below illustrates the combined technological risk activity model which brings together the Quantitative results of fsQCA as well as the Qualitative judgement of the cases. The circle of the diagram depicts the periphery, where the activities within the circle are the primary risk management activities as obtained from fsQCA, while the risk activities outside the boundary (qualitative judgment of the cases) are supplementing and helping to make the most sufficient and necessary risk activities, effective.

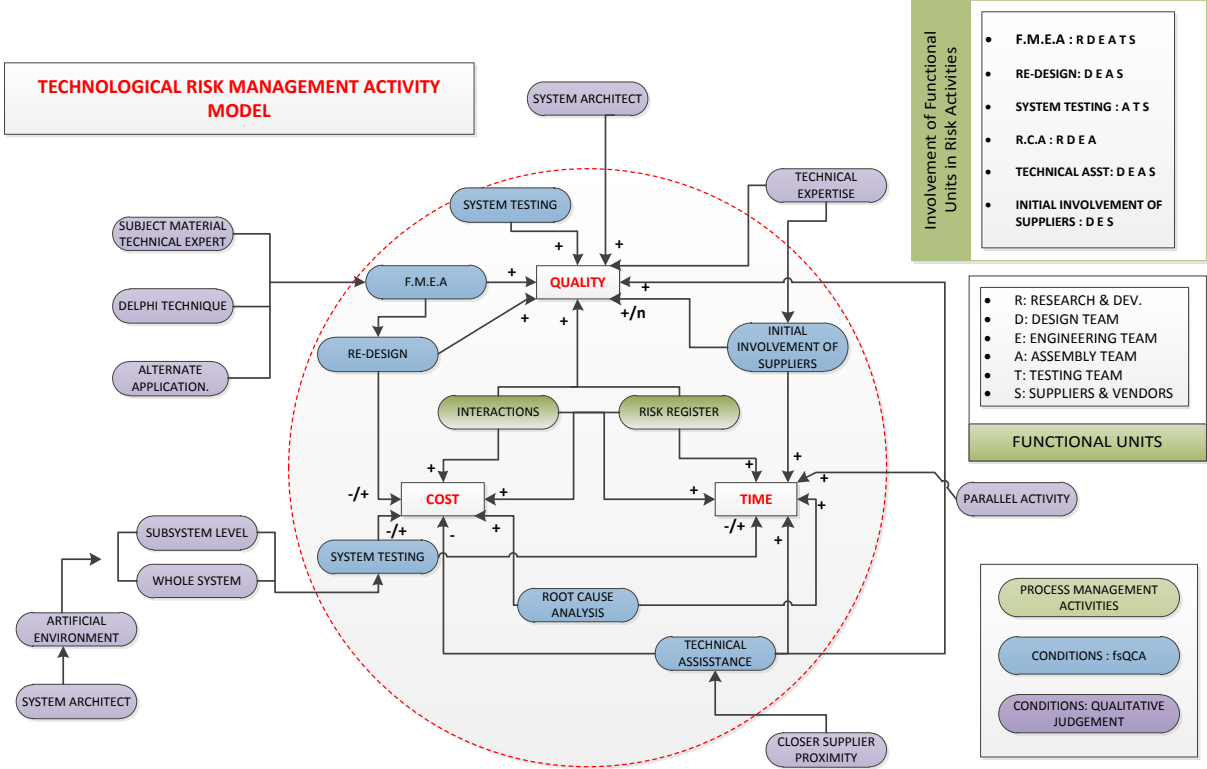


Figure 31: Illustration of the Technological Risk activity Model, a combination of the Quantitative and Qualitative judgment.

The most common application of process management in terms of interactions and discussions always has a positive effect on quality, cost and time. Interactions help to improve quality since brainstorming amongst all the necessary actors of the project helps to find the most optimized, simplest and effective solution. In terms of urgency, interactions helps to find the fastest solution. The most optimized solution also enables a better cost management of the project. In the process of explaining the model, the research tries to relate back to the cases (projects), described in the previous chapter:

- Constant team meetings, keeping the client constantly updated on proceedings, brainstorming amongst technical experts helps the project to propel in the right direction. In the Riser inspection tool development project of company A, since the main solution involved the combination of complicated theories, interactions and discussions were the primary risk management activities to narrow down to the simplest and optimized solution. The more complicated the structure of the organization as found in company B and C, interactions and discussions were mandatory amongst all cross functional units. In C a strong process management approach was followed were the teams met at the beginning of the week, to discuss and identify the probable risks, decide on the plan of actions and they again met at the end of the week to discuss on the progress. Risk workshops also help to interface all the actors involved in the project on technical grounds as well as project grounds.

The other most important process management to manage risks is the documentation process in terms of an extensive risk register. It was interesting to study that B used the risk register most extensively as well as effectively.

- As seen in the QXT machine development project the risk register should be used as a documentation process, which allows both the parties, the parent company, the suppliers as well as the end client to know each other better. It should provide a provision for all the parties to document the risk they identify. Depending on the common consensus of all parties the most important and highly prioritized risks should be dealt on a weekly schedule and the low priority risks should be dealt on a monthly duration.

The researcher follows the discussion by analyzing the technological risk management activities which influence Quality of the system

DISCUSSION TECHNOLOGICAL RISK ACTIVITIES - QUALITY

We have already discussed that redesigns help to achieve a correct concept design which is one of the important stage gates of the product development process. The Failure Mode Effects analysis and the Root cause analysis on the concept design helps to realize the changes that should be incorporated to redesign the concept design. Rigorous system testing helps to realize if the desired features and functionalities of the product is successfully realized. Inclusion of a system architect ensures smoother integration and assembly of all the subsystems to realize the final product. Involving the suppliers and the vendors at the initial design stage helps the suppliers realize the complexity of the technology and the project. The Qualitative judgment further shows how a successful re-design, would propel the concept design in the right track, rigorous system testing would ensure the proper functioning of the system.

- As studied in company C a subject material technical expert whose expertise lies in stripping down the product into their specific technical sub-systems and components should be effectively used in the F.M.E.A to judge if the designs of the individual subsystems are technically correct. This would lead to the design of the subsystems in the correct direction. The extensive use of Delphi technique as studied in most of the cases , makes use of the judgment of the experts to point out the faults and the changes that needs to be incorporated to develop a concept design which realizes the conceptualized idea. As seen in the Riser development project (case2), the experts should propose for alternate and possible applications of the concepts which help to develop appropriate concept designs for different applications. A wider application of the product makes the client more interested and convinced on the project. F.M.E.A and re-design is more effective when all the functional units, the R&D, the design and the engineering team, the assembly and the testing team get together to identify the shortcomings and the fallacies of the concept design. The experiences of the individual functional unit members are crucial for the development of the right concept design.
- As seen in the projects definite subsystem and complete system testing should be carried out at each stage gate of the product development. This ensures that the system is being progressively developed in the right direction. Moreover it is important to test the system in artificial environment in which the product has to originally function. It helps to test the robustness of the product in extreme environmental conditions. Involvement of a system architect who is specialized in the system integration is extremely beneficial. It is advisable that the organization has dedicated assembly and testing units. The suppliers should also be involved in the assembly and the testing stage gate, since they are the best trouble shooters for the technical complexities of the subsystems.
- In most of the cases in the organizations it is realized that the final quality of the system being developed is improved if the suppliers are involved in the initial design stage of the product. Since the technical precision and complexity of the subsystems are high it is important that the parent

company provides complete technical support to the suppliers. Deputation of a dedicated project engineers at the client end or vice versa ensure that the subsystem is being developed as per the technical requirement of the system. Closer supplier proximity ensures correctness of the subsystem being developed.

The above discussed risk activities primarily helps to improve the quality of the system being developed, be it the technical precision or adaptability of the individual system with the main system, correct development of the concept design, or proper functioning of the complete system ensuring that the desired functionalities are achieved. Table 53, below charts out the added value or the effectiveness of the risk management activities which help to improve the quality of the system on technological grounds.

TECHNOLOGICAL RISK MANAGEMENT ACTIVITY (QUALITY)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1. F.M.E.A	1. Helps to find faults in concept designs. 2. Helps in re-designing the concept design.
2. Re-design	1. Helps to attain perfection in concept design. 2. Helps to achieve alternate solutions.
3. System Testing	1. Helps to realize the proper functioning of the system and the sub-system.
4. Initial involvement of suppliers.	1. Suppliers realize the complexity of the technology. 2. Ensures correctness and the technical adaptability of the subsystem.
5. Technical Assurances	1. Helps suppliers realize the specific technical requirements and scope. 2. Ensures correctness and technical adaptability of the system.

Table 53: Added value of Technological Risk management activity model on Quality

Next the researcher discusses of the Technological risk management activities which influences the cost management of the project:

DISCUSSION TECHNOLOGICAL RISK ACTIVITIES – COST MANAGEMENT

The technological risk management activities primarily influence the technical quality of the product. The effects of the risk management activities either have positive or negative effect on the cost management of the project. The following discussion analyzes how system testing, redesign, root cause analysis and technical expertise helps in the cost management of the project.

- In the projects analysed we realize that system testing, redesign initially has a negative effect on the budget of the project. Certain steps having to be redone mean that there is an extra cost incurred on the project budget. Especially redesigning and carrying out system tests in artificial environment is costly. This stops the system being developed with defects and faults. It ensures that the desired functionalities of the system is being achieved. Looking futuristically they have a positive effect on the cost management since it avoids sunk costs of realizing a faulty system at the end of the project.
- The case studies reveal that root cause analysis should be used on two levels, the product level as well as the project level. This is a similarity of application found between the literature and the industry. Root cause strongly helps in the cost management since it perceives the faults due to the environmental conditions, the materials used, the tools and tackles being used as well as the technical method applied to the project.
- In all the project cases especially for company A, as well as for company C the technical complexity is so high that technical assistance to the suppliers is mandatory. Technical assistance as seen in the MK2 Rayscan project as well as the tooling and handling project is achieved by

closer supplier proximity. This is achieved either by deputing a project engineer at the supplier end or inviting the supplier engineers at the organization leads to excess budget for the project. This leads to the excess budget of the project since creating a smooth process of execution between the supplier and the main organization is essential

Table 54, below charts out the added value and the effectiveness of the technological risk management activities on the cost management of the project.

TECHNOLOGICAL RISK MANAGEMENT ACTIVITY (COST)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1. System Testing	1. System tests specially in an artificial environment has an added cost budget but helps in the realization of a technically correct system.
2. Re-design	1. Re-design has an added cost budget but helps in the realization of a technically correct system.
3. Root cause Analysis	1. Root cause analysis helps in cost management by identifying the faults and selecting the correct materials and the tools, tackles and machinery.
4. Technical Assistances	1. Technical assistance also increases the cost management of the project, but it is important to ensure a technically correct subsystems to be developed.

Table 54: Added value of Technological Risk management activity model on Cost

The above analysis suggests that in order to ensure and enhance the technical quality of the system, it is very difficult to stick to the budget of the project. As studied in the cases maximum budget is planned for the executional stages of the project.

The researcher follows the discussion by analyzing the Technological risk activity which influences the time management of the project.

DISCUSSION TECHNOLOGICAL RISK ACTIVITIES – TIME MANAGEMENT

The technical risk management activities help to propel the process of design, engineering and development at a much faster pace. Delay of the development of the products occur due to the incapability of the suppliers to develop the subcomponents, or inability of the project engineers to design the conceptualized idea, or failure of the suppliers to deliver their components within the scheduled lead time. The following discussion analyses how technical assistance, initial involvement of the suppliers and parallel activities helps in a better time management of the project.

- As studied in the cases we realize that technical assistance by deputing a project engineer at the supplier end or vice versa initiates a better understanding of mutual requirements of the subsystem and the main system at a much faster pace. On technical grounds it brings about clarity at a much faster pace. The concept design and the product development propels at a faster speed.
- In the Riser Tool development project it is realized that the fact that the suppliers were involved at the very initial stage of the project helped the suppliers constantly adapt to the dynamic changes in the technical scope of the project. It also helps the subsystems to be redesigned and developed accordingly to the stipulated time period.
- In the MK2 Rayscan project the design as well as development and testing was done in parallel. If the time is a major constraint then parallel activities should be adopted. The risk of compromising the quality arises. Moreover the activities should be parallel carried out considering that there are dedicated functional units who are experts in their dedicated domains of either engineering, design, assembly or manufacturing.

Table 55, below charts out the added value and effectiveness of the technological risk management activities on the time management of the project.

TECHNOLOGICAL RISK MANAGEMENT ACTIVITY (TIME)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1. Technical assistance	1. Helps the supplier realize the technical requirements of the subsystem. 2. Speeds up the process of the subsystem development.
2. Initial Involvement of the Supplier.	1. The supplier adapts to the technical complexities of the system. 2. It gives the supplier the space and time to adapt to the dynamic changes in the needs of the client.
3. Parallel activity of the project.	1. Dedicated functional units perform parallel activities to speed up the process of system development.

Table 55: Added value of Technological Risk management activity model on Time

TECHNOLOGICAL SCENARIOS:

The study of the cases helps us to analyze that there are certain scenarios which can be visualized on the perspective of the technological aspects. There are three main technical scenarios, the technical complexity of the system or the product, the technical expertise of the project group, and the supplier expertise. We further elaborate on the technical scenarios.

- The technical complexity depends whether the system or the product to be realized is of incremental innovation or radical innovation. The complexity of the incremental and radical innovation further depends on the number of subsystems involved in the project.
- The technical expertise of the project group helps us visualize the scenario of an inexperienced project group and an experienced project group.
- Finally the expertise of the suppliers chosen helps us identify the final scenario of new suppliers and old suppliers.

The experience of the project group and the suppliers are also dependent on how new or radical the technology of the new product to be developed is. It depends if the project group and the suppliers have been exposed to such a product earlier on.

The diagram below charts out the essential scenarios on the technological aspects.

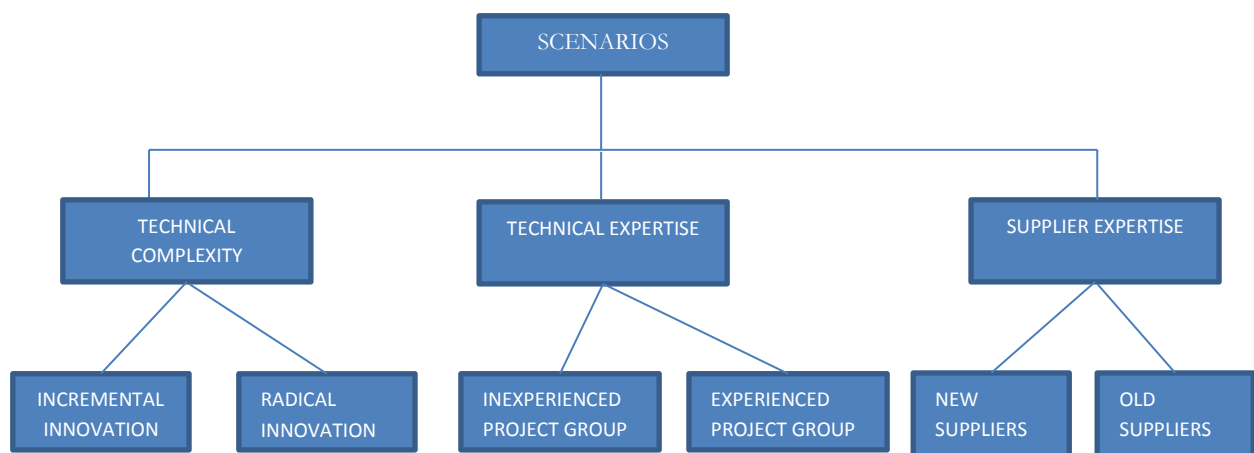


Figure 32: Scenarios on technological aspects.

The technological risk activities discussed above are best applicable in some of these scenarios. The table below charts out the Risk activities and the scenarios they are best applicable in

RISK ACTIVITY	SCENARIO
1. F.M.E.A	Applicable under all scenarios.
2. Re-design	All scenarios, but effective when the project aims at a radicle innovation
3. Initial Involvement of Suppliers.	Most effective when the project aims at radical innovation, suppliers are new, and the group is inexperienced.
4. Technical Assistance	Most effective when the suppliers are new (especially if the technical complexity is new to the supplier).

Table 56: Effectiveness of the Risk activities in specific Technological scenarios.

A more detailed chart elaborating the Technological risk activities (Appn, chp5,5.8) charts out the difference between the risk activities as discussed in literature, and the risk activities as analyzed from practice.

DEDUCTIONS FROM THE RISK ACTIVITY MODEL

The analysis of the risk activity model as built up on the quantitative results of fsQCA and the qualitative analysis of the cases which backs up the fsQCA results helps us make certain deductions:

- The technological risk activities primarily improve the technical quality of the system. The activities have an added bye effect on the cost management and the time management of the project. The activities tend to increase the budget, but improve the time efficiency of the project.
- There is a stark difference between the technological risk activities as mentioned in literature and the technological risk activities as practiced in the projects. The risk activities in the projects are more driven in terms of project management. The activities are planned out in lieu to the situation.
- The technological risk activities are most affective when the Quality is chosen as the major driver of the project.

5.5.2 Internal Organizational Risk Management activity model:

The data set created for Internal Organizational Risk management activity (Appendix 3) was fed into the fsQCA tool. Since the number of conditions was high in ratio to the number of cases, only the most complex solution of combinations of risk activities was attained after the first level of fsQCA solution. This ended in a rather broad scope of risk management activities from which strong conclusions could not be attained. Expert interviews conducted with manufacturing organizations helped to narrow down on the four most important Internal Organizational Risk Management activities affecting quality, cost, and time. The table below charts out the most important factors as per expert interviews. These identified conditions were fed into the fsQCA tool for the second level of analysis.

INTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITIES	
Quality	Interactions, Clear Task Specifications, System Architect, Technical Expertise
Cost	Interactions, Application of ICT, Escalations, Milestone based Approach
Time	Interactions, Milestone based approach, Clear task specification, Parallel activities

Table 57: Conditions chosen on the basis of Expert validation Interviews.

The results of the fsQCA (Appn, chp5,5.6) help us make the following conclusions:

- The combination of intensive Interactions along with distinct task Specifications has the maximum consistency and coverage to enhance quality in terms of Internal Organizational Risk

management activities. Strong Technical Expertise of the project engineers helps to improve the technical quality of the prototype realized.

- The combination of intensive Interactions, Escalations, and Milestone based payment system has the maximum consistency and coverage to enhance cost management in terms of Internal Organizational Risk management activities.
- The combination of Interactions, Distinct Task Specific and Pragmatic Approach has the maximum consistency and coverage to enhance the time management of the project in terms of the Internal Organizational Risk management activities.

The process of making the above deductions are shown in the fsQCA results (set and subset analysis in the (Appn, chp5,5.6). The diagram below illustrates the model proposed by fsQCA for Internal Organizational Risk management activities to improve the Quality of the product or the system, the cost management of the project and the time management of the project.

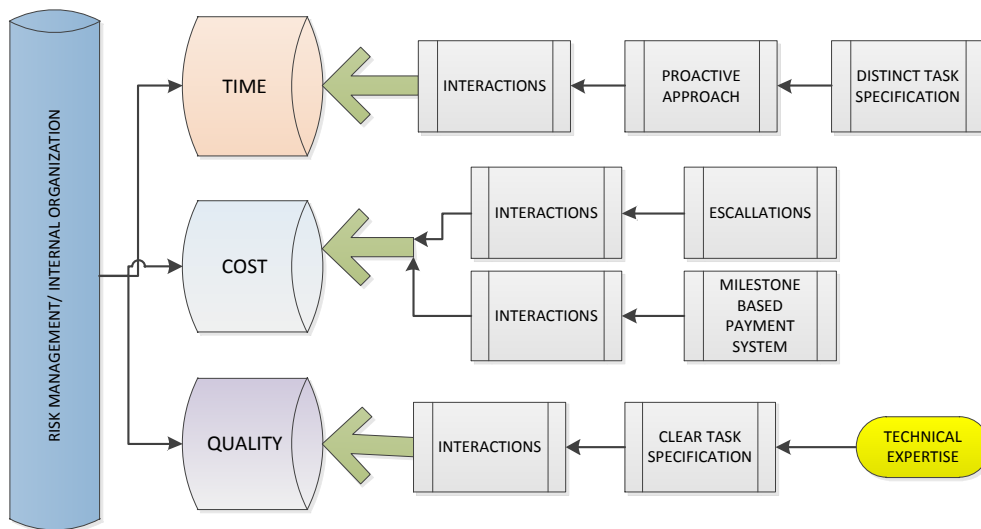


Figure 33: Most important risk activities for Internal Organizational Risks. (Results fsQCA)

The product development in manufacturing organizations are primarily realized due to the coordination and co-operation amongst all the cross functional silos. In order to ensure that the quality of the product is ensured it is essential that the work breakdown structure is attained perfectly, where distinct task specifications are made amongst all the functional silos. This prevents confusion amongst all the cross functional units. The technical expertise of the project engineers help to enhance the quality of the product, considering the fact that they are better adept at facing technical complexities. Cost management is best handled by means of escalations to the higher management, and a milestone based payment scheme. Since the organizations in consideration are primarily established organizations with large organizational structures, it is important that the management decides on issues and risks related to budget, and resources of the project. Pragmatic approach and pro activeness amongst the cross functional units also helps in attaining a better time management of the project. Pragmatic approach harps on the fact that the teams proactively change the planning and allocates resources as per changes in client needs.

The above figure 32. illustrates the Internal Organizational Risk management activities as obtained from the fsQCA results. The figure below illustrates the combined Internal Organizational risk activity model which brings together the Quantitative results of fsQCA as well as the Qualitative judgment of the cases. The circle of the diagram depicts the periphery, where the activities within the circle are the primary risk management activities as obtained from fsQCA, while the risk activities outside the boundary (qualitative judgment of the cases) are supplementing and helping to realize the most sufficient and necessary risk activities.

As discussed in the previous model, interactions, discussions, risk workshops and risk register are important process management techniques to bring the different functional units within the organization on a common platform. Interactions, documentations of all probable risks and risk workshops help to reduce information asymmetry within the organization. Miscommunication within the organization leads to complexities within the organization. The above internal organizational risk activity model depicts the most sufficient and necessary risk activities and how these activities need to be supplemented by other identified risk activities, in order to reduce Internal Organizational Risks. The Risk activities identified by qualitative judgement supports and help to realize the sufficient and necessary conditions as identified by the fsQCA results.

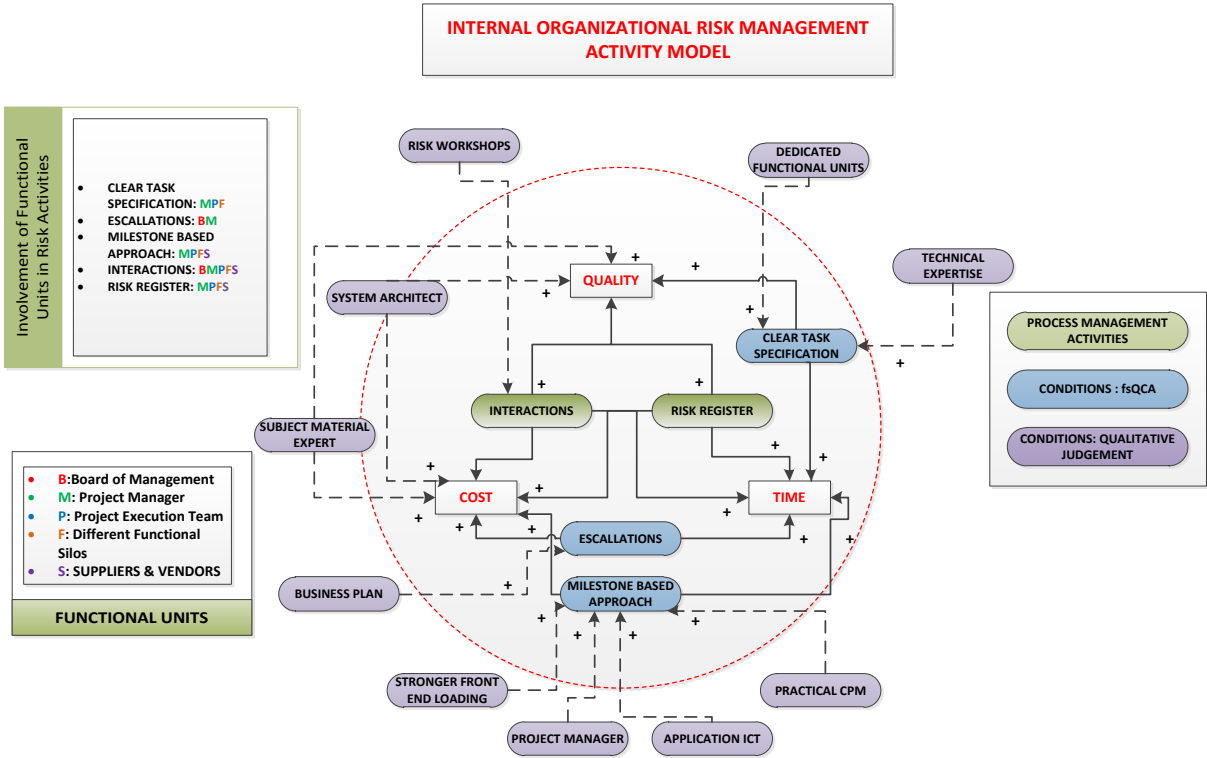


Figure 34: Illustration of the Internal Organizational Risk activity Model, a combination of the Quantitative and Qualitative judgment.

**Please note that all the risk management activities depicted in the model are derived from qualitative judgement. The risk management activities fed into the fsQCA tool are also derived from Qualitative understanding. The conditions depicted within the circle are the results of fsQCA, whereas the risk activities outside the boundary help in the successful implementations of the necessary and sufficient conditions.

DISCUSSION INTERNAL ORGANIZATION RISK ACTIVITY: QUALITY

The study of the cases and the fsQCA results help us to narrow down to the consideration that effective and clear task specification amongst all the functional units help to reduce risks and uncertainties that arise within the organization. However the success of the risk activity of a well-defined task specification is only achieved if the tasks are allocated to functional units who have the technical depth and expertise in their field. It is also important that organizations have dedicated functional units who are responsible for carrying out specific tasks. Inclusion of technical experts like subject material technical experts as well as a system architect who acts as an interface amongst all the functional silos helps in the better interface of all the functional silos. We find a strong relevance of the above mentioned risk activities in the cases (projects studied):

- As seen in the Rayscan MK2 Project, the operations and the maintenance department was expected to also carry out the assembly and the integration of the entire system though they lacked the skill. At times a single functional unit is expected to carry out multiple functions. The lack of the technical expertise leads to the depreciation of the quality of the entire system. A dedicated assembly unit was created henceforth for the integration of the systems. It is always beneficial if there are individual engineering and design units, conceptualizing the concept design and assembly units responsible for the integration of the complete system.
- As studied in all the cases it is very important that the project team has certain experienced members who possess the technical knowledge of the subject. As seen in the cases of company C a subject material technical expert who has the perfect knowledge of the subcomponents and the subsystems acts as the interface between the purchase department and the suppliers in selecting and ordering the accurate subcomponents. Inclusion of a system architect as seen in the Inspection Riser tool development project ensures a strong interface between the project team and the assembly and the testing unit. A system architect is beneficial if the technical complexity of the system or product is high.

The table below charts out the added value of the internal organizational risk activities in terms of quality of the entire system or the product:

INTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITY (QUALITY)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1.ClearTask Specification.	1. Less ambiguity in the responsibilities and the tasks to be carried out amongst the different functional units.
2.Dedicated Functional Units	1. Ensures that a specific activity of the product development is being carried out by the experts of the activity. This enhances the quality of the system.
3. Subject Material Technical Expert	1. Acts as an interface that has expert knowledge on the individual subsystems and components between the purchase and procurement team, the design and engineering department and the suppliers and vendors.
4. System Architect	1. Acts as an interface that has expert knowledge on the integration and assembly of all the subsystems and components between the assembly and testing team, the design and engineering department and the suppliers and vendors.

Table 58: Added value of Internal Organizational Risk management activity model on Quality of the product

The researcher continues the discussion by analyzing the internal organizational risk management activities that affects the cost management of the projects executed.

DISCUSSION INTERNAL ORGANIZATIONAL RISK ACTIVITY: COST & TIME MANAGEMENT

The fsQCA result reveals that well defined task specification and milestone based(stage gate) approach are the most common, and sufficient conditions necessary for managing risks on grounds of cost management and time management of the project in terms of internal organization structure. The researcher relates back to the cases how dedicated and clear task specification amongst all the functional units and milestone based approach can be successfully implemented by supplementing and backing them up with other risk activities:

- Well defined tasks amongst all the dedicated functional units ensures that experts of the specific activity are on the job. This ensures that different activities are being executed in parallel at the same time. Technical expertise of the different functional units ensures that the activities are being executed at a faster speed. As studied in the projects, as soon as the concept design of the system is in the process of being realized, the purchase and procurement team should start

looking out for appropriate suppliers. As the subsystems are being identified, the process of selection of the suppliers should start. A tender should be floated for the selection of the suppliers. Suppliers offering the best technical solutions as well as optimised cost should be selected. The project manager plays a very important role in the correct job allocation amongst the different functional units. He is responsible for identifying the expertise and qualities of the members of his project team, and allocate tasks accordingly. Deputing the correct people on jobs and activities in accordance to their respective expertise and interest not only ensures the project to propel at a faster speed, but it also leads to a better cost management of the project. Inclusion of a subject material technical expert ensures that the correct subcomponents are chosen. They are able to identify the most appropriate components at the most optimized cost. Even a system architect who is responsible for the complete integration of the system helps in a faster and more optimised integration and assembly of the entire system. Clear task specifications with involvement of experts like subject material technical expert as well as system architect helps in a better time as well as cost management of the project.

- All the projects studied are executed in stage gates. It is critical that the stages are well defined by charting out a practical critical path method, and a stronger front end planning amongst all the actors involved in the project. The cost management of the project is more effective if budget is allocated for each stages. Once each stage gate is achieved a re-evaluation of the budget should be carried out for the next stage gate as well as for the entire project. New suppliers should be paid only after the scrutiny of the delivered products. A milestone based payment approach should be developed for the suppliers. In order to establish an effective relation between the suppliers and the organization a contract should be developed in accordance to the relationship existing between the suppliers and the organization. In case of new suppliers a more stricter contract should be developed. In case of existing suppliers a more informal contract should be created, respecting a sense of trust existing amongst both the parties. Since most of the manufacturing organizations in consideration are large organizations with complex structures, in case of lack of revenue or resources escalations to the higher management is encouraged in order to achieve a faster and more cost effective solution. Company A had effectively put forward a business plan to their management for more monitory revenue, which convinced the management on the return of investments of the projects. Putting forward a business plan is an effective ploy to manage and convince the higher management for more revenue support for the project. This helps in a better time management of the project.

The table below charts out the added value of internal organizational risk management activities in terms of time and cost management of the project.

INTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITY (TIME & COST)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1.ClearTask Specification.	1. Experts are allocated tasks which fall under their interest. 2. Less ambiguity on responsibility propels the task at faster pace. (better time management)
2.Dedicated Functional Units	1. Ensures that a specific activity of the product development is being carried out by the experts of the activity. Experts narrow down to the most cost optimised solution. 2. Experts achieve solutions on a faster pace.
3. Subject Material Technical Expert	1. Expert knowledge on the individual subsystems and components helps to choose the most technically as well as commercially viable subcomponents.
4. System Architect	1. Acts as an interface that has expert knowledge on the integration and assembly of all the subsystems and components between the assembly and testing team, the design and engineering department and the suppliers and vendors.
5. Milestone based approach	1. Milestone based approach helps to breakdown the project into achievable stage gates.

	2. Reduces the sunk costs of projects. 3. Pushes the team to execute the project in desired time schedule.
6. Escalations.	1. It's a faster route to approval of resources from the management.

Table 59: Added value of Internal Organizational Risk management activity model on the Time & Cost management of the product.

INTERNAL ORGANIZATIONAL SCENARIOS:

The study of the cases helps us to analyze that there are certain scenarios which can be visualized on the perspective of internal organizational aspects. There are three scenarios, the size of the organization, the complexity of the organization structure, and the technical complexity of the project. We further elaborate on the internal organizational scenarios.

- Most of the organizations in the context of manufacturing or new product realization are large scale organizations. This brings to the scenarios of a medium sized organization or large sized organizations.
- The size of the organization, influences the complexity of the organization structure. This leads to building the scenario of a complex organization structure and a simple organizational structure.
- The technical complexity depends whether the system or the product to be realized is of incremental innovation or radical innovation. The complexity of the incremental and radical innovation further depends on the number of subsystems involved in the project.

In case of most of the organizations if the organization is large they generally have a complex organization structure. The diagram below illustrates the scenarios as discussed above:

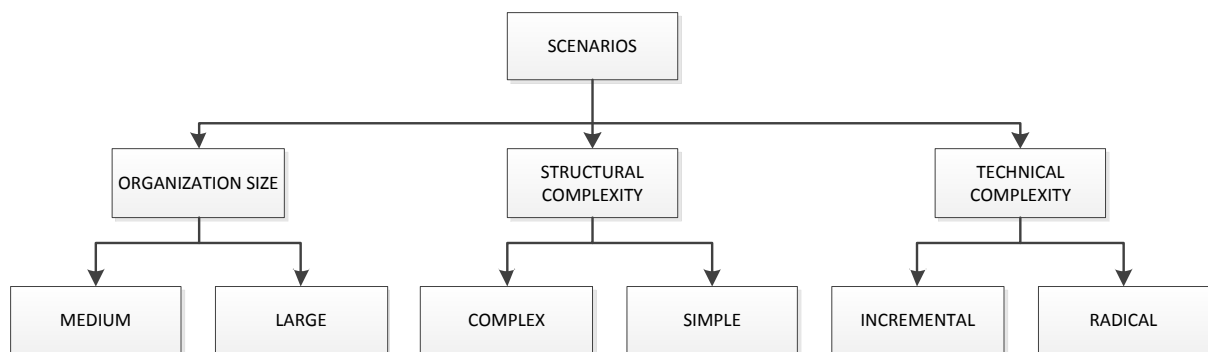


Figure 35: Scenarios of Internal Organizational aspects.

The internal organizational risk activities discussed above are best applicable in some of these scenarios. The table below charts out the Risk activities and the scenarios they are best applicable in.

RISK ACTIVITY	SCENARIO
1.Clear Task Specification.	All scenarios.
2.Dedicated Functional Units	Must be implemented, but more applicable for large sized organizations with complex organizational structures.
3.Subject Material Technical Expert	Extremely useful but more suitable for complex organizational structures with different functional units. They are effective when the system to be realized is of incremental innovation.
4.System Architect	Extremely useful but more suitable for complex organizational structures with different functional units. They are effective when the system to be realized is of incremental innovation.
5.Milestone based approach	All scenarios.
6.Escalations.	Most effective in large organizations with complex organizational structures.

Table 60: Effectiveness of the Risk activities in specific Internal Organizational scenarios.

A more detailed chart elaborating the Technological risk activity (appendix) explains the difference between the risk activities as discussed in literature, and the risk activities as analyzed from practice.

DEDUCTIONS FROM INTERNAL ORGANIZATIONAL RISK ACTIVITY MODEL:

The analysis of the risk activity model as built up on the quantitative results of fsQCA and the qualitative analysis of the cases which backs up the fsQCA results helps us make certain deductions:

- The internal organizational risk activities primarily improve the time and the cost management of the project. The activities have an added by effect on the quality of the product being developed. The activities tend to manage the budget, and improve the time efficiency of the project.
- There is a stark difference between the internal organizational risk activities as mentioned in literature and the internal organizational risk activities as practiced in the projects. The risk activities in the projects are more driven in terms of project management. The activities are planned out in lieu to the situation.
- The internal organizational risk activities are most affective when time is chosen as the major driver of the project.

5.5.3 External Organizational Risk Management activity model:

The data set created for External Organizational Risk management activity (Appendix 4) was fed into the fsQCA tool. Since the number of conditions was high in ratio to the number of cases, only the most complex solution of combinations of risk activities was attained from the first level of fsQCA analysis. This ended in a rather broad scope of risk management activities from which strong conclusions could not be attained. Expert interviews conducted with manufacturing organizations helped to narrow down on the four most important External Organizational Risk Management activities affecting quality, cost, and time. Table 62 below charts out the most important factors as per expert interviews. These below mentioned identified risks were fed into the fsQCA tool for the second level of fsQCA analysis.

EXTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITIES	
Quality	Interactions, Production Approval Part Process, Risk management Team, Competent Suppliers
Cost	Interactions, Closer Supplier proximity, Back up Resources, Competent Suppliers
Time	Interactions, Initial Involvement of Suppliers.

Table 61: Conditions Chosen as per Expert Interviews

The results of fsQCA (Appn,chp5,5.7) help us make the following conclusions:

- The combination of intensive Interactions with the suppliers along with the activity of choosing competent suppliers and a dedicated risk management team, has the maximum consistency and coverage to enhance quality in terms of external organizational risk management activities related to suppliers and vendors.
- The same above combination along with the condition of a closer proximity in terms of geographical distance with the suppliers has the maximum consistency and coverage to enhance cost management in terms of External organizational risk management activities related to suppliers and vendors.
- Finally a combination of Interactions with Initial involvement of the suppliers and the vendors in the very beginning of the planning phase and the concept design phase helps to counter risks related to the time management of the project.

The process of making the above deductions are shown in the fsQCA results(set and subset analysis). (Appn,chnp5,5.7). The diagram below illustrates the model proposed for External Organizational Risk management activities to improve the quality of the product or the system, the cost management of the project and the time management of the project.

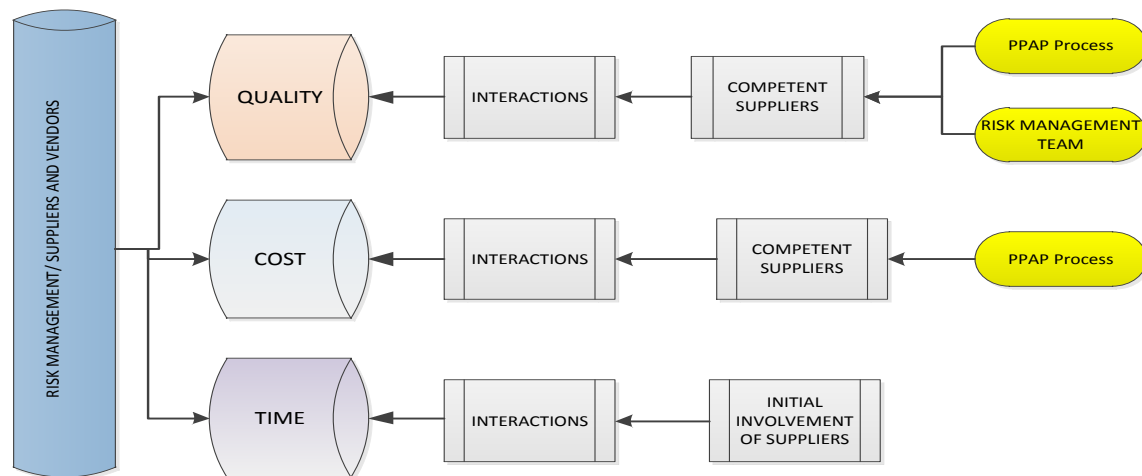


Figure 36: Most important risk activities for Technological Risks. (Results fsQCA)

Apart from the fact that the technical competence of the suppliers and the vendors helps in developing quality as well as technically adaptable subsystems/subcomponents, a production part approval process test , completely scrutinizes if the suppliers have the technical ability to develop subcomponents abiding by the required technical specifications within a pre-determined lead time. It ensures that the suppliers would be able to adapt to the dynamic changes and the demands of the client. As discussed earlier, initial involvement of the suppliers would enable in the time management since they are exposed to the complexity of the project at the earlier stage. This builds up a stronger sense of urgency amongst the suppliers to keep to their lead times. Finally we also conclude that a dedicated Risk management team having a detailed notion of the past performance of the suppliers and the vendors helps in finalizing various tenders of the project.

The above figure 35. illustrates the External Organizational Risk management activities as obtained from the fsQCA results. The figure 37. below illustrates the combined External Organizational risk activity model which brings together the Quantitative results of fsQCA as well as the Qualitative judgment of the cases. The circle of the diagram depicts the periphery, where the activities within the circle are the primary risk management activities as obtained from fsQCA, while the risk activities outside the boundary (qualitative judgment of the cases) are supplementing and helping to make the most sufficient and necessary risk activities, effective.

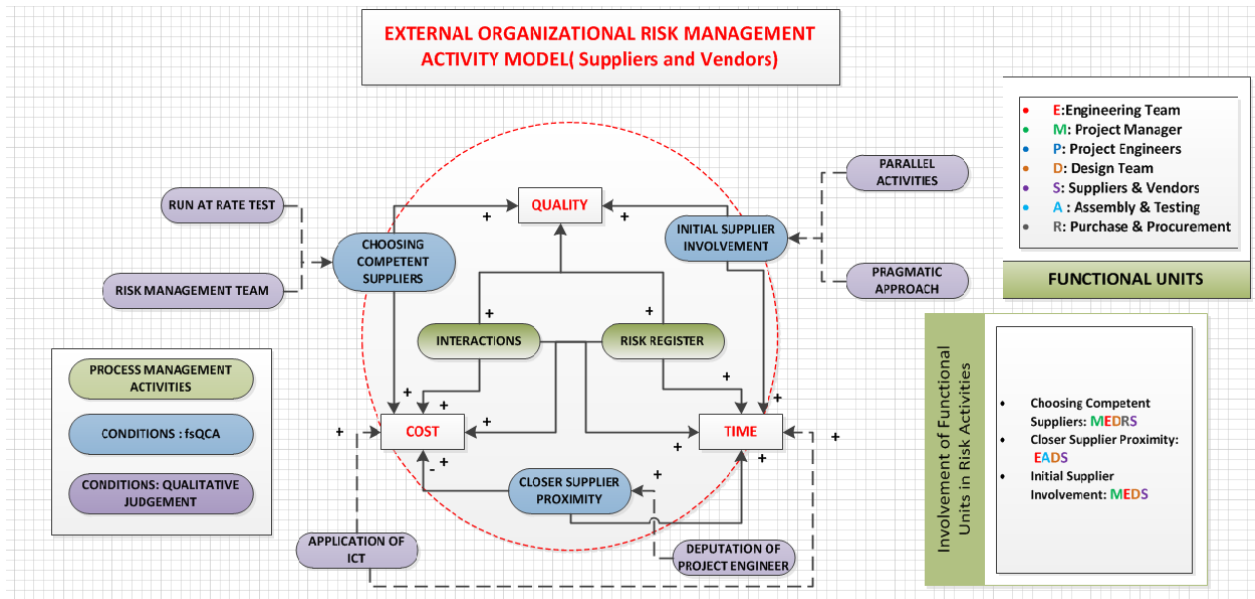


Figure 37: Illustration of External Organizational Risk activity Model, a combination of the Quantitative and Qualitative judgment.

As discussed in the previous model, interactions, discussions, risk workshops and risk register are important process management techniques to bring the suppliers and the organization on a common platform. At times the process and the approach to work is completely different for the supplier and the main organization. The supplier and the organization might be almost a black box to each other. A risk register allows both parties to document the risks they perceive. In the process the parties get to know each other better. Detailed discussions and interactions helps the organization to pass on the exact, streamlined technical specifications to the suppliers. This clarifies the expectations and the deliverables between the primary company and the suppliers. The above external organizational risk activity model depicts the most sufficient and necessary risk activities and how these activities need to be supplemented by other identified risk activities, in order to reduce External Organizational Risks. The Risk activities identified by qualitative judgement supports and helps to make the sufficient and necessary conditions as identified by the fsQCA results, effective.

**Please note that all the risk management activities depicted in the model are derived from the risk list of theory of consolidation. The risk management activities fed into the fsQCA tool are also derived from Qualitative understanding. The conditions depicted within the circle are the results of fsQCA, whereas the risk activities outside the boundary help in the successful implementations of the necessary and sufficient conditions.

DISCUSSION EXTERNAL ORGANIZATION RISK ACTIVITY: QUALITY

Analysing from a technical perspective the quality of the product or the system developed enhances if the subsystems or the components provided are technically compatible to the main system. This leads to managing risks by choosing technologically competent suppliers. The various cases studied helps us to realize that there are various ways in which the risks can be handled.

- The suppliers should be put under scrutiny by making them deliver sample subcomponents under specified time frame. The suppliers should be put under a run at rate test, where the suppliers need to produce a certain quantity of subcomponents in a specified time duration. This ensures if the suppliers have the ability to produce in bulk, following specified quality standards. The above practice was found to be practiced dedicatedly by company C. The run at rate risk activity is also more effective when the supplier has to deliver subsystems , or materials or components in bulk.

- A dedicated risk management team ensures that a perfect database of the suppliers are mentioned with their past records , be it financial statements of the suppliers or the projects executed by them. The risk management team helps to narrow down on the most appropriate suppliers for the project. In durations of crisis the team also helps to resort to and choose backup suppliers. In the projects studied for company B, especially for the tooling, development and handling projects, project executives and teams had also discussed with other organizations as a reference check on the past performance of the suppliers.
- The suppliers being involved in an initial design stage of the projects tends to improve the quality of the final system. This helps the suppliers have a better idea on the complexity of the project. It helps the suppliers adapt to the changing demands of the end client. If the complexity of the main system is better understood then the suppliers develop the ability to change, mould and develop alternative solutions. This was realized in the Inspection Riser tool development project, where the suppliers had to constantly change their scope and deliverables with the changing demands of the end client, yet maintain the initial time schedule of deliverables.

Table 64. below charts out the added value of the internal organizational risk activities in terms of quality of the entire system or the product:

EXTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITY (QUALITY)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1. Run at Rate Test	1. Production capabilities of the suppliers are judged. 2. The technical expertise of the suppliers are judged.
2.RiskManagement Team	1. Ensures a database of suppliers. 2. Helps to prioritize and choose the most appropriate suppliers. 3. Ensures the availability of back up suppliers at times of crisis.
3.InitialSupplier Involvement.	1. Realize the technical complexity of the project. 2. Provides sufficient time to deliver a subsystem which is technically adaptable to the main system.

Table 62: Added value of External Organizational Risk management activity model on the Quality of the system being developed.

DISCUSSION EXTERNAL ORGANIZATION RISK ACTIVITY: COST AND TIME MANAGEMENT

The risks related to the time management and the cost management of the project in perspective of the suppliers and vendors is managed by involving the suppliers initially at the very design stage of the project. It is also extremely important from the governance point of view of the organization over their suppliers that the organization tries to attain closer supplier proximity . It is also important that the suppliers are allowed to follow dedicatedly the progress of the product or system development at each stage gate by means of better ICT solutions.

- The initial involvement of the suppliers has a huge added advantage on the quality of the product being developed. This has been already discussed above. As studied in most of the projects initial involvement of suppliers creates the scope of the parallel design of the subsystems along with the main system. The suppliers should assist in building up the concept design. This not only brings correctness of the system on technical grounds but also propels the design and engineering on a much faster speed.
- It is also crucial that the organization adopts a very pragmatic approach. They should be dynamic enough to change and adjust their scope, budget and time frame of execution with the changes from the client end.

- It is extremely crucial that the organization tries to achieve a closer supplier proximity. As seen in the projects of company A, company B, usually a dedicated project engineer should be deputed at the supplier end. Though this leads to extra incurred costs on the budget, it ensures that the subsystems and the application softwares are being developed in the right direction. It was critical that the project engineer guided the software developers in the Rayscan MK2 project. This ensures that the right specifications are passed onto the supplier, as well as the development of the subsystems propel in the right direction. This manages the risk of falling out of time schedule as well as the proper cost management. It is more of a tactic to ensure that certain amount of pressure of developing their systems correctly and within the stipulated time frame is maintained.
- The advantages of strong ICT applications were dedicatedly found in company C. The applications of the PLUS and the VONTIK, and EPIC software brings about complete control and co-ordination amongst all the actors involved in the project. It ensures the actors to inspect and monitor the progress in all the stage gates of the projects. Access of these applications to the suppliers builds up a closer relation between the company and the supplier. The suppliers are indirectly reminded about their targets and deliverables. Moreover any sort of critical resource deficits from the supplier end gets immediately conveyed amongst all the actors. It provides the adequate time and space to organization to resort to other suppliers.

The adequate suppliers should be chosen by the common consensus of the Project manager, the Engineering team, the Design team and the Purchase and Procurement team. The design and the engineering team should specify the exact technical requirements whereas the past experience of the Purchase and procurement team with the suppliers helps to make a decision on the choice of the supplier. The engineering and design team, the assembly and testing team should be in as close proximity as possible throughout the development phase with the suppliers. The added value of the External Organization risk activity model is explained in table 63 below.

EXTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITY (COST & TIME)	
RISK ACTIVITY	ADDED VALUE/EFFECTIVENESS
1.Stronger application of ICT	1. Better co-ordination between the suppliers and the main organization. 2. Tactical way of putting the suppliers under time pressure.
2.Deputation of project engineers.	1. Better clarity of expectations and specifications between the organization and the suppliers which leads to better time management 2. Ensures subsystems and software's have better technical adaptability and less sunk costs.
3. Initial Supplier Involvement.	1. Realizing the technical complexities of the entire system ensures the development of the concept design (at an item level) at a much faster rate. 2. Provides sufficient time to deliver a subsystem which is technically adaptable to the main system.

Table 63: Added value of External Organizational Risk management activity model on the cost management and the time management of the project.

EXTERNAL ORGANIZATIONAL SCENARIOS:

The study of the cases helps to analyze that there are certain scenarios which can be visualized on the perspective of external organizational aspects. There are three scenarios, the size of the organization, the technical expertise of the suppliers, and the type of suppliers. The researcher further elaborates on the external organizational scenarios:

- The size of the organization, whether the organization is large or small plays a very important role. The process in which the suppliers are chosen depends on how formal or informal the organization is. The formality of processes depends directly whether the organization is large or small.

- The technical expertise of the suppliers have always played a very important role . We can categorise the suppliers to be new or old. This depends whether the suppliers have initially faced such technical complexities as involved in the projects.
- Finally the type of suppliers is also very important. The way a supplier should be handled depends on whether the suppliers are bulk suppliers or system or software developers.

The chart below illustrates out the critical scenarios related to the External organization or the suppliers and vendors.

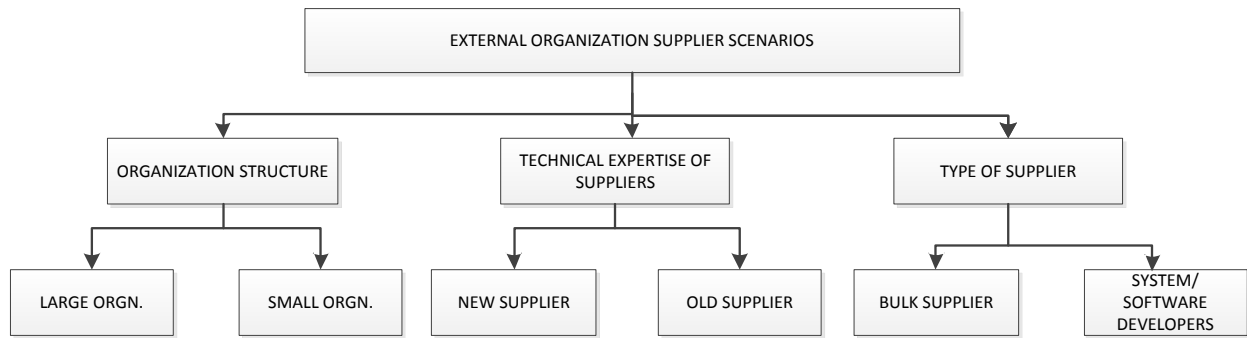


Figure 38: Scenarios of Internal Organizational aspects.

The internal organizational risk activities discussed above are best applicable in some of these scenarios. The table 64. below charts out the Risk activities and the scenarios they are best applicable in.

RISK ACTIVITY	SCENARIO
1. Run at Rate Test	Bulk Supplier, New Suppliers
2. Risk Management Team	Large organization, Complex structures
3. Initial Involvement of Suppliers	All scenarios, especially for subsystem developers during the design process.
4. Application of ICT	Extremely effective in large organizations.
5. Deputation of project engineers	Most effective for new Suppliers, and System and software developers.

Table 64: Effectiveness of the Risk activities in specific Internal Organizational scenarios.

A more detailed chart elaborating the External Organizational risk activities (Appn, chp5,5.8) explains the difference between the risk activities as discussed in literature, and the risk activities as analyzed from practice.

DEDUCTIONS FROM EXTERNAL ORGANIZATIONAL RISK ACTIVITY MODEL:

The analysis of the risk activity model as built up on the quantitative results of fsQCA and the qualitative analysis of the cases which backs up the fsQCA results helps us make certain deductions:

- Choosing technically appropriate suppliers in the context of the project is extremely important for the correct development of the system. Suppliers and vendors not only have a very important role to play in the correct development of the system but also in an efficient time management and cost management of the project. The technical adaptability of the subsystems ensures the quality of the system developed, the timely deliverables of the components. The technical expertise of the suppliers also ensures that the subsystems and the software developed are cost optimised. Hence the risk management activities on the external market has a direct positive

effect on the quality of the product being developed, the time management of the project and the cost management of the project.

- There is a stark difference between the external organization risk activities as mentioned in the literature and the external organizational risk activities as practiced in the projects. The risk activities in the projects are more driven in terms of project management. The activities are planned out in lieu to the situation.
- The external organizational risk activities are most effective when the system being developed is complex with a number of subsystems.

NOTE: KEY POINTS OF CHAPTER 5.

- The technological risk activity model, internal organizational risk activity model and the external organizational risk activity models are build up in the above chapter.
 - In each risk activity model, the influence of the individual risk activities on the dependant project outcomes of quality, cost and time are charted out. The researcher explains the added value of the effective risk management activities.
 - Each section builds up the scenarios relevant to technology, Organizational structures, and the suppliers and vendors. The researcher further points out the risk activities which are most effective in these scenarios.
-

CONCLUSIONS & RECOMMENDATIONS

The detailed study and analysis of the six executed projects from the three companies helps us to realize how Risk management is actually carried out in practicality in the industry. The analysis also helps the researcher to realize how the design, engineering and the development team should be actually formed, what is the general framework of risk management that is followed in the organizations. The thesis tries to conclude on the most effective risk management activities that should be followed by the organizations from the perspective of managing Technological risks, Internal organizational risks and the External organizational risks related to suppliers and vendors. The researcher also analyses how these risks activities have an added value on the project. We realize how these activities influence the Quality of the product being developed, the Time management and the Cost management of the project. In this segment the thesis constructs some conclusions and backs the conclusions with certain recommendations.

6.1 Structure of Product Development Team

The involvement of specific actors plays a very important role in the development process of a prototype. At all stage gates it is important to ensure that there is a source of expert knowledge which helps to face and manage risks along the execution of product development.

The Engineering, Design and Development team generally consists of a steering committee. The steering committee is responsible for managing and manoeuvring the project ahead. The steering committee defines the goals of the project. They are the main decision makers of critical instances. The steering committee is responsible for guiding the execution team to meet the defined stage gates. The team should be in close contact with the Technological Centre or the Research and Development units. The engineering and design team in the process of developing the first blue prints of the conceptualized ideas and solutions should be in constant touch with the Technological centres or the Research and Development units. The project manager or the group lead is responsible for striking the right balance between the project management and the technical drive necessary for the project. The operational team should be also included in the design, engineering and the development process of the product or system development. The operational team learns of the technical complexities, the functionalities of the system and how the system should be operated in dedicated environmental settings.

The project execution team consists of expert engineers from the mechanical team, electrical team, the electronics team, and also experts from physics departments. It is important to strike a proper balance and mix of knowledge of these different fields. The manufacturing and assembly team is also a part of the project execution team. The manufacturing and the assembly team helps in choosing the correct subsystems and components which ensures a smoother integration of the entire system. The purchase and procurement team helps in choosing the appropriate suppliers and vendors in the initial phase of project planning. The study of the past executed projects also helps us to conclude that the project execution teams should definitely have a subject material technical experts, whose expertise lies in

stripping down the entire system into technically correct and adaptable subsystems and subcomponents. A dedicated system architect enables a smoother integration of all the subsystems to realize the final system or product. The diagram below (fig 39) charts out the general structure and all the important actors that should be involved for a success full design, engineering and development of the project.

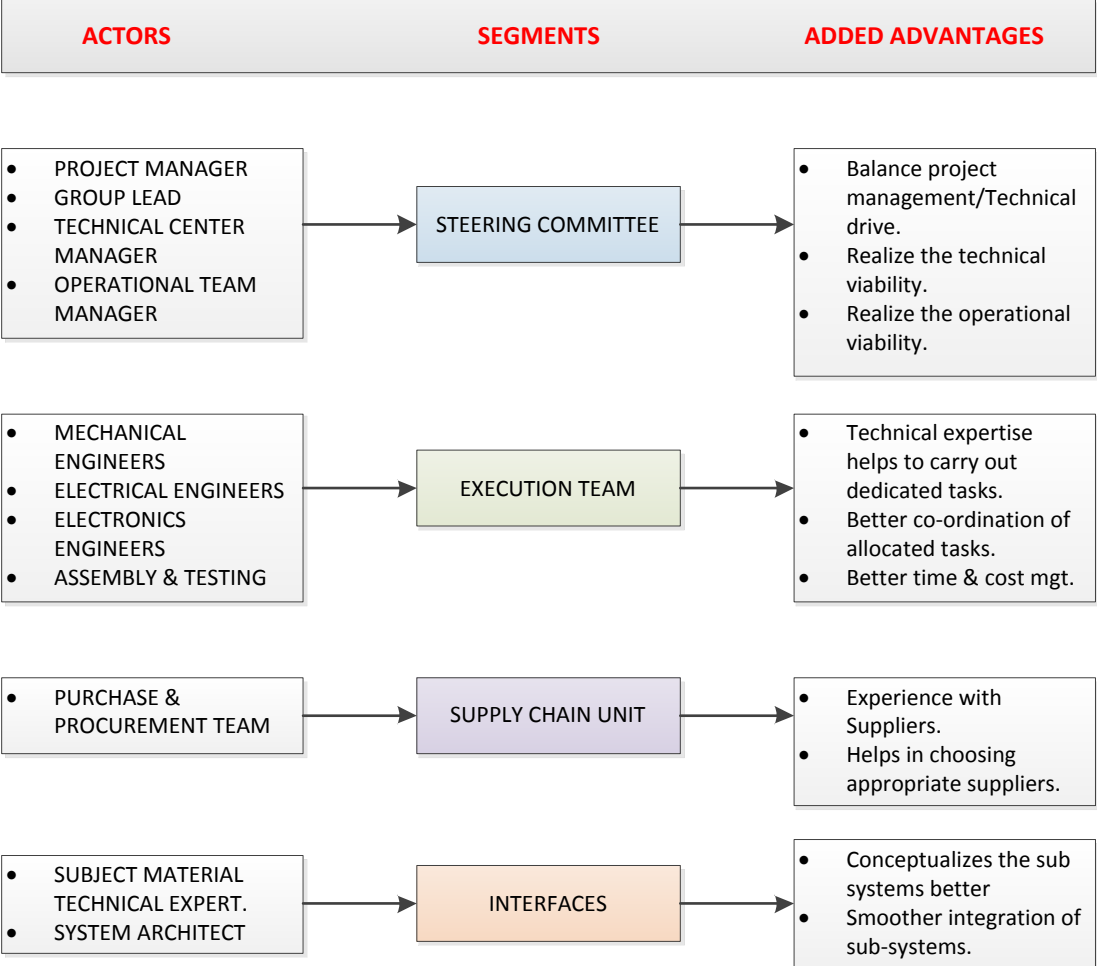


Figure 39: Recommended team structure for Product Development

CONCLUSIONS & RECOMMENDATION: The following are the conclusions on how the design, engineering and development team should be structured:

- *The steering committee should aim to bring about the correct balance between project management and the technical drive of the project. They should aim to implement a solution which is technically viable and operationally viable.*
- *The project execution team should have the right balance and mix of technical expertise, so that dedicated tasks can be carried out in parallel, with better co-ordination amongst the cross functional units.*
- *A subject material technical expert is extremely critical to conceive the correct product strip down into technically adaptable subsystems and sub-components.*
- *A system architect is important in the team since he enables a smoother integration of all the subsystems to realize the final system.*

6.3 Risk Management Framework

There is a huge difference between risk management as described in the theory and the Risk management as actually practiced in the industry:

- *Risk management as described in the literature is more algorithmic with predefined steps whereas Risk management in actual practice is more aligned in towards a project management approach.*

THEORY	PRACTICE
1. Algorithmic in Approach	1. More inclined on Project management and process management
2. Pre-defined steps: <ul style="list-style-type: none"> ➤ Risk Identification. ➤ Risk prioritization. ➤ Risk Assessment. ➤ Risk Planning 	3. Situation and Scenario oriented <ul style="list-style-type: none"> ➤ Impact driven, based on the driver of the project Quality, Cost and Time management.
3.High application of Quantitative tools.	3. Risks are assessed and judged on Qualitative judgement

Table 65: Difference in Risk management between theory and practice

As described in the above table risk management as described in literature is more algorithmic in nature with predefined steps of Risk identification, Risk prioritization, Risk assessment, Risk Planning. In practice risk management is more oriented towards project management. All the actors co-ordinate amongst each other by means of process management techniques to arrive at a conclusion or action plan best suited to the situation. The risk management activities are highly dependent on the situation or the scenario in which the risk arises. *One of the similarities between literature and actual practice is the fact that the action plan as decided for the risks identified are highly dependent on the risk impact assessed.*

The risk management framework as followed in practicality is highly influenced by the driver of the project, which could be Quality, Cost or Time management of the project. Some of the projects aimed to make a prototype which is highly robust. The technical precision and the quality of the prototype is the main driver of the project. The main aim of the organization is to put forward a system or product in the market which is technically sound and has unique features. In such cases the time management and the cost management of the project takes a back seat. The main priority is the Quality of the product being manufactured or developed. This generally occurs when the organization is the market leaders of their systems or products. There is no pressure of market entry, or survival amongst competitors. However when the organization has to prove themselves and capture the market, definitely the product needs to be unique, but the cost management and the time management of the project gets high priority. The timely entry to the market becomes an important factor. The quality of the product is iterated and brought to perfection in due course of time with client feedback.

As studied in the cases Risk management framework is either informal (that is more driven in line with project management) or the Risk Management is more formal that is it is more structured and algorithmic in nature with pre-defined steps. The cross case analysis helps us to make the following deductions:

The larger the size of the company , the more structured and streamlined is the risk management- The cross case analysis amongst the firms helps us to realize that larger the size of the

organization, more complex is the organization structure considering that there are more cross functional silos, interdependencies, and a larger external market(suppliers and vendors). The risk management demands to attain a more structured format, a more formalized and dedicated approach.

The smaller the size of the company, the more informal is the risk management. The risk management is almost carried out from the perspective of project management- The cross case analysis helps us to realize that when the organization is medium sized and number of functions are carried out by the same functional unit, the risk management is less formal. It is more situation and scenario oriented. Risks are addressed in the due course of the project.

RECOMMENDATION: It is very important to identify the main driver of the project. The analysis helps us to realize that there is always a trade-off between the quality and the cost and time management of the project. If the main priority of the project is to attain a technically sound product then automatically the executional costs tend to overshoot the pre-determined budget and time schedule. It is recommended that more budget is allocated for the executional phase. If the main aim is to enter the market then the prime focus should be on the cost management and the time management of the project.. Hence the risk management is highly influenced by the driver of the project.

In the following section we try to conclude on the necessary risk activities that must be adopted by the organizations in order to manage risks in the context of the technology, the internal organization, and the external market viewed as the suppliers and the vendors. The results depicted are concluded from the results of fsQCA. In the cross case analysis we have analysed how these results obtained from fsQCA can be made effective and successful by backing them by other risk activities as obtained from the consolidation process by means of Qualitative judgement.

6.4 Most Essential Risk Management Activities

In this section we summarize the most important and necessary risk activities that should be practiced in order to manage technological risks, internal organizational complexities, and the risks related to vendors and suppliers. The cross case analysis also helps us realize how these risk activities have an added influence on the quality, cost and time management which are the dependant project outcomes.

The table below discusses about the Technological Risk Activities:

TECHNOLOGICAL RISK ACTIVITIES	
DEPENDANT VARIABLES	INDEPENDENT RISK ACTIVITIES
QUALITY	<i>F.M.E.A , Redesign, and System testing helps to enhance the Quality of the system being developed.</i>
	<ul style="list-style-type: none"> • F.M.E.A and Redesign helps to improve the concept design • System Testing helps to realize if the desired features of system testing is achieved through the proper functioning of the systems and the subsystems.
COST	<i>System testing, re-design, Root cause analysis, and Technical Assistance to suppliers helps in a better cost management of the project.</i>
	<ul style="list-style-type: none"> • Redesign and system testing prevents the project from incurring sunk costs at the end by developing a technically incorrect system. • Root cause on a project level helps in a better planning and selecting the appropriate resources. • Technical assistance to suppliers increases the cost management but prevents information asymmetry.

TIME	
	<i>Initial involvement of the suppliers , parallel activities and technical assistance rendered to the suppliers helps in a better time management of the project.</i>
	<ul style="list-style-type: none"> • Initial involvement of the suppliers provides the suppliers sufficient time to realize the complexity of the project as well as adjust to the dynamic changing needs of the subsystems.
	<ul style="list-style-type: none"> • Parallel activities speeds up the process of system development
	<ul style="list-style-type: none"> • Technical assistance helps the supplier adopt to the technical complexity faster, and also realize the subsystems faster.

Table 66: Most essential Technological Risk management activities , and their influences on Quality, Cost, Time

The cross case analysis also helps us to make the following deduction –

The technological risk activity primarily helps to improve the technical quality of the system. The actives have a bye effect on the cost management and the time management of the project.

The table below discusses about the Internal Organizational Risk activities:

INTERNAL ORGANIZATION RISK ACTIVITIES	
DEPENDANT VARIABLES	INDEPENDENT RISK ACTIVITIES
QUALITY	
	<i>Clear task specification, dedicated functional units with subject material technical experts and system architects acting as an interface amongst all the cross functional silos helps in improving the technical quality of a system being developed.</i>
	<ul style="list-style-type: none"> • Less ambiguity in the responsibilities and experts carrying out dedicated tasks.
	<ul style="list-style-type: none"> • Subject Material technical Expert has expert knowledge on subsystems and product strip down. • System architect has expert knowledge on the system integration.
COST/TIME MANAGEMENT	
	<i>---Clear task specification, dedicated functional units with subject material technical experts and system architects acting as an interface amongst all the cross functional silos helps in improving the cost management as well as the time management of the project.</i>
	<i>---Milestone based approach as well as escalation of issues to the higher management enables to arrange resources faster as well as achieve a better cost management.</i>
	<ul style="list-style-type: none"> • Experts are able to optimize costs better. • Experts of dedicated functional units are able to carry out tasks at a much faster rate. • Milestone based approach reduces sunk costs on unachieved targets. • Escalations act as a faster route to approval of resources.

Table 67: Most essential Internal Organizational Risk management activities , and their influences on Quality, Cost, Time

The cross case analysis also helps us to make the following deductions –

The internal organizational risk activities primarily improves the time and the cost management of the project. The activities have a bye effect on the quality of the product being developed.

In the next table we discuss about the external organizational risk activities related to suppliers and vendors

EXTERNAL ORGANIZATION RISK ACTIVITIES	
DEPENDANT VARIABLES	INDEPENDENT RISK ACTIVITIES
QUALITY	<i>To attain a technically adaptable as well as technically correct subsystem it is important to choose technically competent suppliers and vendors which is achieved by means of a Risk Management Team, and also put the suppliers through a Run at Rate Test.</i>
	<ul style="list-style-type: none"> • Production capabilities of the suppliers are judged.
	<ul style="list-style-type: none"> • The Risk management team helps to maintain a database of suppliers which helps to prioritize and choose the most appropriate suppliers for the projects. It helps to study the past performances of the suppliers.
COST/TIME MANAGEMENT	<i>Involving the suppliers initially in the very design stage of the project as well as achieve closer supplier proximity enables to attain a better cost management and time management of the project.</i>
	<ul style="list-style-type: none"> • Helps to achieve better co-ordination between the suppliers and the main organization.
	<ul style="list-style-type: none"> • Involving the suppliers initially in the design phase allows the suppliers and the vendors the time and space to adapt to the technical complexity.
	<i>Stronger application of ICT helps in the better co-ordination between the various cross functional silos as well as the various suppliers.</i>
	<ul style="list-style-type: none"> • Helps in monitoring the advancements in each stage gate of the project.

Table 68: Most essential External Organizational Risk management activities , and their influences on Quality, Cost, Time

The cross case analysis helps us to make the following deductions –

The risk management activities on the external organization has a direct positive effect on the quality of the product being developed, the time management of the project as well as the cost management of the project.

RECOMMENDATION TO THE MANUFACTURING INDUSTRY

The research helped to realize that a successful design, engineering and development of a system or a prototype is achieved on the individual successful completion of each of the dedicated stage gates of the project. The researcher recommends that there are no perfect Risk management activities, or a risk management algorithm which can be proposed to be followed, which ensures a risk averse system of product development. In spite of adopting a vigorous and formal risk management practice, a project might face completely un conceived risks which creates obstacles for the project. It is important to be well equipped and well protected to face the risks. In order to be prepared to face unknown risks it is important to practice and institutionalize the above discussed effective risk management activities in terms of technology, internal organizational and external organizational structure. This ensures a smoother project management and project execution. The following are some of the important activities that is recommend that the manufacturing organizations should adopt to manage risks.

- It is extremely important to decide what your project drivers are. The drivers of the project differ with the context of the project. Depending on your drivers the project planning should be pragmatically charted out.
- Most of the manufacturing firms in consideration are established organizations. It is important that the risks are managed in an efficient way that the brand image of the firms are maintained.. It is critical that the boundaries and the scope of the project are crystal clear so that the product and system is achievable. Risk management being an extended version of the project management should not only be efficient but also effective. It is important to realize a product which lives up to the expectations of the clients and the customers. Therefore it is important to manage the risks in a way that it leads to the realization of a meaningful product.
- As recommended earlier on in this chapter it is important to build the project team in a way that there is a right balance between the technical drive and the managerial aspect of the projects. There should be co-ordination amongst the R&D team, the supply chain unit, the design and engineering team, the assembly and marketing team and the testing units to achieve a successful product. The project manager should be responsible for clearly defining the tasks amongst the different cross functional units. Involvement of experts like the subject material technical expert, or the system architect helps to act as an interface between the different functional units.
- The marketing team should be involved more in the process of engineering, design and developmental of the product. The marketing team is the best source or link of feedback from the client. Risk of not realizing a product which does not cater to the needs of the client is delineated. Though the project execution team definitely needs to meet the end client on technical grounds, inclusion of the marketing team in the process of product development will lessen the burden, specially of the design, engineering and development team. The design and engineering team is more focused on the technical aspects and solutions, which the marketing team can take forward to the end client. The risk of overseeing technical risks is somewhat evaded.
- It is important to choose technically competent suppliers and vendors. Creation of a master data base of suppliers is important. A risk management team should be developed who looks into the past performances and past projects executed by the suppliers. The suppliers could also be made to undergo the Run at Rate test, to judge their production and manufacturing capabilities. It is very crucial to involve the suppliers at the very initial stage of realizing the concept design.
- The design and engineering phase is critical from the point of view of the quality of the product or system being developed. Redesigns and iterations helps to attain perfection of the concept design. It is important to get constant feedback if the designs are in accordance to the client requirements. A F.M.E.A on the product level and a Root cause analysis on the project level should be carried out. The F.M.E.A helps to attain a perfect concept design, whereas the root cause analysis helps in a better time and cost management of the project.
- A milestone based payment system for the suppliers should be adopted. Contracts with suppliers should be made pragmatically. Budgets should be calculated after the execution of certain stage gates as well as the complete project. This ensures a better cost management of the project.
- The next step is the assembly and testing, in which the agile methodology should be adopted. Every fragment and subsystem which is assembled should be tested. Testing should be conducted on a subsystem level and then on the complete system. This probably leads to more budget and time schedule, but enhances the reliability of the system being manufactured. It also prevent sunk costs and time if evaluated at the end of the project.
- In the past executed project dealt in this research we have studied that breaking the project execution into parallel activities are some of the effective risk management actives. Till the complete detailed item level as well as complete system level design is achieved it is important to follow the stage gate approach of V-Methodology. It is important to conceive the correct picture or design of the system which needs to be achieved. Once the assembly and the testing of the

system starts it is more advisable to resort to the agile methodology. The execution is more fragmented, realized on smaller parts but ensures correctness.

- The risk register is the most important form of documentation. A rigorous documentation process leads to a master data base which acts as a reference for future projects. In order to attain better co-ordination amongst all the actors of the network, involved in the system development, stronger application of ICT should be adopted.

The researcher prescribes the below model which acts as a prescription model. The above recommended activities depicted in the figure 39, needs to be institutionalized and practiced by the manufacturing industries. These recommendations should be followed in order to be better equipped, and protected to manage risks in the technological grounds, internal organizational grounds and external suppliers and vendors:

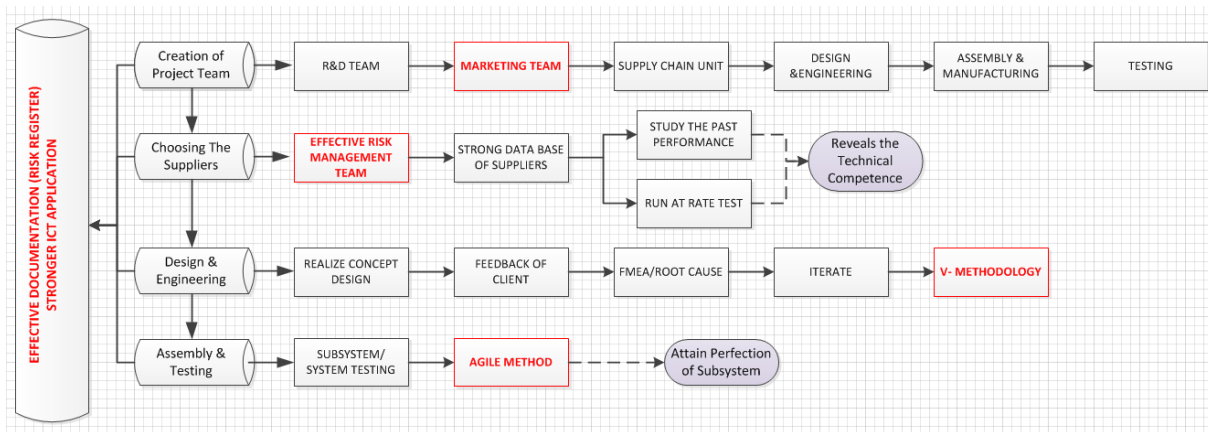


Figure 40: Prescription Model for Risk Management in Manufacturing Organizations.

With the above model we conclude that in order to be well equipped to manage risks it is important to build a project team which has the right balance of technical expertise, project management and feedback from the client. It is crucial to choose suppliers intelligently so that they have the technical capabilities to endure the dynamic needs of the end client. It is critical to achieve a technically correct concept design and adopt a final parallel assembly and testing methodology (agile technique) to attain technical perfection as well as manage the time schedule of the project.

NOTE: KEY POINTS OF CHAPTER 6.

- A recommendation on how the product development team should be structured with key personalities and experts from the different functional units is made.
- General recommendations and conclusions on the framework of risk management followed in the organizations are made. The researcher points out that risk management as followed in the literature is more algorithmic in nature with pre-defined steps whereas risk management in actual practice is more aligned in towards a project management approach. The framework followed in the organization is highly influenced by the driver of the project which could be quality, cost, and time management of the project. The author deduces that larger the size of the organization, the more structured and streamlined is the risk management framework. Smaller the size of the company, more informal is the risk management. In such organizations risk management is almost carried out from the perspective of project management.

- The researcher identifies the most effective risk management activities that must be adopted to improve the quality of the system being developed, the cost management and the time management of the project in the context of technological risks, internal organizational complexities, and the external organizational suppliers and vendors.
 - The researcher concludes the chapter by illustrating a prescription model of risk management for the manufacturing industry.
-

REFLECTIONS

In this chapter the researcher speaks of the intrinsic aspects of Risk management activities that has surfaced out of Risk management activities that has surfaced out of the experience of conducting this research. The researcher tries to explain the positives and the negatives that has been realized by making choice of the sample or the domain of manufacturing organizations, and the choice of the research methodology. The robustness of the research in terms of internal validity as well as the external validity is explained. The scientific and the managerial contributions of the research is also pointed out. The scientific and managerial contributions achieved in the project further paves way for the future research.

7.1 Discussions

The case study research carried out is a combination of exploratory, descriptive and explanatory studies. The study is exploratory since the researcher is trying to explore how the risk management activities are being carried out in the manufacturing industries. A part of the research is descriptive in nature since it is described what were the risks faced in each of the executed projects studied. The researcher has described in details the instances and the complexities which lead to these risks. The risks have been clearly described to be either technological risks, or internal organizational risks, or risks related to the external market viewed as the suppliers and vendors. The third part of the research is explanatory since the researcher analyses and explains how the risk management activities helped to influence and shape the project outcomes that is Quality, Cost, and Time.

To understand how risk management is actually carried out in practice, as suggested by Yin, a multiple case study research design was an useful research method. The semi structured in-depth interviews enabled to get a vivid picture of the risks faced in the projects, the risk management activities adopted to manage the risks and finally how the projects faired in the end in terms of quality, cost and time. The combination of the project managers, the group leads as well as the technical heads or the chief technical architect helped to attain a picture of how the managerial and the technical aspects were balanced in the project. This helped the researcher to realize what was the primary drive of the project, whether the project was inclined to cater risks more on the technical aspects, or the main goal was to keep to the planned cost budget, or the time schedule. It helped the researcher conclude that to manage risks on all the three fronts, technical, internal organization as well as the external market, it is difficult to find the perfect balance of the quality of the product ,the cost management and the time management of the project. It is a trade-off between attaining precision of quality on one end, and cost management and time management on the other hand, especially for new product developments.

The choice of selecting past executed projects which aimed at realizing a new prototype was interesting from the context of analysis of risk management activities since designing, engineering and developing a new product is highly risk averse. Developing an existing system in the market is less risk intensive since the obstacles and the hurdles have been already surpassed. The projects studied were a mix of incremental innovations(Mk2 Rayscan, Tooling Handling and Hoist development project, QXT 450 lithography system development, BMW/5 series seat manufacturing project) on one hand and radicle innovative projects like (riser inspection tool development project, GMJ300 seat manufacturing involving a new vinyl technology) on the other hand. Moreover the diversity in the size of the companies ranging

from the medium sized companies to large well established organizations, and the type of technical innovation the project aimed at, helped in creating scenarios in which the risk activities are best suited and effective.

Though company A is a well-established group, A is a medium sized company in comparison to company B and company C who are the technology leaders in their respective domains. Though the diversity in the company had some disadvantages which will be discussed later in this chapter in the segment of limitations, it helped mainly in an in-depth analysis to construct the scenarios in the cross case analysis. The researcher held the validity of studying these diverse companies on grounds of reality that the systems developed were based on extremely complex technologies with strongly rooted concepts of mechanical, electrical, electronics and mechatronics engineering . These manufacturing organizations realized the final system due to the co-ordinated efforts of dedicated functional silos. The complexity of the organization structure formed a strong base of comparison for the researcher. Company A had a relatively less complex structure in comparison to company B and company C. The diversity of the projects helped the researcher note an interesting point. Risk management is also like a road map in which it follows a trajectory from an informal , more project management oriented structure to a more formal and algorithmic structure. Every project that a company executes, the company grows in experience. More the involvement of the organization in different projects, the company also tends to grow in size. This automatically leads to a more complex structure in the organization. With experience and growth the risk management also tends to become more structured, in order to counter the complexities.

It is important that the risk management activities as concluded to be effective must be institutionalized as a practice in all the projects executed. It's more of a discipline which needs to be inculcated in the organizations which acts as a shield to face and cope up with risks, which might evolve in the pathway of the new product development. The added advantages of Risk management is intangible and cannot be quantified.

7.2 Reflection on fsQCA as a Tool

What makes fsQCA (fuzzy sets qualitative comparative analysis) tool interesting is the fact that fsQCA is a combination of qualitative judgement as well as quantitative judgement. The inputs to the fsQCA tools are the different risk management activities which the researcher identified from the theory of consolidation. The theory of consolidation is based on a qualitative judgement. However the fsQCA tool makes the analysis on quantitative terms. As discussed previously the risk management activities which acts as conditions are calibrated on a six point scale in-between 0 to 1 (0, 0.2, 0.4, 0.6, 0.8, 1). The calibration depends on two factors, the factor of relativity and the factor of specificity. Specificity defined how specifically the risk management activity has been adopted in the company and relativity defined how relatively this particular activity has been applied in comparison to other projects or the cases. When the risk management activities act as the input conditions, the dependant project output in terms of quality, cost and time act as the project outputs. The project outputs have been also calibrated on the six point scale on terms of qualitative judgement.

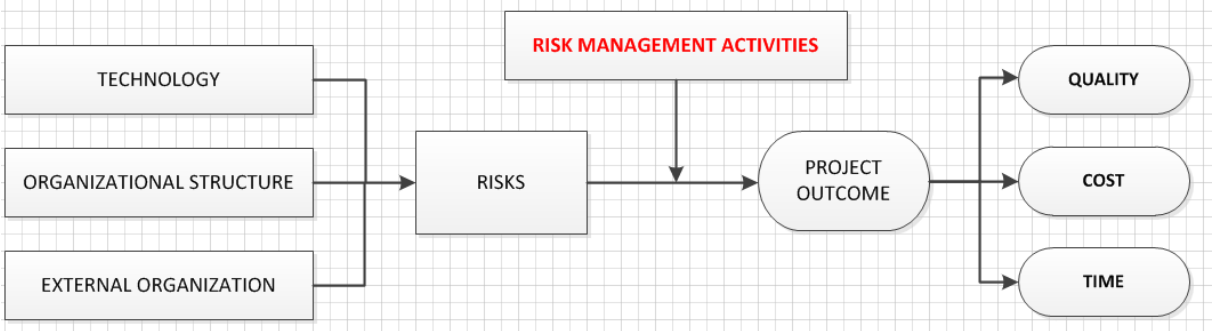
The fsQCA creates a vector space of 2^K combinations of conditions. It makes correlations by studying the combinations which has the maximum coverage as well as the conditions which are consistently used in all the cases. The combination of the consistency and the coverage is defined as the sufficiency. The fsQCA tool helped to make a bold step by defining the research question as “ what are the most effective risk activities that should be practiced by the organization” and not merely keep the research question as “ what are the most commonly used risk activities practiced in the organization” . The advantage of fsQCA as realized in this research was the fact that it was not only a study of frequency of occurrences of the risk activities in the cases, but the analysis helped to judge on the necessity of conditions by means of a cross case study of the outcomes of the projects verses the extent of application. Though fsQCA defines the results as the sufficient conditions , the researcher realizes that by defining

certain combinations of conditions(results of fsQCA) as the sufficient conditions would lead to erroneous deductions. Hence the researcher build the risk activity model as a combination of the fsQCA results as well certain other risk activities which are necessary to be adopted to back up or make the conditions obtained from fsQCA successful and effective. Therefore the research question has been constructed to be “ What are the most effective risk management activities , which needs to be practiced”.

The disadvantage of the fsQCA tool was that the number of conditions for each of the fuzzy sets (technological risk activity fuzzy set, the internal organization risk activity fuzzy set, and the external organizational risk activity fuzzy set) were high in comparison to the computational power of the tool. This lead to the most complex solution after the first level of analysis of fsQCA with the results having combinations of six to nine conditions. This made the result ambiguous. This also made the researcher carry out expert interviews from the industry where experts were asked to choose the five most important factors from the first level of conclusions. The ratio of the number of cases to the number of conditions should be kept to 2:1 specifically for the fsQCA application. That means in the perspective of the research the number of cases should have been around 12 projects and the number of conditions should have been around 6. This ratio would lead to the optimum results from the fsQCA tool.

7.3 Research Contribution(scientific & managerial)

The contribution of this research is twofold, scientific as well as managerial. Definitely the research is aimed to gain an idea of how risk management is carried out in the industry and in the process the researcher tries to suggest the necessary risk activities that should be practiced by the managers of organizations. However in the process of trying to get accustomed to risk management activities in practicality a strong academic relevance has also been built up in this research. Initially in the very first chapter the literature helped us to create the conceptual model for the research. We realized that risks in the engineering, design and development phase of new product development is faced in the context of technology, internal organization structure and finally the external organization seen as the suppliers and the vendors. Risk management activities acts as a moderating variable which helps to manage the risks and shape the dependant project outcomes in terms of the quality of the system developed, the cost management and the time management of the project. The diagram below once again illustrates the conceptual model which the researcher has built up for the study.



Though literature defines Risk management models like the ATOM model, the models defines the basic key steps of Risk Identification, Risk Assessment, Risk Planning and Risk review. The risk management lifecycles as described in the literature did not define the key aspects and elements. The key aspects and elements of each step is identified from literature. The key risk management activities as defined by literature which is applicable to each of these steps are also identified. The information identified from the literature is consolidated and structured to form a research protocol (fig 14) which is used as a reference for all the semi structured interviews. This research protocol structured by the researcher can be viewed as one of the contribution of science. The protocol can be defined to be a more detailed

framework of the risk management lifecycle, which guides the reader into the key aspects that should be dealt with in each step, as well as the risk management tools that could be implemented for analysis in each of the steps.

Having carried out the research the researcher points out three important conclusions:

- *The technological risk activity primarily helps to improve the technical quality of the system. The activities have a bye effect on the cost management and the time management of the project.*
- *The internal organizational risk activities primarily improves the time and the cost management of the project. The activities have a bye effect on the quality of the product being developed.*
- *The risk management activities on the external organization has a direct positive effect on the quality of the product being developed, the time management of the project as well as the cost management of the project.*

These conclusions help to further paves way for the improvement of the conceptual model where we have an in-depth vision between the independent technological risk activities, internal organizational risk activities and the external organizational risk activities on the dependant project outcomes of quality, cost and time. The relations explained in the diagram 40 below is a contribution to science, which can be visualized as an extension of the conceptual model.

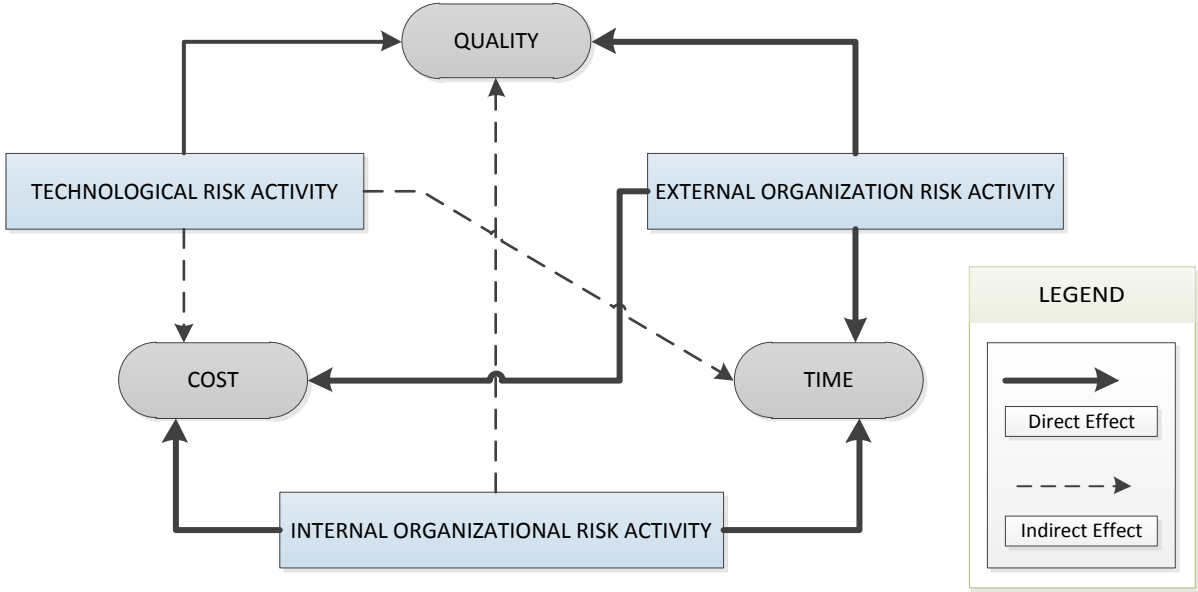


Figure 41: Relations between Independent Risk activities and Dependent project outcomes.

The research protocol as well as the extended conceptual model also paves way for the managerial contribution. The technological risk activity model, the internal organizational risk activity model as well as the external organizational risk activity models are some of the key models that the researcher has developed from the cross case analysis which acts as a guideline for the managers to adopt and practice the necessary risk activities. These researcher advises the manufacturing industry that there are no definite risk activity algorithm, however the adoption of certain risk activities during the different phases of the design, engineering and development phases would definitely help to manage and encounter the risks that might crop up. The researcher also makes the industries aware of the added values and the benefits of the adoption of these risk management activities. The recommendations also advises the manufacturing industries that it is important to look at risk management on the industrial level in a much more pragmatic

way. The managerial contributions of the research can be defined to be the Technological Risk activity model (fig 30), the Internal organizational Risk activity model (fig 33) and the external organizational Risk Activity model (fig 36). These models suggest the manufacturing organizations the risk activities that should be practiced in order to improve the quality of the system being developed, or the cost management and the time management of the project.

7.3 Judging the Quality of the Research

The quality of a case study research is judged on four logical tests (YIN, 2003). These four logical tests are used to establish the quality of any empirical social research. These four tests are defined as below.

- **Construct Validity:** This validity confines with establishing correct operational measures for the concepts being tested.
- **Internal Validity :** The validity is usually applicable for explanatory or causal studies. The study helps in establishing causal relationships where certain conditions are shown to lead to other conditions. This distinguishes them from false relations.
- **External validity:** The external validity helps in defining the domain in which a study’s findings can be generalized.
- **Reliability:** the reliability test helps in defining that the operations of a study such as the data collection procedure can be repeated within the same results.

The table below illustrates how the tactics as defined by YIN, has been employed in practice with reference to the research being performed.

TEST	CASE STUDY TACTIC	PHASE OF RESEARCH	IN PRACTICE IMPLICATION
CONSTRUCT VALIDITY	Use of multiple sources of Information.	Data Collection	Qualitative Interviews , scientific literature, books on risk management, scientific journals, company websites.
	Establish chain of evidence	Data collection.	Sample interview transcripts are shared in the appendix of the report.
	Have key informant review draft case study	Composition	All interview transcripts are being verified by respective interviews to confirm the content.
INTERNAL VALIDITY	Pattern matching	Data Analysis (Literature Review)	A theoretical framework (a research protocol) was build up. The protocol was used to build questions for the cases.
	Explanation Building	Qualitative data analysis (Transcription)	The semi structured interviews were transcribed to identify the dependant risk activities and dependant project outcome.
EXTERNAL VALIDITY	Cross case Analysis	Theory of Consolidation	Define the independent risk activities
		fsQCA (Qualitative/ Quantitative	Establish necessary and sufficient conditions (the risk activities that should be adopted by companies)
RELIABILITY	Use case study protocol	Data Collection	Case studies were performed as per the protocol defined. For every case the same protocol was defined.
	Develop case study protocol.	Analysis	Data collected from each case is well defined as case description and case analysis .

Table 69: Judging the Quality of the Research

In the next section we discuss the limitations of the research.

7.5 Research Limitations

There are four main important domains that raise questions on grounds of external validity and the internal validity of the research. The following limitations are discussed below:

- The first limitation being the fact that risk management is quite a generic topic which is applicable in all the industries. The risk management activity models developed by the researcher is applicable to only the manufacturing organization which aims at developing a new prototype or a system. It is not sure if the research is also applicable to the large scale production focussed organizations which relates to some of the biggest FMCG based organizations.
- The access of information was limited to the general risk management techniques and activities which were carried out by the project teams for the concerned project. Information related to specifically how much budget was saved due the practiced risk management could not be achieved. Moreover for each of the cases studied, the project managers or the group leads and the technical heads or the design architects of the projects were interviewed. The group heads and the managers gave a good perspective of the steering committees of the projects. The technical heads and the design architects gave insight on all the technical complexities of the projects. However due to lack of accessibility as well as lack of time , the researcher could not intervene into the executional level. The perspectives and views of the project engineers, who were responsible for the executions, are missing. The combination of the views of the managerial level as well as the executional level would make the data collection more robust. It would be interesting to study the approaches and the thoughts of the engineers on the risk management activities which were carried out by the team since it is these engineers who encounter these risks first.
- Definitely there is always the possibility of biasness, when it comes down to Qualitative judgement. Biasness from the perspective of the interviewee as well as the interviewer. The possibility of the executives being biased on a particular risk activity, and perceiving them to be more effective than some other activities always exists. The interpretation and qualitative judgement of the interviewer also possess a question, though the interviews transcribed have been verified by the respective organizations
- An obstacle which was faced in the process of the research was the robustness of the fsQCA tool. The effective application of the tool was realized on a later stage on discussion with some experts of the fsQCA tool. The tool is rather more applicable when the number of cases are large that is the sample size should be big. It functions optimally when the number of cases are around ten to twelve. However the research was an in-depth study of six projects cases of three companies. It was difficult to increase the number of cases, or make further in-depth studies of other projects. On the contrary the number of conditions should be half of the number of cases, that is the number of conditions should be around six. The cases and the conditions of the research was diametrically opposite to what it should be for optimal results. The situation was handled by means of experts validation interviews to narrow down the input conditions for the fsQCA tool.

7.6 Future Research

The research findings as well as the limitations of the research paves way for the future research. The design, engineering and the development phase is more of an intermediary stage. The following are the possibilities to extend this research:

- As discussed the design, engineering and the development is an intermediary step in which the conceptualized idea is given shape. However what is extremely important, is the fact that the conceptualized idea should be well accepted by the market. In order to make the new system a success in the market it is important that the execution is backed by an effective and appropriate business model. In order to make this research successful, it is important we make an analysis of

the risk management activities necessary for an effective market research. A correct market research helps in making the correct business model.

- Secondly the risk management activity models developed by the researcher is built on the analysis of six projects dedicated to three organizations. It is important to validate the risk management models by applying it to other manufacturing organizations. Specially make a broader research on the automotive industries, since from a system engineering perspective the automotive industries are the perfect combination of technology, engineering and manufacturing. This would increase the internal validity of the project. The models developed are more robust for the domain of manufacturing.
- Finally on the front end of the research, the findings are valid only in the manufacturing industries. The risk management activity models can be further strengthened by extending it beyond the manufacturing organizations but make it also applicable to the large scale production organizations like the FMCG industries. This would make the models more robust and improve the external validity of the research.

NOTE: KEY POINTS OF CHAPTER 7.

- The research is a combination of exploratory, descriptive as well as explanatory studies.
- The multiple cases study method implemented in the research helped to attain the final goal of analysing the most effective risk management activities in the design, engineering and development phases of the manufacturing organizations.
- Risk management also has a trajectory in which the risk management tends to become more structured and formalized as the organization grows in experience as well as size or magnitude.
- It is important that the risk management activities as concluded as effective, should be institutionalized in organizations.
- The researcher points out that fsQCA is most effective when the ratio of number of cases to conditions is 2:1.
- The scientific and the managerial contributions of the research are depicted. The researcher advises that in order to increase the internal validity of the project, the research should be extended by testing the risk activity models in other manufacturing organizations especially other automotive industries. The external validity of the project can be improved by trying to extend the risk activity models for the production based organizations.

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APPENDIX

CHAPTER 1.

1.2 Definitions of Key Terms

In this section we define some of the key terms that are used in the report. We clarify the definitions of Risks, Risk Management, “Design, Engineering and Developmental phase”, Risk Management Strategies, Complexities, Interfaces, Contexts, and Project Outcomes. The following are the definitions of the above terms.

Risks: Risks can be defined as any uncertainty that if it occurs would have either a positive or a negative effect on the achievements of one or more objects of a project. Risk is a probability that an event will occur. Hence it is a potential future event. An issue can be defined to be the result of a risk that has happened. An issue is generally addressed from a negative perspective. There is big difference between a risk and a problem. A problem exists in the present. It must be addressed now. (PMBOK), (J.G.V.Hernandez, May 2010), (D.Hillson & P.Simon)

Cause: The cause describes existing conditions that might give rise to risks. (D.Hillson & P.Simon)

Effects: The effect of an event arises in the future (that is it is not a current problem). However its existence depends on whether the related risk occurs. (D.Hillson & P.Simon)

Risk Management: Risk Management refers to the process of understating the nature of uncertain future events and making the positive plans to mitigate the uncertain future events where they present threat or take advantage of them where they present opportunities. Risk management should facilitate the innovation and product development process rather than stifle them. The following are the benefits of Risk management: (T, R, & R, February 2005)

- Risk management enhances the ability of an organisation to manage risks at all stages.
- The best solution is to improve project performance by means of systematic identification, appraisal and management of project related risks.
- Decision making inside an organisation should be more controlled, consistent and yet it should be flexible.
- Risk Management should establish the appropriate contexts of the problem.
- Recognise the risks of the project which the stakeholder organization will face.
- Analyse the identified risks.
- Develop the response to those risks.
- Control and monitor the risks during the projects.
- Risk management should allow the post project capture of the risk knowledge.

Design, Engineering, Developmental phase:

A product is realized in a manufacturing organization due to a number of logical project stage gates. (J.B.Schmidt, Fall 2001) The very first stage is the conceptualization of an idea. The research and development unit is primarily responsible for generating a new solution to cater to the constant demands of up gradation of the technology of the client. The customer requirements and necessities are reported to the research and development team via the marketing and sales force as feedback. The incepted idea is defined and shaped into a business plan by the culminated efforts of the R&D, Business Development teams and the marketing units. The business plan is further strengthened by designing the process to achieve the desired product. The business development team is responsible for recognizing the essential actors of the various crucial stages of the project. The time frame for the execution of the project is determined. Hence they schedule the respective stages of the project. **The very next stage is the Engineering and Design phase. It is an extremely crucial phase since it acts as the corridor and interface between the conceptualized theoretical solution and the physical structure of the prototype.** (PMBOK) The Engineering and Design team is responsible for delivering the blue prints of design to the Manufacturing and Assembly units. The Manufacturing and the Assembly unit backed by all the engineering, design teams and all vendors and suppliers integrates and assembles the products. The realized prototype undergoes rigorous testing process by the Quality and the Testing units. This ensures the validity and the robustness of the new product developed. Hence the complete process from the Engineering and designing of the conceptualized idea to the final testing of the goodness of the prototype can be defined to be the “Engineering, design and Developmental Phase”. The diagram below illustrates the definite stages of the new product development process (NPD) tending towards mass production. (J.B.Schmidt, Fall 2001)

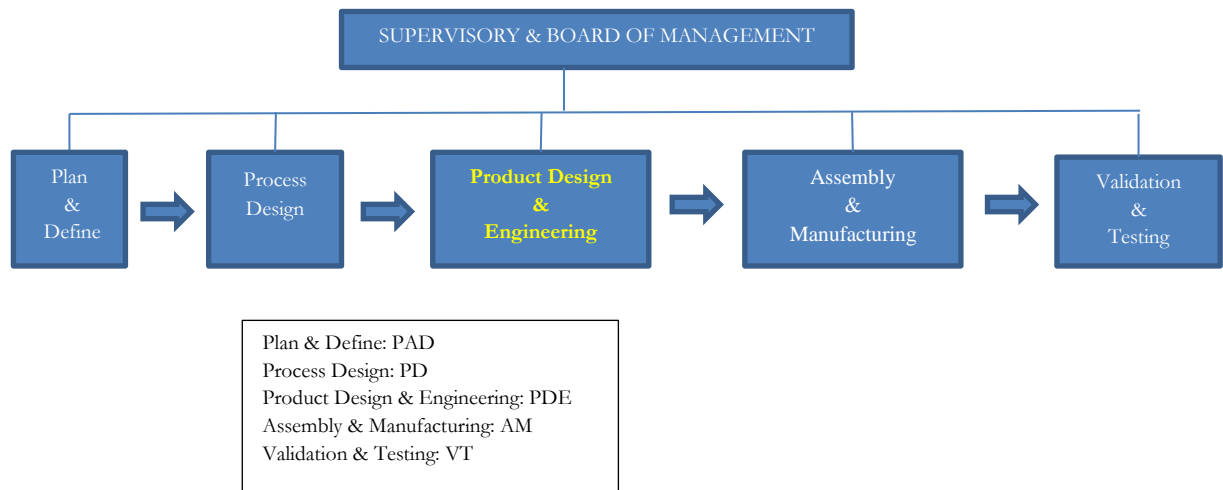


Figure 42: Stage gates of New Product Development

Risk Management Activities: Risk management activities can be defined to be the methodology or approach adopted by the organisations in order to manage the risks identified in the organisation. Hence risk management strategies are a process for identifying, assessing, managing risks and uncertainties, affected by internal and external events and scenarios, that could inhibit an organisations ability to achieve its strategy and strategic objectives with the ultimate goal of creating and protecting shareholder and stakeholder value. (M. Jifeng, 2009)

Complexities: In view of an organisation, the system approach extends to the theory of complexity, which in terms of social systems corresponds to the idea of system which denotes presence of many independent entities, agents that behave in accordance with their objectives and perform mutual interactions. Complexity as a characteristic feature grows when interdependence of the elements within the system becomes relevant. The dynamics are present because of interrelations, interactions and influences of numerous agents. (M.Hobbey, 1998)

Interfaces: Interface can be defined to be the point where two systems, subjects, organizations, meet and interact with another system or person. Hence an interface can be defined to be the point of conjunction between two organisational functional units. An interface can also be defined to be a tool or a program which synchronises the functionality of two components and subsystems, which in turn leads to the successful functionality of the entire system. (R.Fabac, 2010) (M.Hobbey, 1998)

Contexts: Contexts can be defined to be the boundaries or the aspects of the risk management. It can also be defined to the circumstances that form the setting for an event, statement or idea. In relevance to this report context rather refers to the various factors which are relevant to risk management.

Project Outcomes: Project outcome in the context of this report refers to the result or the way consequences shape up in terms of the various stage gates of a project. Project outcome might not necessarily mean the final result of a project. Project outcome can be viewed as the influence of certain strategic plans and actions which have been executed in order to achieve certain predetermined goals, on the project proceedings.

1.3 Research Problem Statement

Literature and theory proposes, various risk management frameworks. Risk management activities as mentioned in the literature, are generally in the nature of algorithmic steps, which follows certain preconceived steps. However, there is no standardized uniform approach to risk management in the industry. Moreover in the industry the primary goal is to achieve the targets set during (M. Swink, 2006) the project planning, by means of project management. At times circumstances rise to intense complexities. Projects reach stagnation. At such instances during the project a formalized risk management framework might not be effective, which propels the project ahead. Managers rather tend to deal with problems and issues Proper application of risk management saves time, money, and improves the quality and outcome of a project. (M. Swink, 2006) However improper application of risk management may lead to more complexities in the project outcome. (D.Hillson & P.Simon) It is necessary to carry out risk management in an efficient and effective way. Moreover unnecessary risk management tends to stifle product or system development. Excessive Risk Management even tends to stifle innovation. (J.G.V.Hernandez, May 2010) Through my research I would like to find the correlation of how independent risk management activities influence project outcomes. It is important to study the different risk management strategies implemented industry to manage the identified risks. Hence analysis of the practical risk management approaches would enable me to find out the differences between the proposed theory and industrial practices. This will enable me to generate hypothesis related to project outcomes due to definite risk management approaches.

There are always common excuses of not carrying out risk management practices. It is difficult to find time in an already overloaded working environment. Even when time is found, risk processes cost money as effort is spent in risk workshops and review meetings. There is always a cost of addressing risks, but it is important to realize that risk management is an investment of near future. Moreover if risk management is performed without proper commitment, it is not effective. Hence it is important to carry out risk management in an effective and strategic way. (M. Swink, 2006) Failing to identify risks does not

make them go away. The risk impacts tend to cascade and magnify. Hence it is important to manage the risks of product development in an effective and strategic way. However in practicality, situations, contexts and complexities force the teams to deviate away from the theory of risk management. Following the theories might not fetch the optimal results, and calls for dynamic and flexible decisions to be taken.

It is quite clear what risk management is. The problem is not a lack of understanding the why, who, or when of risk management. The lack of effectiveness comes from not knowing how to manage or carry out risk management activities. The problem lies in not knowing which is the most effective ploy or activity for a certain situation. (D.Hillson & P.Simon) It is important to analyze how the risk management is carried out and how is it beneficial to the project outcome. It is essential to establish a causal relation between the independent risk management activities and the dependent project outcome, so that companies perceive the distinct benefits of carrying out risk management activities in the process of product development. The perception of risk management in real life projects will also give an opportunity to improve the existing risk management tool or algorithms.

CHAPTER 3

3.2.1. Risk Management Initiation

Risk is an uncertain event or condition that if it occurs it has its effect on at least one project objectives which is scope, schedule, cost, quality. A risk may have one or more causes and if it occurs it may have one or more impacts. Project risks have its origin in the uncertainty present in all the projects. Organizations and stakeholders are willing to accept varying degrees of risks. This can be defined as the risk tolerance. Risks are accepted if risks lie within the tolerance level. Individuals and groups adopt attitudes towards risks that influence the way they respond to it. The risk attitudes are driven primarily by biases, perception and tolerances wherever possible. The normative literature suggests that there are certain phases or risk management. Risk management can be planned following certain predetermined steps. The very first step of Risk management is Risk Initiation, where the structure of the risk management is planned. (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012)

Usually a project is manoeuvred in terms of its scope, cost, schedule, and plan of communications, which is further guided by the organizational processes. The initiation of the project usually starts by realizing the key aspects governing the critical aspects of scope, cost management, time management, planning of interactions and certain rules and procedures that the organization follows.

The process of Risk Initiation helps to identify the main goal of the project. Hence the periphery and the boundaries of the project are realized. Hence the scope definition helps to realize the following aspects: (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012), (D.Hillson & P.Simon), (PMBOK)

- The range of possibilities, the deliverables of the project, and also the significance the risk management will have on this project.

The financial costing and the budgeting of the project is extremely essential. The financial support helps to propel a project ahead. Hence the cost management plan is essential for the following aspects:

- The cost management plan helps to realize the risk budgets, the financial contingencies and the reserves that the project should have.

Once the financial support is ensured the project should be conceived and fragmented in a certain time scale, where each and every crucial stage gates are scheduled. A certain time frame is extremely necessary to propel project execution. Hence project time management helps to realize the essential aspects:

- Stage gate achievement time lines.
- The schedule of contingencies.

Once the project time frame is visualized, it is important that the communications and the interactions amongst the different functional units in the organization are planned. Hence the planning of communications helps to realize the following aspects:

- It helps to define the Interactions.
- The people and actors who are available to share information.
- The different authorities and the hierarchies who are crucial for the decision making.
- Communications also helps to define the various risk categories.

The organizational processes and assets bring about decorum to the risk management cycle. The risk initiation is carried out by means of planning meetings amongst all the actors. The diagram below illustrates the steps of Risk Initiation. The Risk Initiation step is followed by the Risk Identification Step.

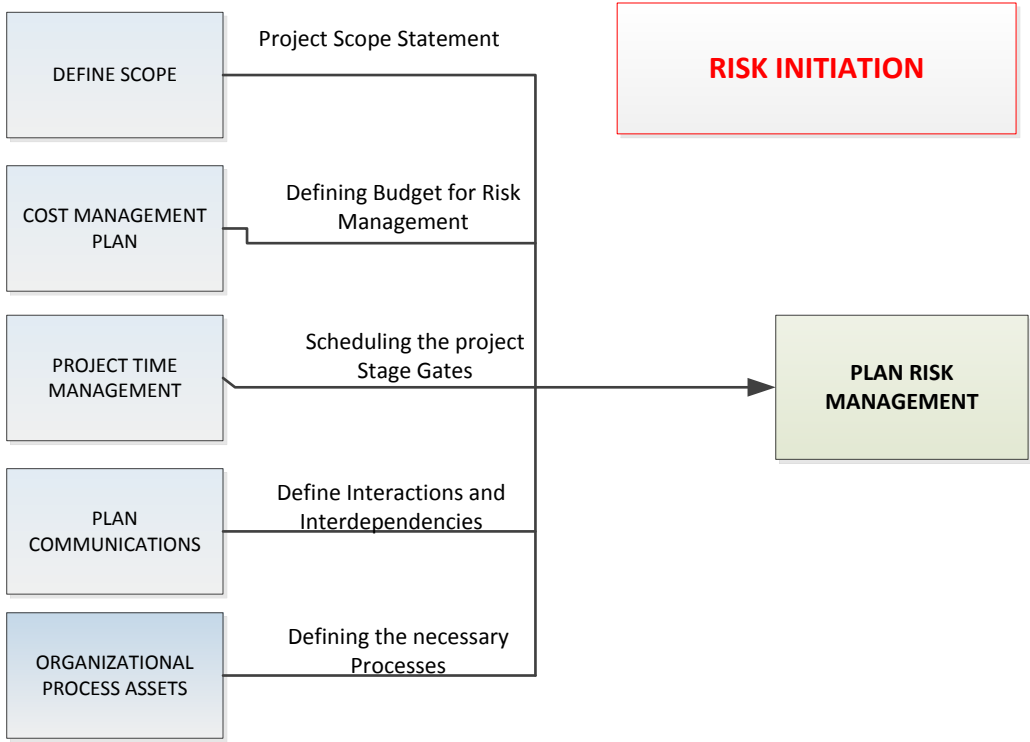


Figure 43: Schematic Diagram of Risk Initiation

3.2.2. Risk Identification

Risk Identification is an important step in the Risk management lifecycle. Risk Identification is crucial since the ability to foresee upcoming risks, helps to plan the execution of a project. To make risk identification effective it is important that there are certain critical inputs from the Risk Initiation step. (D.Hillson & P.Simon), (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012), (PMBOK)

At the very outset the organisational process assets needs to be freezed. The organizational process controls helps to realize the complete organizational hierarchy structure through which the decision making of the project plan flows through. The organizational process assets also decide on the project documentation procedures which need to be followed. The schedule management plan provides the crucial input of the viable project management time. It provides the possible activity duration estimates of the various stage gates and important deliverables of the projects. The next extremely crucial input for the risk identification stage is the estimates of the project costs that are made in the project initiation step. The scope baseline determined in the project initiation stage helps to fragment the project into the preliminary work breakdown structure. The work breakdown structure is also a very crucial input

for the Risk Identification stage since the WBS helps to realize the important actors and stakeholders who are responsible for carrying out the important activities. To have an efficient Risk Identification it is important to realize the network and the cluster that is important for realizing the complete project. (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012), (PMBOK), (D.Hillson & P.Simon)

Risk Management also depends on Quality Management, since it is important to define the tolerance levels of addressing an identified risk. It is important to define the Quality standards of the entire system as a hole, the subsystems and the components individually. The past risk trends, industry studies, risk attitudes, published information and academic studies also act as important critical information for identifying risks. (D.Hillson & P.Simon), (J.W.Troxel & P.L.Schillings, Nov 1993), (J.W.Troxel & P.L.Schillings, Nov 1993)

Once the necessary information is gathered Risk identification can be carried out using various tools and techniques. Literature identifies Brainstorming by experts, Delphi technique, and Root cause analysis, creating checklists, making system analysis, fault tree diagrams, Ishikawa cause and effect analysis, SWOT analysis being some of the effective tools for identifying Risks. The primary output of the Risk Identification process is the creation of the Risk Register. The Risk register lists out the cause of the risk, the event that might occur and the effect the event will have in future. Risk Identification forms the baseline for assessing and prioritizing the risks.

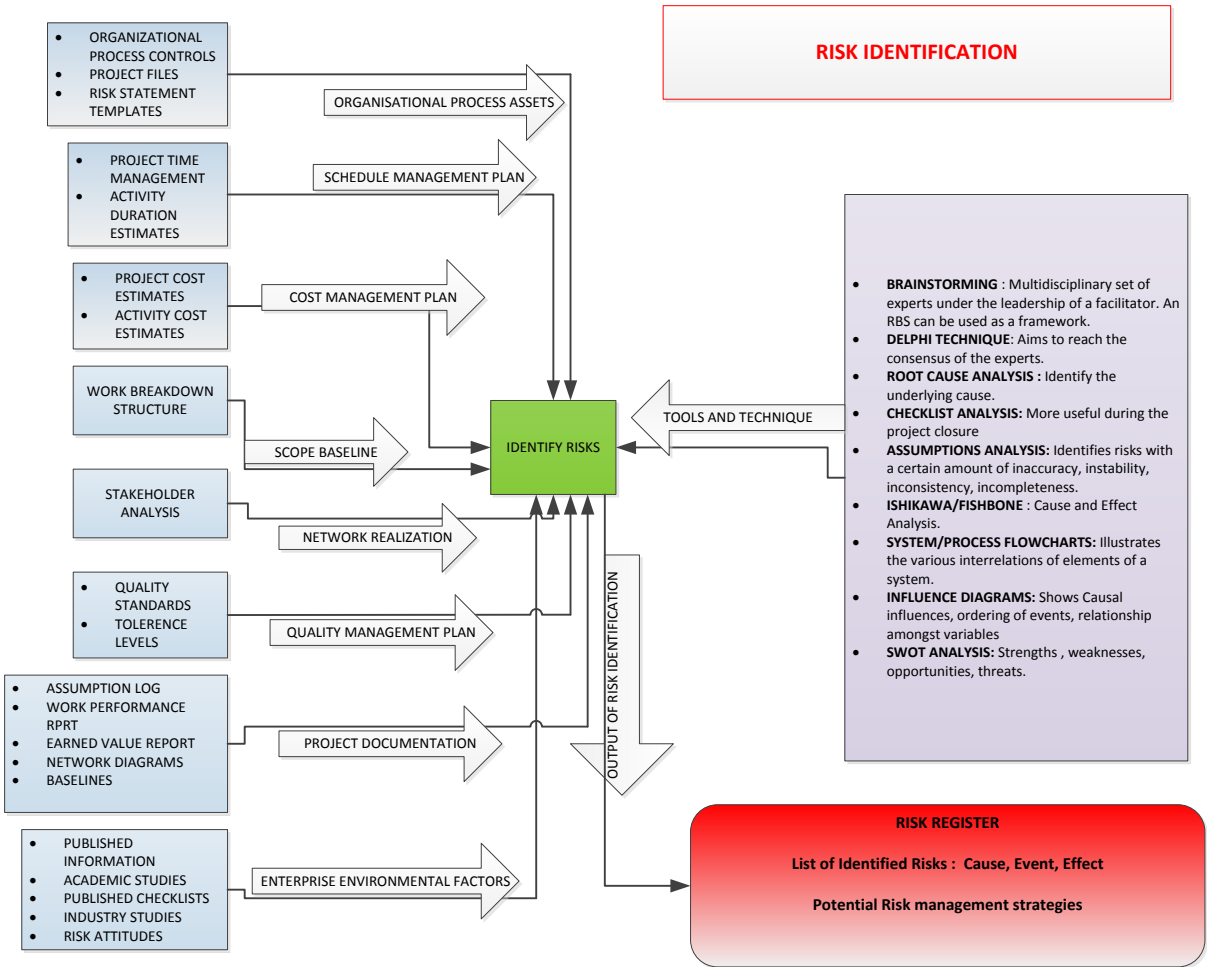


Figure 44: Schematic Diagram showing Risk Identification

3.2.3. Risk Assessment or Prioritization

Once the risks of the process are identified, it is extremely crucial to make an assessment of the risk impacts. The identified risks are prioritized depending on the respective risk impacts. The risk index is calculated as the product of the probability of occurrence and the risk impact. The primary goal of the risk assessment is to make a correct assessment of the future consequences as the result of occurrence of an event. Generally the primary focus is on high priority risks. In an organization's perspective, the risk tolerance level is extremely essential to be determined in the Risk Initiation step. A clear vision and acceptability of the tolerance level helps to assess risks. Moreover the project objectives and the project goals help to judge which project will have a greater impact. Hence the identified risks can also be prioritized on the scope of the project which can be associated to the scope, cost and quality. Risks can be either assessed on a qualitative basis or on a quantitative basis.

The qualitative judgment forms the foundation of the preliminary judgment. Qualitative Risk analysis is a rapid and cost effective means of establishing priorities, but the quantitative risk analysis gives an appropriate numeric value which is defined as the risk rating. (S.M.Sadaba, A.P.Ezcurdia, A.M.E.Lazacano, & P.Villanueva, 2014), (D.Hillson & P.Simon), (PMBOK)

Qualitative Risk assessment generally helps to update the risk register with the assessed impacts which are expected as a result of the Risk assessment. The following are the outputs of the Risk assessment:

- Relative ranking or the priority list of projected risks. The probability and impact matrix is used to classify risks according to individual significance. They are grouped as high, very high, low, very low and medium.
- Further Qualitative risk analysis helps to categorize risks and it also reveals root causes. It defines the particular areas in the project that needs attention. Realizing the concentration of risks improves the effectiveness of risk responses. As an analysis is repeated, the trends for particular risks become apparent.

The figure below charts out the various necessary inputs for carrying out Qualitative risk assessment for a particular project. The tools and techniques which are necessary are as follows in (fig

Qualitative risk assessment depends completely on the actors ability to perceive the risks on their past experiences and the various contextual inferences. The various scenarios helps to judge the possibility or the frequency of a risk occurrence. The next immediate step after the risks are assessed through qualitative methods is to conduct a quantified risk assessment. Quantified risk assessment brings about more precision, accuracy and transparency of the risk impact that has been judged through the qualitative methods. Quantitative risk assessment brings about more specificity in the risk rating. Especially when risk processes include both the threats and the opportunities, modelling outputs are neither optimistic, but they are more realistic and they reflect the true risk exposure of the project. Usually for quantitative risk estimation a single analysis is carried out for much iteration. Quantified risk analysis also acts as a part of the Monitor and control of risks. It determines if the overall project risk has been decreased or increased. The numerical rating and the numerical analysis of the risks helps to plan risk responses and the actions. The figure below explains the necessary inputs required for carrying out quantitative risk assessment and it also explains the various tools and techniques which are efficient in carrying out risk assessment. (D.Hillson & P.Simon), (PMBOK)

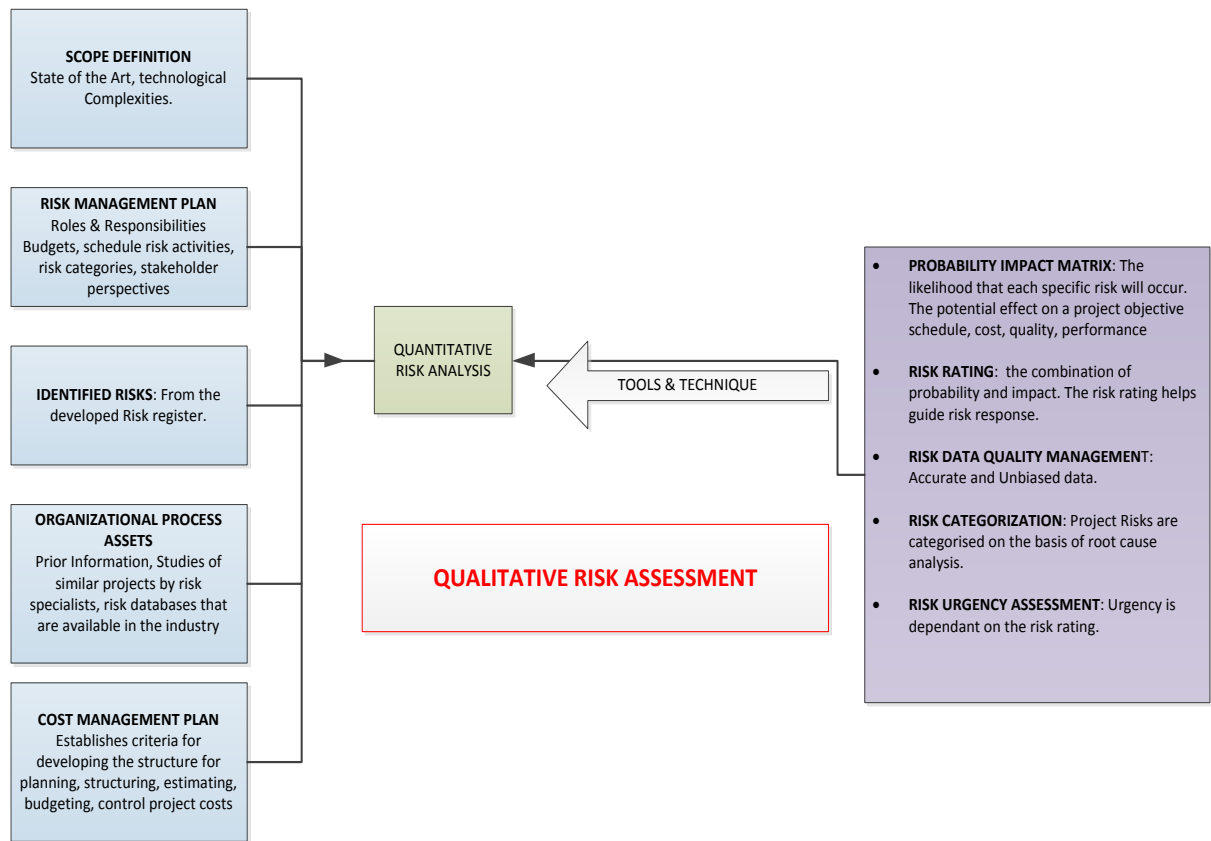


Figure 45: Schematic diagram showing the different Tools and Techniques for Qualitative Risk Management

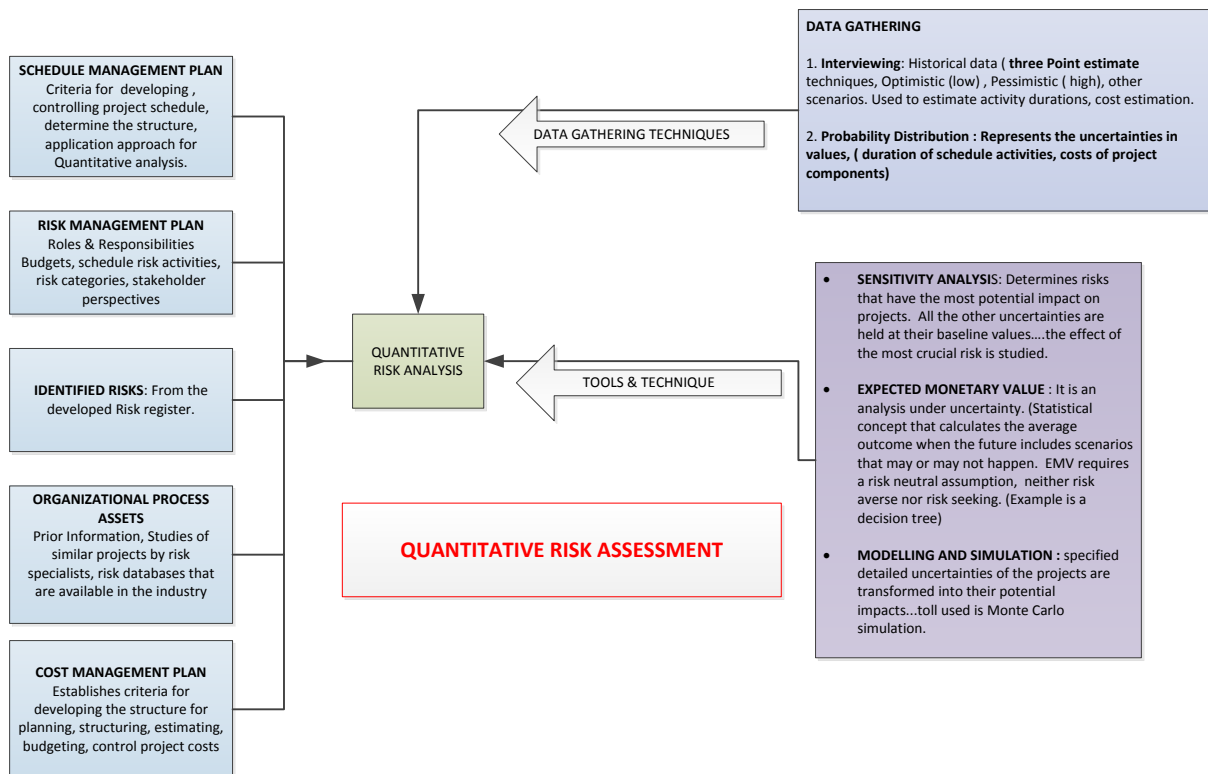


Figure 46: Schematic Diagram showing the different methods for Quantitative Risk Assessment

3.2.4. Risk Planning

Planning risk responses is the process of developing options and actions to enhance opportunities and reduce threats to project objectives. Risk responses addresses the risks by priority, inserting resources and activities into budgeting, scheduling and project management plan as needed. It is important to select the best risk response from the several plans that are possible. It is important to address negative risks in a specific way and opportunities in a different strategic way. The project planning must be realistic within the project context. It must be significant, cost effective and agreed by all the parties. More important is the fact that the timing of the execution of the planned action should be absolutely apt for get the best outcome. The project objectives can be changed or isolated from the risk impacts. Negative risks are generally addressed in the following ways: (PMBOK), (S.M.Sadaba, A.P.Ezcurdia, A.M.E.Lazacano, & P.Villanueva, 2014), (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012)

- The schedule of the project can be extended.
- The specific strategy which is being implemented can be modified to achieve the goal.
- If realized that the scope of the project is too broad then the scope of the project can be reduced to achievable limits.
- If the project is beyond manageable limits then the project should be shut down.
- If it is realized that the project lacks adequate resources then the project requirements should be clarified.
- The process of obtaining necessary information should be designed correctly. Communication amongst the different functional units might be improved.
- It might be necessary to acquire expertise knowledge to increase the tacit knowledge of the project group.

The general methods of mitigation of risk activities can be categorised as the Risk Avoidance, Risk Transfer, Risk Acceptance, and Risk Reduction. There is a tendency to shift some or all of the negative impact of a threat, along with the ownership of the response to a third part. Transferring a risk tends to have the possibilities of paying a risk premium to a party who takes the ownership of handling the risks. Contracts can be used to signify the liability of specified risks to another party. Literature suggests that there are different methods of reducing the risks of an adverse risk event. The following mentioned are the procedures: (S.M.Sadaba, A.P.Ezcurdia, A.M.E.Lazacano, & P.Villanueva, 2014), (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012), (PMBOK)

- Literature suggests that risks can be accepted if the impact of the adverse risk between the acceptable threshold limits.
- The probability of the risk can be reduced.
- Designing redundancy into the system may reduce the impact of the risk and can also reduce the possibility of the failure.
- The complexity of the process may demand to adopt less complex processes.
- To ensure that the project abides by quality standards more number of tests can be conducted..
- Literature also suggests that the linkages should be targeted to determine the severity of the impact.
- Developing a prototype is always a main solution to conceptualize the various problems.

Sometimes it is not possible to eliminate all the threats from a project and hence the strategy of risk acceptance is adopted. A negative risk is generally accepted when it is impossible to identify any other important response strategy. The strategy can be active or passive in nature.

Positive risks and opportunities are dealt with different strategies. The positive risks and opportunities needs to be exploited. Organizations most talented resources are assigned to the project to reduce the time to completion or to provide lower costs than originally planned. It is important to identify and maximize the key drivers of the positive impacts. In this case the risks may increase the probability of

their occurrence. At times the risk is shared with a third party and someone who has the ability to capture the opportunity for the benefit of the project. Certain contingent risk strategies are designed to ensure that the some responses are designed for use only if certain events occur.

The primary outputs of the Planned risk responses are: (D.Hillson & P.Simon), (PMBOK)

- The phase generally ends with agreed upon risk strategies.
- Plans specific actions to implement chosen strategies. It triggers symptoms and warning signs of risk occurrence.
- It plans upon the budget and scheduled activities required to implement the chosen strategy.
- It decides upon the contingency plans. Hence it triggers the call for their execution.
- It strategizes the fall back plan for use as a reaction to a risk that has occurred and the primary response.
- It identifies the residual risks that are expected to remain after planned responses have been taken.
- The risk planning phase also tends to plan the secondary risks that have been deliberately taken.
- It determines the plan of strategies for risks related to contract decisions. These are the decisions to transfer risks, agreements for insurance, contractual services, and other appropriate items are selected in the process.

3.2.5. Risk Review

The best risk planning in the world is not of any use unless you have a clear picture of how the situation in you project is developing into reality. It is imperative that you keep track of the identified risks, monitor the effectiveness of your risk responses, and identify new or changed risks. It is important to have effective reporting mechanisms in place and ensure that risks are covered in all key reports and reviews. Most of the key issues are covered in the section on managing project phases in the project management procedure. Effective monitoring and control also involves creating the right conditions for openness and transparency in the project. The most crucial steps for risk monitoring can be defined as follows: (T, R, & R, February 2005), (B.Guebitz, H.Schnedl, & J.G.Khinast, 2012)

- Risk reassessment involves the identification of the new risks, reassessment of the current risks, and closing of risks that are outdated.
- Risk audits are also important mechanisms of carrying out risk monitoring since the appropriate frequency of occurrence of the risks can be judged. Risk audits help to judge the effectiveness of the risk management process. It may include routine project review meetings, or separate risk audit meetings may be held. The format of the risk audit and its objectives are clearly defined before the audit is conducted.
- Variance and trend analysis helps to compare the planned results to the actual results. The trends in the project execution should be reviewed using the performance analysis tools.
- In the process of risk monitoring even the technical performances are measured. The process compares the technical accomplishments during the project execution to the project management plans for scheduling technical achievements.

3.2.6. Risk Assessment Tool

RI: Risk Identification

RA: Risk Assessment

RP: Risk Planning

RR : Risk Review

TOOL	SCOPE	QUALITY	TIME/SCHEDULE	COST	HOW/METHOD	KNOWLEDGE ACQUIRED	ORGANIZATIONAL RESPONSIBILITY
Critical Path Method	RI		RI		<ol style="list-style-type: none"> CPM assesses the probability of uncertainty related to time required to complete project activities. It determines the critical activities on the longest path. It aims at shortening the critical path by adding resources. 	<ol style="list-style-type: none"> It helps to assess the time span and the time duration of the project. PROJECT TIME MANAGEMENT Realize methods in which project duration can be shortened. ORGANIZATIONAL PROCESSES Realize crucial and main activities. IDENTIFY RESOURCES which helps to smoothen project execution. 	<ol style="list-style-type: none"> CPM is used mainly during the planning phase. More PROCESS MANAGEMENT before project execution. The Engineering Team, Design Team, Manufacturing Team, Testing Team should provide a predetermined schedule of the crucial activities. The purchase and procurement unit determines the time schedule of procuring the subsystems or components
Program Evaluation & Review Technique	RI,RP		RI,RP		<ol style="list-style-type: none"> Pert is used to schedule, organize and co-ordinate tasks for complex projects with many interdependencies. Network diagram is constructed using activity sequence information. It mainly provides the Expected Project completion date, probability of completion before a specified date, critical path activities that directly have an impact on the completion time. Primarily helps in decision making. 	<ol style="list-style-type: none"> Schedule of the project (TIME SPAN), PROJECT TIME MANAGEMENT. Realize COMPLEXITIES and INTERDEPENDENCIES within functional units and external resources. ORGANIZATIONAL PROCESSES. Sequence of Activities. 	<ol style="list-style-type: none"> Helps to create a network amongst the R&D team, the Marketing Team, The Engineering and Design Team, The Manufacturing Assembly Units, and External Suppliers and Vendors. Responsibilities of Teams to pre plan their activities and let the team know of the schedule of activities. Realize each other's interdependences.
Model Predictive Control		RA, RR	RA, RR	RA, RR	<ol style="list-style-type: none"> MPC is a prediction model of the entire process which is used to predict the future evolution of the process. At a certain time it helps to solve an optimal problem over a finite future horizon. 	<ol style="list-style-type: none"> Helps to predict a trend in the future. Having a perception and Knowledge of the future the present actions are taken. COST AND TIME MANAGEMENT 	<ol style="list-style-type: none"> The Sales and Marketing Team is in close affinity to the Planning Department. The Sales and Marketing team generally has experience of the past trends, knowledge of the market and the competitors. Moreover after the project has been executed the Sales and marketing unit along with the Production and Planning department keeps a review of the trends and risks. They have the ability to provide a futuristic vision.
Failure Mode Effects Analysis	RI, RA, RP	RI, RA, RP			<ol style="list-style-type: none"> FMIEA is a proactive method which identifies the different risks, it assess the relative impact of different failures, and identifies parts of processes that needs to be changed. The causes of the risks are identified, and the Risk Priority Number is calculated, and hence it suggests the actions to reduce the occurrence of failure. 	<ol style="list-style-type: none"> It provides the organization knowledge of the various probable risks. (According to SCOPE, RESOURCES, COST, and TIME, TECHNICAL COMPLEXITIES, And ORGANIZATIONAL STRUCTURE). Helps the organization to realize their drives and goals of the project. Hence the knowledge helps to 	<ol style="list-style-type: none"> The various cross functional units should make each other aware of their perceived risks. Integral activity of the organization in terms of designing of Products, Processes' and Services. It is the responsibility of the cross functional units to discover the potential failures and the cause of the potential failures

						prioritize the risks in terms of Cost Impact, Time Impact, Scope Impact. And Risk Probability	4. FMEA is usually conducted by a core team of 3 or 4 people with supporting subject matter experts.
Responsibility Assessment Matrix	RI,RP		RI,RP		1. RACI hierarchy matrix is constructed to delegate tasks, activities, create milestones, and clarify expectations on their own level of participation.	1. RACI matrix brings about the knowledge in the clarity of the job allocations, expectations and responsibilities of each individual. ORGANISATIONAL PROCESS	1. The organisation creates a RACI Hierarchy. 2. Projects involve large number of people often from different departments, functions and divisions. 3. People are designated to be either Responsible for a Task, Accountable for a Task, or Informed about a certain process, or consulted for certain actions.
Root Cause Analysis(ISHIKAWA / FISH BONE ANALYSIS/ BOW AND TIE)	RI	RI			1. Root cause analysis is a tool which helps in risk identification by means of a cause and effect diagram. The causes and effects are categorised in terms of Environment, Material, People, Method, and Machine. 2. It identifies the probable causes of an identified problem.	1. It helps to gain knowledge of the cause of a risk. 2. It further categorizes the cause of the Risk to be either due to the Environment, Material, People, Method and Machine. 3. In the pursuit of corrective measures it helps to gain knowledge of the Root Cause of the failure.(TECHNOLOGICAL COMPLEXITIES, ORGANIZATIONAL COMPLEXITIES, MATERIAL ISSUES)	1. Can be performed by a single person , however the outcome is more effective when a group of people work together to find the problem causes. 2. The organisation is responsible for removing the identified root causes. Prominent members of the analysis team set out to uncover them. 3. Team members belong to business processes or area of the organization that experiences the problem. 4. Analysis lasts for a couple of months ... evenly distributed between defining and understanding the problem.
Fault Tree Analysis	RA	RA	RA	RA	1. Fault tree analysis is a Logical and probabilistic technique used in probabilistic risk assessment (PRA) and system reliability assessment. 2. Fault trees are logical deductive methods for analysis of hazards that leads to an accident. This is a logical sequence of a top event which is the objective or the problem, the scope, the resolution and finally the ground rules.	1. FTA provides knowledge of the top level of problems. 2. Provides knowledge of the parallel or the serial combinations of malfunctions to find the root of the problem. 3. The knowledge helps to correct the problem before it occurs again. 4. The technique provides a graphical aid for the analysis and it allows many failure modes including common cause failures. TECHNOLOGICAL COMPLEXITIES	1. It is the responsibility of the team to implement FTA especially in the Design and Engineering Phase. 2. Experts who have the ability to visualize potential event sequences , evaluates the incident consequences of the outcomes. 3. They have the responsibility of estimating the risk of events occurring.
Delphi Technique	RI				1. Delphi technique is a risk identification tool that tends to realize the scope of the project, where a panel of experts try to reach a common consensus. 2. The experts try to define the scope of the project, and hence in the process identify the probable risks.	1. Delphi Technique is generally implemented in the preliminary stages of the planning phase before the project execution. 2. Helps in realizing the boundaries of the project and hence the scope of the project. DEFINING THE SCOPE	1. It is the responsibility of the experts of the various processes or the functional silos to use their expertise to identify and visualize the risks associated with the project in the context of the Technology and the organizational structure. 2. The experts use their past experience to channelize the execution in the right direction.
Three Point Estimates			RA	RA	1. It is a tool in which the likelihood of occurrence of a risk in the various stage gates of a project are estimated on a scale of low, most likely, and high.	1. Three point estimates is a tool which is used in the preliminary stages of the project, which acts as a probability impact matrix, which provides the knowledge of the probability and the impact of the identified risks. (TECHNICAL COMPLEXITIES, SCOPE, TIME, RESOURCES)	1. The responsibility of the experts of the various functional silos to assess the impacts of the various identified risks.
Sensitivity Analysis(Tornado Diagram)		RA, RR		RA, RR	1. Sensitivity analysis is a technique by which critical components' or factors of a project are varied to test the substantial changes in the output of the project.	1. The tool of sensitivity analysis helps to identify how the uncertainty in the output of a mathematical model or system can be apportioned to	1. It is the responsibility of the organization to identify the critical factors which when changed, destroys the optimum balance of the optimum balance

					<ol style="list-style-type: none"> Sensitivity analysis is generally carried out for determining prices and quantities of the project. Tornado diagram helps in prioritizing the risks depending on the impact scales. 	<ol style="list-style-type: none"> different sources of uncertainty in its input. A related practice to gain knowledge of the Robustness of the prototype. Helps to gain a vivid knowledge in the parameters of the input. Hence the knowledge helps in uncertainty reduction. (TECHNICAL COMPLEXITIES, COST MANAGEMENT, QUANTITY TO BE PRODUCED) 	<p>of the functionality of the product.</p> <ol style="list-style-type: none"> It is the responsibility of the organisation to realize the various factors that could have a great impact on the price and quantity of the product to be manufactured. The sensitivity analysis is generally carried out in the testing phase when the prototype is tested, with the expert inputs from the R&D and the Engineering and Design phase.
Monte Carlo Analysis		RA , RP	RA , RP	RA, RP	<ol style="list-style-type: none"> Monte Carlo Simulation is based on the generation of random numbers, which allows the random sampling of arrange of possibilities from predefined input data in a risk model. The input data reflects the degree of uncertainty in the project, based on the risks exposed in the risk process. Monte Carlo analysis is generally represented by a histogram which shows the range of possible outcomes. The Y axis on the left hand side demonstrates the number of times a particular outcome was achieved. Monte Carlo analysis plots the range of possible outcomes against the cumulative probability of achieving a given value. 	<ol style="list-style-type: none"> The Monte Carlo analysis provides the knowledge and ability to predict future performances against key objectives like time and cost and indicates the range of possible outcomes from best case to worst case. It calculates the statistical mean or expected value if no further action is taken. It gives a view of the overall project risk exposure arising from the totality of risks which might affect the project. It makes an analysis of the effectiveness of the planned responses. The analysis provides exact numbers rather than a ambiguous analysis or approximation of High or Low. It exposes the key risk drivers. The risks which have the greatest influence on the overall project outcome. COST MANAGEMENT, TIME MANAGEMENT 	<ol style="list-style-type: none"> It is the responsibility of the organisation to use well established statistical techniques and computer software. It predicts the overall risk of the project. The organization should aim to achieve a more quantitative or an appropriate risk probability number which is more significant.
RATA	RP	RP	RP	RP	<ol style="list-style-type: none"> RATA is a risk planning tool in which the identified risks are either reduced, or avoided, or transferred to a third party or accepted. 	<ol style="list-style-type: none"> This tool provides the knowledge which is necessary to plan the action of the mitigation strategy, or the risk management strategy. KNOWLEDGE OF HOW TO PERFORM RISK PLANNING 	<ol style="list-style-type: none"> It is the responsibility of the organisation to identify the functional units and silos that are responsible for and capable of tackling the identified risks. The individual experts of the functional units should come together and by means of process management they should decide the appropriate strategy to mitigate the risk.
Layers Of Protection Analysis(LOPA)	RP	RP	RP	RP	<ol style="list-style-type: none"> LOPA is a powerful risk analysis tools which helps in assessing the adequacy of protection layers used to mitigate process risks. It applies in the various stage gates of the lifecycle of a project, where the team decides on a protection measure to encounter hazards. It is most successful in front end loading of the project. 	<ol style="list-style-type: none"> LOPA provides knowledge of the various risk management strategies that has been planned for the various stage gates of the project. Each and every project stage gate has certain risks which are associated to it. LOPA provides knowledge whether a precautionary measure has been taken or not. PERFORM RISK PLANNING 	<ol style="list-style-type: none"> Different functional silos are responsible for activities of the different stage gates of the project. Hence experts of the different processes are rather equipped to know of the risks of each stage gates. Hence they are expert in planning out the risk management strategy of each stage of the project.
Risk audits	RR	RR	RR	RR	<ol style="list-style-type: none"> Project audit teams which can be internal audit teams of the organisation or external audit teams, ensures that the project teams are abiding by the risk regulations, and standards of the government and the organisation. They ensure if adequate risk management measures are taken. It can be visualized as a tool for 	<ol style="list-style-type: none"> Provides the knowledge if the organization is following the self-implemented process rules. Risk audits provide knowledge if there is a fault in the final prototype or there is a lack in the quality of the final system/ product/ or even subsystems or components. ORGANIZATIONAL 	<ol style="list-style-type: none"> It is the responsibility of the organisation to have external or internal risk audit teams performs inspection of the organizational processes and the final prototype.

					risk monitoring.	PROCESS	
Variance and trend analysis	RI, RP		RI, RP	RI, RP	<ol style="list-style-type: none"> 1. Trend analysis reveals a certain pattern or trend when one looks at a large amount of data or information. 2. Variance or trend analysis can be used to predict future events or even understand changes over a time. 3. It has the ability to predict business cycles, trends and hence effectively manage projects. 	<ol style="list-style-type: none"> 1. Provides knowledge with past data. 2. The knowledge helps to identify trends and sequence of activities in future depending on present circumstances. 3. It gives knowledge of the past experienced risks, with similar contexts and factors. ORGANIZATIONAL PROCESS	<ol style="list-style-type: none"> 1. Usually the trend and variation analysis is a kind of a market analysis. 2. Hence it is the prime functionality and responsibility of the Sales and Marketing team along with the Production and Planning units to make a strong market survey of the related risks of the various scenarios and contexts.
Earned Monetary value/ (EVS: Earned value Analysis)				RR	<ol style="list-style-type: none"> 1. It is a tool or technique which helps to evaluate the monetary expenses, which analyses if the expected project costing is similar or varying with respect to the planned project costing or budget. 	<ol style="list-style-type: none"> 1. It provides a basic estimation and evaluation of the actual expenses against the planned budget. COST MANAGEMENT PLAN	<ol style="list-style-type: none"> 1. It is imperative that the organization keeps a track of the actual expenses against the planned budget. 2. It helps to mitigate financial crisis, and arrange resources if needed.
RBS (Risk Breakdown Structure)	RI, RA, RP	RI, RA, RP	RI, RA, RP	RI, RA, RP	<ol style="list-style-type: none"> 1. A risk breakdown structure is a tool which needs constant up gradation with each and every stage of the risk management plan. 2. The RBS is first updated with the identified risks in the technical, managerial, commercial, and external risks. 3. The next stage relates to the identification of the various causes of the risks. 4. The risks are prioritized and finally the risk management strategies are planned. 	<ol style="list-style-type: none"> 1. Builds up as result of the entire risk management practice. 2. It records the probable risks, the probability, the cause, and the mitigation strategies. ORGANISATIONAL PROCESS	<ol style="list-style-type: none"> 1. It is built up as a culminated effort of all the functional units in the organisation. 2. It is a final recorded organisational process. 3. It is the responsibility of the functional units to regularly update the risk register or the risk breakdown structure.
8-D Process	RI, RA, RP, RR	RI, RA, RP, RR	RI, RA, RP, RR	RI, RA, RP, RR	An algorithm or flowchart of steps followed	Organisational Practice.	Culminated efforts of the various functional units of the different organisations.
Double Probability Impact Matrix	RA	RA	RA	RA	<ol style="list-style-type: none"> 1. It helps in risk assessment or prioritizing the risks by means of categorizing the impact of the risks as High, Very High, Low, Very Low, and Medium. 	<ol style="list-style-type: none"> 1. It provides knowledge of the probability and impact of threats as well as opportunities. 	<ol style="list-style-type: none"> 1. Preliminary qualitative assessment. It initiates the assessment. And chalks out the major identified threats and opportunities

3.3 Identification of Risk Factors

The normative literature suggests that when a project is conceptualized, generally the project is decomposed into its risk breakdown structure. The team tries to assess the different lacunas that might emerge from the probable risk categories. Risk categories provide a structure that ensures a comprehensive process of systematically identifying risks to a consistent level of detail. It contributes to the effectiveness and quality of the risk identification process. The risk breakdown structure is a hierarchically organized depiction of the identified project risks arranged by risk category and subcategory that identifies the various areas and plausible causes of risks.

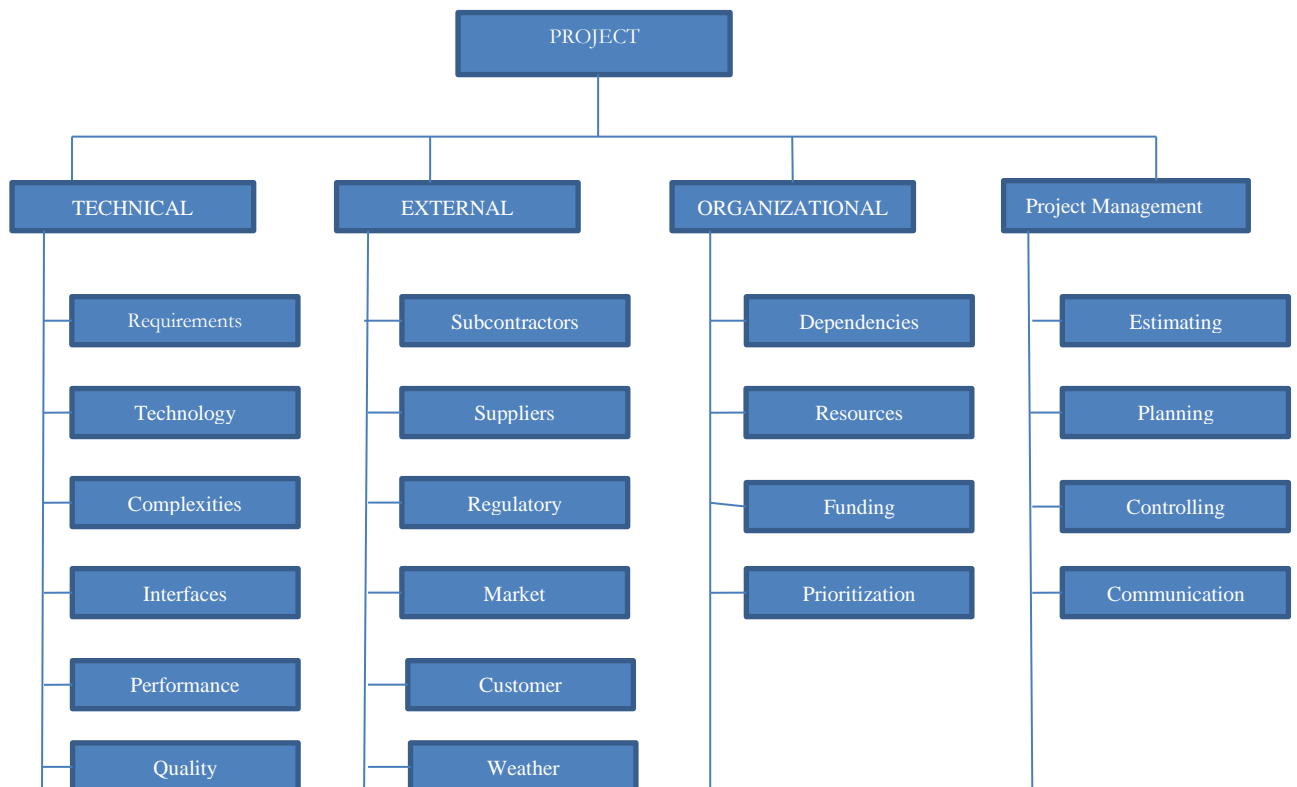


Figure 47: The Different Contexts of Risk Management

. Usually project risks are visualized in the context of the Technical risks, the External market which represents the Subcontractors, the Suppliers, the Regulatory market, the Customers and the Competitors. The organizational interdependencies, the various resources, the financial resources for funding are the other important aspects which lead to risks in the context of the Internal Organizational structure. The way the risks are managed depends on the day to day project management methods. The way the project is estimated, the planning and the scheduling of the project, the way the project is controlled through the various organizational processes, leads to the various roots of the risks and hence also the management of the risks.

Hence from the literature we can define that in the perspective of a project in the manufacturing organisation some of the most important factors that are critical for the success of a project can be defined to be the scope definition of the project, the mechanisms of cost management, the technical complexities observed in the project, the ability to identify resources, the organizational processes that define the various work flow processes, and the project time and schedule management.

It is important to define the scope of the project. Unclearness in the scope definition of the project leads to ambiguity in the technical boundaries and limitations of the project. If the scope is not frozen, individuals are unsure of their responsibilities. Hence this leads to a faulty work breakdown structure and hence the job segregation is not perfect. This means that if the project team is not sure of the exact scope of the project, the final goal or the basic prototype of the project may eventually emerge to be completely different from the idea which was conceptualized by the research and development team.

The financial planning is extremely important for the project to propel ahead. A constant financial resource is extremely important for the continuation of the project. The financial resource could be seen as the clients, or the Research and Development budgets of the organization, or the government or some external bodies who sponsors the projects. Hence to delineate financial risks it is important to plan the budget of the project before the procurement and the project execution begins. A faulty or miss calculated project budget could allocate insufficient budget for the resources, the manufacturing assembly and the testing processes. The project always deals with the risk of not being able to manage a buffer account for the project proceedings. Absence of a buffer account may prove to be one of the biggest risks that the project has to face in the future.

Technical complexities are one of the most crucial roots of risks faced during the engineering, design and developmental stages of the project. Incorporation of new features might make the design to be realized extremely complicated in nature. There is always a risk of losing the advantages of the previous design. The complexity of the design with all its subsystems might make the prototype extremely complicated to be achieved. The complexity of the design might tend to depreciate the quality of the product. Working with a dominant design for certain tenure, runs the risk of the design and engineering team being locked in with the design. The risk of being biased on a particular model reduces the capability of realizing a new idea. To achieve the precision of the designed blue prints, the manufacturing and the assembly units might require tools, Tackles and Machinery which they might not possess. The risk of not considering the capabilities and the resources of the manufacturing and the assembly units always exists. The project execution team might face the risk of not achieving the integration of the entire system due to lack of knowledge of the individual subsystems and the components.

Manufacturing organizations are major technology providers and the integration of the entire system is realized due to a strong network of suppliers and vendors. Hence it is extremely vital to recognize the appropriate suppliers and vendors. It is crucial that the suppliers poses the adequate technical competency, they should have the ability to survive in turbulent market conditions. The delivery lead time of the suppliers is a major source of risk in the context of engineering, design and development of the prototype. Hence it is crucial to establish an extremely strong supply chain both upstream and downstream. It is extremely important that the project execution team is backed by the suppliers and the vendors.

An organization plans the launch of a new system considering a certain time frame. Hence the scheduling of the project stage gates is of high importance. It is important that the procurement of the components, the assembly and the integration of the entire system takes place within the scheduled time frame. Inefficient project time management will lead to the risk of the delay of the project.

Above all the execution of the entire project is manoeuvred by the governance of the board of management. The hierarchy in the organizational structure might always lead to clashes of interest between the project execution team and the management body. The clash of crucial decision making is huge risk that tends to deter the progress of a project. Complexities of the cross functional team interactions and the interfaces are also a source of major project risks.

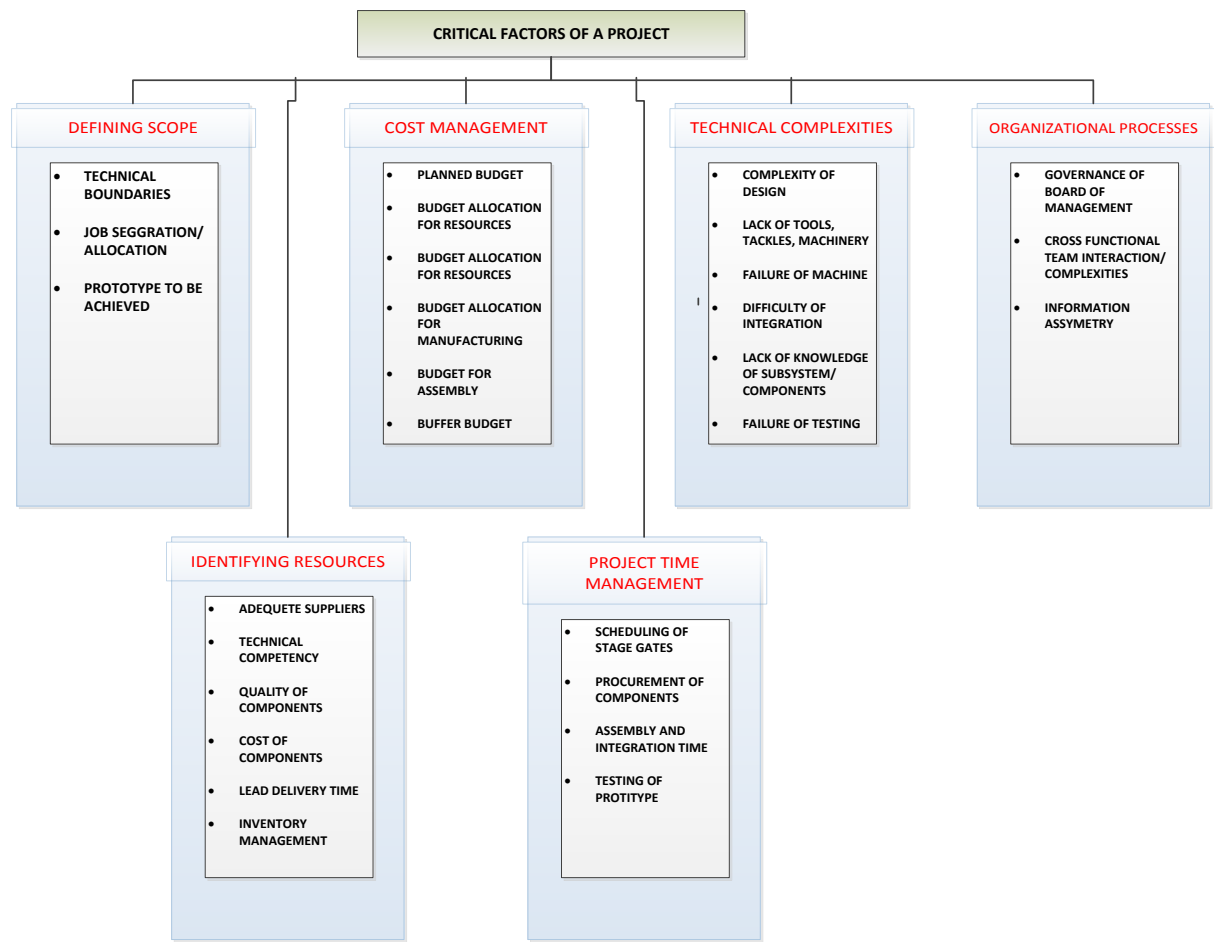


Figure 48: Critical factors leading to Risks in a Project

A manufacturing based project generally takes the form of a waterfall structure. The projects are generally realized in stage gates. The risks if unnoticed and not catered too, tend to have a cascading effect on the project. If the risk is a negative risk then the project tends to proceed in the wrong direction and the success of the project is at risk. If the risks are an opportunity, and dealt in the correct manner, the probability of the success of the risk tends to be manifolds.

CHAPTER 4

4.1 Explanation of Risks faced in “ Rayscan Mk2”

Explanation of the Technical Risks Faced: (Appendix)

1. **P1-R1:** The second generation prototype of the MK2. Rayscan was perceived to be technically easier to be realized. Hence the project was perceived to be easy. This crept in a sense of complacency in the front end planning of the project. (Perceiving a project to be easy).
2. **P1-R2:** A software is the heart of a physical device. The correct functioning of the software itself is a major challenge since the software has to take into consideration the complexities of the theories of physics as well as the mechanical and the electrical sub- systems. Hence the successful integration of the software developed by the software developer for the correct functioning of the

device itself was one of the greatest technical risks. Though the software developer had the technical expertise they had not developed such a software with definite specifications before.

3. **P1-R3:** Integration of the X- ray equipments with the complete system was highly risk prone. It was complex since if an electrical subcomponent did not have the correct specifications and technical capability, it would not allow the physical device to function correctly. Hence it was complex to design a technically correct subsystem by the supplier for the proper functioning of the complete system.
4. **P1-R4:** As the complexity of the project was underestimated the time estimated at the front end loading of the project was also calculated to be insufficient.. A wrong time estimation for project goals could have an adverse effect on the project execution.
5. **P1-R5:** As the project was conceptualized in a wrong way the Engineering and the Concept designs at the front end loading were imperfect. It is a major technical risk since incorrect designs would lead to a faulty device, or a device in which the desired goals are not achieved.
6. **P1-R6:** If there are too many mechanical and electrical subsystems it is a major risk. Each subsystem has its own technical complexities and technical precision. Integrating all the subsystems together to achieve a successful correct system is risk prone.
7. **P1-R7:** Design and Testing of Individual components if done parallel definitely speeds up process but the Quality of the system is unsafe. The primary reason being individual subcomponents are tested and finalized not knowing the finalized designs of the subsystems. Hence the risk of two subsystems not being technically compatible with one another always remains.
8. **P1-R8:** To finally realize the prime objective that is to make the system technically robust enough for extreme temperatures is itself a major challenge. It is highly dependent on the successful achievement of individual stage gates of the project.

Explanation of Internal Organization Risks Faced: (Appendix)

1. **P1-R9:** The fact that the product itself is technically so complex, calls for a technically driven team. It definitely has an added advantage. However in order to drive a project to success, the time management and the budget management calls for adequate project management. Hence it is a risk since technically driven team will help to achieve success in terms of Quality, however Cost and budget management would be absent.
2. **P2-R10:** The operational unit acting as the client would definitely want the project to be developed within the planned time frame. The operational units wanted their deliverables. They denied to look at the technical complexities , the lack of resources, which the product development team faces. This is a major risk since the quality of the product might get affected.
3. **P3-R11 :** The absence of a dedicated assembly unit is a major risk and can be critical. Integration of all the subcomponents is a very critical stage of the product development stage. Absence of a dedicated assembly unit could affect quality, especially when the job was expected to be carried out by the maintenance department. The maintenance department lacked the technical skills.
4. **P4-R12:** Absence of definite logistics would definitely affect the cost and the time management of the project.
5. **P5-R13:** Since the integration of the software was conceived to be less complicated, and less time was planned for the integration process, costs were exceeding the scheduled budget. Hence wrong analysis of complexity lead to wrong time management and hence budget. Less budget can stop the proceedings of a project.

Explanation of Suppliers and Vendors(External Organization) Risks faced: (Appendix)

1. **R1-RA14:** Definite lack of resources which are not foreseen initially can be seen to be a risk. Sudden lack of resources can stop proceedings of the project.

2. **R1-RA15:** Interactions with Ajat was extremely risk. The project team needed to pass on to the software developers the exact specifications and the technical requirements. Hence it always runs the risk of Information Asymmetry.
 3. **R1-RA16:** Interactions with the suppliers of the Umbilical cord was also complicated. Firstly the suppliers did not have expertise in cable testing and secondly the project team needed to pass on to the suppliers exact specifications and the technical requirements. Hence again the risk of Information asymmetry always runs.
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ANALYSIS OF COMPANY A, RAYSCAN MK2 PROJECT

APPLUS M.K.2 PROJECT	RISKS	RISK MANAGEMENT STRATEGY	Extent of Application	QUALITY	COST	TIME	EXPLANATION	TAGS
TECHNICAL RISKS	1. The second generation prototype of the MK2.rayscan projectwas perceived to be technically easy. It was perceived to be an easy project	Team meetings, interactions, updates with clients	0.8	1, (I)	1, (I)	1, (I)	Team meetings, interactions and updates with clients are process management mechanisms which tends to improve the Quality, cost, and time of the project.	P1-RA1
	2. Integration of the software developed by AJAT with the physical hardware system was a major risk	Deputation of a project engineer stationed with suppliers	1	0.8, (I)	0.4, (D)	0.8, (I)	Deputation of a project engineer will lead to cost enhancement of the project	P1-RA2
	3. Integration of the Umbilical chord with the complete system was high risk prone	Complete support from Applus Engineers on technical requirements and specifications	0.8	0.8, (I)	0.6, (N)	0.8, (I)	Support from the Applus Engineers to the Suppliers will help to enhance the Quality but cost management will almost be neutral and the Time tends to improve	P1-RA3
	4. Time considered for the mechanical design and software implementations were highly insufficient	Re-Evaluation of critical path, and Re-Design of the project breakdown structure	0.6	0.6/0.4, (N)	0.8,(I)	0.6/0.8, (D,I)	Re- Evaluation of the Critical Path of the project will definitely improve the project management. However redesigning the critical path for the benefit of the project might improve the future time management of the project but it might also have a reverse effect where the project gets deferred on time schedule.	P1-RA4
	5.Imperfect concept design at the beginning of the project	Redesign of the concept design or redesign of engineering	0.8	1, (I)	0.6, (N)	0.2, (D)	Redesigning will definitely improve the quality of the project tending towards perfection, but also means that the projects starts from the beginning , hence the project might fall out of schedule.	P1-RA5
	6. The system had numerous subsystems with technical precision for each subsystem	Testing of the individual subsystems and the complete system as a whole	1	0.8, (I)	0.4, (N)	0.6, (D)	Testing on the Individual Subsystems will definitely improve the Quality of the project . However testing on the individual level components will definitely increase the time schedule of the project.	P1-RA6
	7. The concept /engineering designs done initially during the front end loading was wrong.	Re-design of the Engineering, or concept design	0.8	0.8, (I)	0.6, (N)	0.6, (N/D)	Redesigning or Re-Engineering always tends to improve the Quality of the Project , having a futuristic look the project tends to have an advantage in trying to keep to the time schedule , because there is no technical hindrance at the end. However it is a repetition of the entire work, and hence a deviation of the entire process.	P1-RA5
	8. Design and testing of individual components were being done parallaly to speed process	Its a definite risks on the technical level, but it can be visualized as a process to speed up excution procedure.	1	0.4, (D)	0.6, (N)	0.8, (I)	Parallel working specially, designing, engineering, purchasing, assembly and testing will tend to decrease the quality of the work, however it will definitely improve the time management of the work.	P1-RA12
	9. To realize the prime objective that the prototype should be more robust for extreme temperatures, with improved sensitivity and hardness.	Testing conducted in artificial environment.	1	1, (I)	0.6, (D)	0.6, (N)	Testing in an artificial environment will definitely improve the robustness of the product and hence the quality of the product improves	P1-RA7
INTERNAL ORGANIZATION	1. The project team was highly technically driven andhence had insufficient project management.	Inclusion of a project manager	1	0.6, (N)	0.8, (I)	0.8, (I)	Inclusion of a Project Manager would improve the Cost and Time management of the entire project , but the Quality remains neutral.	P1-RA8
	2. Strong clashes with the perational team . Operational team being theclient wanted the prototype MK2 to bedeveloped as soon as possible	Weekly and monthly meetings with the clients, Technical Risk workshop	0.8	0.8, (I)	0.4, (N)	0.6, (I)	Technical Risk Workshop tends to improve the quality of a product by means of reducing the critical technicalities of the system.(Technical complexities reduced through technical workshops)	P1-RA9, P1-RA10

	3. The maintenance unit was expected to do the assembly of the entire system since there were no formal assembly units.	Formed dedicated functional units responsible for assembly of the entire system(more of a lesson learnt and applied for other projects)	0.4	0.8, (I)	0.6, (I)	1, (I)	A dedicated assembly unit would improve the quality, cost as well as the time schedule of the project	P1-RA11
	4. The organizational structure lacked definite resources to arrange logistics	By taking back up resources from other projects	0.8	0.4, (D)	0.6, (N)	0.8, (I)	Back up resources from other projects might tend to compromise the quality of the project since its almost like a compromise or a substitute but it tends to improve the time schedule of the entire project.	P1-RA13
	5. Costs were exceeding the allocated budgets, specially for the complicacies in the integration of the software.	Business plan was written to the board of management, highlighting the reasons for exceeding costs as well as positives of the project.	1	0.4, (N)	1, (I)	0.8, (I)	The business plan will help to aquire more financial resources from the management. Hence it will mainly help to improve the cost management of the project	P1-RA14
EXTERNAL ORGANIZATIONAL RISKS (SUPPLIERS AND VENDORS)	1. Definite lack of resources of many aspects	Allocate more budget for Execution	0.6	0.8, (I)	0.8, (I)	0.6/0.8, (N)	Allocating more budget for the execution purpose is a cost management structure, which will tend to improve the time management during execution which is the most complex part of the entire product life cycle.	P1-RA14
	2. Interactions with Ajat was extremely complicated.	Interactions , technical specifications were shared,deputation of project engineers	0.8, 1, 0.8	0.8, (I)	0.6, (D,N)	0.6, (I)	Deputation of a project engineer will lead to cost enhancement of the project, but it will definite improve the quality of the product being developed with AJAT and will also improve the time management of the project.	P1-RA16, P1-RA2, P1-RA3
	3. Interactions with the suppliers of the Umbilical chord were extremely complicated since the suppliers didnot have the expertise of cable testing.	Interactions , technical specifications were shared, assisted in cable testings, sharing technical knowledge with suppliers	0.8	0.8, (I)	0.6, (N)	0.6, (I)	Interactions and sharing of knowledge are means of process management which will improve technicalities of the products that the suppliers are making, and would also tend to improve the time management of the product.	P1-RA17, P1-RA3

4.2 Explanation of Risks faced in “ Riser Inspection Tool development project”

Explanation of the Technical Risks faced:

- P2-R1 : Complex theories of Diffraction, Reflection, and Refraction were being used to find the best solution.
- P2-R2: The accuracy of the device in correct positioning of the inspection tool and sizing of the cracks was an important objective of the product. The risk of not achieving this precision always remained.
- P2-R3: Integrating the basic theoretical concepts along with the electrical and mechanical and software components was always a risk. Realizing a functionality of a device using basic concepts of physics is always unpredictable.
- P2_R4: The software is the heart of a mechanical device. The compatibility of the software along with the physical device is always a risk.
- P2-R5: A complex system having numerous subsystems is always critical. The risks of not realizing a successful assembly of the final system due to criticalities of the subsystem.
- P2-R6: Proper functionality of the device in hazardous environment is always a risk.
- P2-R7: The risk of making wrong technical choices of combination of solutions would make the device exceed cost budgets and also not achieve final objectives.

Explanation of the Internal Organizational Risks faced:

- P2-R8: Risks arose due to the fact that interests between the end client and Company A did not match. The client wanted the project to be designed more from the perspective of a repair mechanism and not from the perspective of inspection. Hence clash of interests.
- P2-R9: The end client expected the solution to have a wider application. Company A was designing specifically for certain definite specifications. Hence the risk of not being capable of keeping up to the risks of the end client.
- P2-R10: The delay in approval from the end client can cause serious risks of not being able to keep to the time schedule. Though there was delay in approval from end client the deadlines for deliverables were not changed though.
- P2-R11: With the broader expectations of the clients, the scope of the project was constantly increasing. Company A had to face the risk of not being able to come up with the plausible solutions for different applications within the same time limit.
- P3-R12: At times A had to depend on the operational unit for lack of resources. They even had to depend on the electrical units for lack of knowledge. At such instances they faced the risk of not being provided adequate back up.

Explanation of the External Organizational risks faced: (Appendix)

- P2-R13: Not being able to arrange the correct resources within the specified time limit would lead to overshooting the time limit.
 - P2-R14: The subsystems and the subcomponents of the entire system are also technically challenging and complex to be realized. Hence if the deadline of deliverables for the end client is short, the risk of the suppliers not being able to abide by the time schedule always remained.
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ANALYSIS OF COMPANY A, RISER INSPECTION TOOL DEVELOPMENT PROJECT

(IRC-Robotic development)	RISKS	RISK MANAGEMENT ACTIVITY	Extent of Application	QUALITY	COST	TIME	EXPLANATION	TAG
TECHNICAL RISKS	1. The solution was combined with 4 different combinations of techniques of Refraction and Diffraction.	1. Brainstorming different solutions . 2. Use the technical expertise of experts. (Delphi method) 3. Involvement of a system architect.	0.8	(I), 0.8	(N), 0.6	(N), 0.6, 0.8	The whole aim of the system architect and technical experts was to improve the quality (accuracy of positioning and the sizing of the device. The experts help to attain a solution with minimum requirement for proper inspection, keep the cost in balance with the solution.	P4-RA1, P4-RA2, P4-RA3
	2. The technical risk of malfunction of the device in high temperature and pressure.	1. Technical expertise of the experts, prototyping , and sample simulations.	0.6, 0.8	(I), 0.8	(I), 0.4/ 0.6	(I), 0.8	1. Presence of a technical expertise definitely improves the quality of the product. 2. Less technical uncertainty would signify that the project would propel within the scheduled time frame.	P4-RA2, P4-RA4
	3. To achieve the complexity of accuracy of positioning and sizing the defects of the cracks.	1. Have alternate possible solutions , by means of prototyping. 2. Technical expertise of the engineers used to optimum level. (project managers motivated and pushed the engineers)	0.8, 1	(I/D), 0.4	(I/D), 0.2/0.4	(I), 0.6, 0.8	1. Alternatives provide the best possible solutions but not sure if the quality is always the best. 2. Alternatives might either turn out to be costlier or cheaper, hence it could either have a positive or a negative effect on the cost management structure. 3. Alternatives and back up options always tends to propel the project faster. hence it has an additive effect on the time management. Alternatives would aim to speed up the process.	P4-RA2,P4-RA15
	4. Integration of the theoretical concepts with the physical Electronics and Mechanical components.	1. Brainstorming different solutions . 2. Use the technical expertise of experts. (Delphi method) 3. Involvement of a system architect : Responsible for the overall project integration. 4. Involve Engineers from the beginning of the design of the concept along with the technical centers, and PIT teams.	0.8, 1, 0.8	(I), 0.8	(N/I), 0.6	(I), 0.8	1.The system architect would probably be able to decide on the components with the optimum cost. Hence cost is 0.6. 2. Involvement of the engineers and the experts from the beginning of the project would enable the project to be technically more correct. Hence the quality of the project would enhance. 3. Involvement of the engineers would also mean that the project would propel ahead in the right direction within the right time frame.	P4-RA1, P4-RA5, P4-RA2,P4-RA3
	5. Integration of the software algorithm with the physical structure was a major challenge and risk	1. Brainstorming different solutions . 2. Use the technical expertise of experts. (Delphi method) 3. Involvement of a system architect : Responsible for the overall project integration.	0.8, 0.8, 1	(I), 0.8	(N/I), 0.6	(I), 0.8	1.The system architect would probably be able to decide on the components with the optimum cost. Hence cost is 0.6. 2. Involvement of the engineers and the experts from the beginning of the project would enable the project to be technically more correct. Hence the quality of the project would enhance. 3. Involvement of the engineers would also mean that the project would propel ahead in the right direction within the right time frame.	P4-RA1, P4-RA2, P4-RA3
	6. Integration of the different subsystems to realize the final system since each subsystem had it's technical criticalities.	1. Involvement of a system architect : Responsible for the overall project integration. 2. Involve Engineers from the beginning of the design of the concept along with the technical centers, and PIT teams.	1, 0.8	(I), 1	(N/I), 0.6	(I), 0.8	1. Same as above	P4-RA5, P4-RA2,P4-RA3

	7. There was always the risk of making wrong technical choices which would have an impact on the cost.	1. Have a strong Project Critical Path. 2. Strong Front End Loading of the project. 3. It was very important to be pragmatic in approach, and have a well defined scope.	0.6, 0.6, 0.6	(N), 0.4	(I), 0.8	(I), 0.8	1. A strong project critical path and stronger front end loading would ensure that the project planning is stronger, which would further ensure a stronger project time and cost management.	P4-RA6,P4-RA7, P4-RA12.
INTERNAL ORGANIZATION	1. Conflict of interest between the end client and company. From shells perspectives the estimates were more in the form of repair than inspection.	1. Make a strong cost benefit analysis and show the client the Net Present Value of Inspection, rather than repairing the whole riser.(Show the client the bigger picture)	0.8	(N), 0.2	(N), 0.4	(I), 0.8	1. Marked 0.8 for time since convincing the client on the return of investments would only initiate the process and make the process much faster. Hence saving on time.	
	2. Client expected to have a solution where the application would have a wider solution. Hence managing the expectation of the clients were a major challenge.	1. Strong communication with the project managers to realize the exact specific requirements. 2. Provide alternate possible applications using the same solution with different technical combinations. (Solution applicable from 8" inch - 18" inch SCR.)	0.6, 1	(N), 0.6	(I), 0.6/0.8	(I), 0.8	1. A wider application of the solution makes it more cost effective. 2. The cost management improves. 3. Communications, interactions----process management mechanisms which improves the time management of the project.	P4-RA10
	3. Client took a lot of time to send approvals but the deadlines for deliverables did not change.	1. Extremely proactive and pragmatic in their approach. 2. Allocate resources on time. 3. Adapt the time schedule immediately if the scope and plan changed. 4. Have alternatives and back up options to stick to deadlines.	0.6, 0.6, 0.6, 0.6	(N), 0.6	(D/N), 0.2, 0.4	(I), 0.8	1. Meetings and interactions tend to provide technical clarity of the process which in turn tends to initiate processes and hence has a direct effect on the time. Cost management structures can be decided but doesnot help to manage costs as such	P4-RA13
	4. Since the scope of the project kept expanding with different applications it was difficult to manage the time of application	1. Budget decided on the basis of stage gates or packages. 2. Maintain established spread sheets to keep track of time.. 3. Have a perspective of the Budget and the Time on the whole project with every stage gate of the project that is achieved.	0.8	(N), 0.4	(I), 1	(N/I), 0.6	1. Stage gate budget decisions propels the project to have a better cost management. 2. A spread sheet approach helps to have a better idea of the process in which project expenses are proceeding, hence better and effective cost management.	P4-RA9, P4-RA11
	5. It was always a challenge to have the right resources and equipments from operations to carry out measurement actions.	1. Some of the tasks were carried out by the engineers themselves. 2. Experts from operations were involved into the steering committee from before.	0.4, 0.6	(D), 0.4	(N), 0.4	(I), 0.6	1. Performing tasks of the other functional units tend to decrease the quality of the product, however tends to have an additive effect on the time of the project.	
EXTERNAL ORGANIZATIONAL RISKS (SUPPLIERS AND VENDORS)	1. It was always a major risk to alot resources on time.	1. Extremely proactive and pragmatic in their approach. 2. Allocate resources on time. 3. Adapt the time schedule immediately if the scope and plan changed. 4. Have alternatives and back up options to stick to deadlines.	0.6	(N), 0.4	(I), 0.6	(I), 0.8	1. Cost and Quality might tend to get affected due to the applications of possible alternatives. 2. A pragmatic approach helps to propel the project within the time schedule. 3. A pragmatic and practical approach tends to make the project have a better cost management structure.	P4-RA14, P4-RA15
	2. Appplus had a very short time to market, the suppliers needed to deliver the parts or the components with extremely short lead times, although it was quite technically challenging.	1. Make the suppliers realize the complexity of the projects. 2. Involve the suppliers from the beginning of the project. 3. Communicate the right requirements to the suppliers.	0.8	(I), 0.8	(N), 0.4, 0.6	(I), 0.8	1. These strategies mainly try to achieve the right components in the right lead times.Hence time management improves.	P4-RA16,P4-RA-18, P4-RA17

4.3 Explanation of Risks faced in “Tooling Packaging & Hoist” development projects

The explanation of the Technological Risks faced: (Appendix)

- **P3-RS1:** The tooling system has too many subsystems. Integrating all the subsystems to realize the final product is always a major risk.
- **P3-RS2:** Tooling and the packaging development is almost dependant on the main system which is defined. The layout of the tooling system is completely dependent on the main lithography system which is already freezed.
- **P3-RS3:** The involvement of the tooling and the packaging system comes at a very late stage when the need arises. It is extremely difficult to manage the layout and realize the accessibility of the space in which the product has to be accommodated. Moreover it is always a risk to compress the plan to accommodate the main lithography system perfectly. Hence the risk of having to redesign the tooling and the packaging system always exists.
- **P3-RS4:** As the tooling design unit is not involved at the very beginning when the primary system is being designed the risk of un clarity in the scope of the tooling development always exists.
- **P3-RS5:** The risk of designing a tool which might not be compatible with the clean room or the factory unit always remains.

The explanation of the Internal Organization Risks faced: (Appendix)

- **P3-RS6:** Often adequate resources in the form of people and budget are not available for the required job. The risk of the project coming to a halt always exists.
- **P3-RS7:** The production unit always demands that the tools should be on the floor at the earliest. The tooling design unit being included at the very last phase always needs adequate amount of time to design the entire system.
- **P3-RS8:** Since the tooling system is catering to the safety of the main device which is the lithography system, at times more budget is required to make the system secure. However the risk of budgets being allotted only for resources but extra budget not kept for enhancing the safety of the system always remains.

The explanation of the External Organizational Risk faced:

- **P3-RS9:** The suppliers and the vendors predetermined by the management were not technically skilful and adept enough to comply with the tooling development of the packaging industry.

ANALYSIS OF COMPANY B, TOOLIND HANDLING HOIST DEVELOPMENT PROJECT

tooling, packaging, hoist, lifting	RISKS	RISK MANAGEMENT ACTIVITY	Extent of Application	QUALITY	COST	TIME	EXPLANATION	TAG
TECHNICAL RISKS	1. The project has too many interfaces, too many subsystems realizing the final component	1. Parallel teams are formed in order to speed up the process.	0.8	0.6, (N, D)	0.4, (N)	1, (I)	Parallel work functions definite initiate processes faster but tends to depreciate the quality of the work.	P2-RA1
	2. Tool and packaging development almost completely dependent on the product which is defined. The layout of the product is already freeze	1. Re-Think and Redo the concept of the tool	1	0.8, (I)	0.4, (N)	0.4, (D)	Re-thinking and Re doing the concept of the product tends to improve the quality but definitely tends to push the project out of time schedule	P2-RA2
	3. It is almost impossible to redesign the tooling and the packaging system.	1. Re-Think and redo the concept of the tool. 2. Suppliers are asked to be a part of the engineering right from the design of a concept.	0.8	0.8, (I)	0.6, (N)	0.6, (I)	Supplier getting involved at the concept stage will help the suppliers have a better idea of the project concept and hence improve the quality on a component level, thereby also tends to improve the time management of the project.	P2-RA2, P2-RA11
	4. the involvement of the tooling and the packaging system comes at a very late stage when the need arises.	1. Focus on the issue by regular interactions with the cross functional units like Production, Supply chain, Engineering.	0.6	0.8(I)	0.6, (N, I)	0.6, (I)	Interactions , on a technical level , or interactions with cross functional silos tends to increase the clarity on technical levels, aswell as always has an additive positive effect on the cost and time management.	P2-RA4
	5. At times it is quite difficult to realize the scope of the project.	1. Interactions, Re- think and Re-Do, FMEA	0.8	0.8, (I)	0.4, (N)	0.6, (I)	A strong Failure Mode effects analysis on the product level will always improve the quality of the product, negating out the technical unclarities and the causes of the failures. The known reasons of the failure will help to initiate and fasten the process.	P2-RA6
	6. The major technical risks are to manage the layout and to realize the accessibility of the space in which the product has to be accommodated.	1. Re-Do the concept of the tool. 2. Risk management carried out on the product by means of F.M.E.A specifically on the safety of the system. 3. Tools used for manufacturing also needs to be certified	1	0.8, (I)	0.6, (N)	0.6, (I)	A strong Failure Mode effects analysis on the product level will always improve the quality of the product, negating out the technical clarities and the causes of the failures. The known reasons of the failure will help to initiate and fasten the process.	P2-RA6
	7. Extremely difficult to realize the clean room compatibility.	1. Technical supervisors ensure that the clean room compatibility is attained.	0.6	0.2, (N)	0.8(I)	0.8, (N)	Accessibility of the clean room compatibility is more of a resource allocation for the assembly of the entire system. Clean Room Compatibility tends to improve the cost management and the time schedule of the project.	P2-RA8
	8. it is extremely critical to realize a solution which is safe enough.	1. Brainstorming. 2. Maintain a risk register mainly from the perspective of the project.	0.6	0.6, (I)	0.6, (I)	0.6, (I)	Brainstorming is a normal process which tends to have a positive effect on quality , cost as well as time. Risk register is a process of building up the master document.	P2-RA9, P2-RA10
	9. it is impossible to compress the plan.	1. Re-think and Redo the concept 2. Involve the suppliers from the design stage.	0.6	0.8, (I)	0.6, (D,I)	0.8, (I)	Re-thinking and Re doing the concept of the product tends to improve the quality but definitely tends to push the project out of time schedule Involving the suppliers from the concept design stage counters the deficiency in time management, hence tends to improve the time management of the project.	P2-RA11

INTERNAL ORGANIZATION	1. Often adequate resources in the form of people and budget are not available for the required job.	1. Escalations to higher management. 2. Budgets are resource driven by showing the urgency of safety.	1	0.2, (N)	0.6, (I)	0.6, (I)	Escalations in the process of the projects tends to have a direct impact in the budget management and the time management in a positive way.	P2-RA12,
	2. The production unit demands that the tools should be on the floor at the earliest. However to avoid risk the production units still aspire to use the tools that are already present on the shop floor.	1. Focus on the issue by means of regular meetings within the cross functional silos of the Production unit, the supply chain unit and the engineering team.	1	0.8, (I)	0.4, (N)	0.8, (I)	Team meetings, interactions and updates within the cross functional units are process management mechanisms which tends to improve the Quality, and time management of the project.	P2-RA4
	3. The budgets are resource driven and not dependent on the value of the tools.	1. Escalations to the higher management.	1	0.4, (N)	0.8, (I)	0.8, (I)	Escalations in the process of the projects tends to have a direct impact in the budget management and the time management in a positive way. Hence the quality remains unaffected.	P2-RA12,
EXTERNAL ORGANIZATIONAL RISKS (SUPPLIERS AND VENDORS)		1. Closer contact with the suppliers, even in terms of distance	0.6	0.8, (I)	0.6/ 0.8, (I)	0.8, (I)	Closer proximity with the suppliers tends to have a positive impact in terms of quality , cost and time.	P2-RA13
		2. Specifications and the needs from the suppliers are extremely streamlined	0.8	0.8, (I)	0.4, (N)	0.4, (N)	Specific and streamlined specifications tends to improve the quality of the products by means reducing unclarities.	P2-RA14
	1. the suppliers need to be technically adept to comply with the tooling development of the packaging industry.	3. As a strategy check while choosing suppliers the teams check with other companies the developmental skills.	0.6	0.6, (I)	0.6, (I)	0.6, (I)	This is a strategy which proves and helps select the supplier, hence choose the right supplier in terms of quality, cost and time.	P2-RA15
		4. The suppliers are involved at the very design phase of the project.	0.8	0.8, (I)	0.6, (N)	0.8, (I)	Involving a supplier at the very early, concept stage helps to improve the quality of the product on the technical subsystem level	P2-RA11

4.4 Explanation of Risks faced in “ Machine Design Project”

Explanation of the different Technological risks: (Appendix)

- **P4-R1:** The QXT system has too many subsystems specially the base frame and the air mount system. Integrating all the subsystems to realize the final product is always a major risk.
- **P4-R2:** At times the technical feasibility of the hardware is too complicated that the project always had the risk of technical complexities not being realized.
- **P4-R3:** The project had three main units the Mechatronics unit, the Mechanical unit and the Electrical and Electronics department. The mechatronics unit relied on the electrical and the electronics unit for technical input. Dependence on other technical units always lead to the risk of time delays.
- **P4-R4:** The concept design had to be redone numerous times. Hence the project always faced the risk of falling out of the planned time schedule and budget.

Explanation of the different External Organizational Risks involved are as follows: (Appendix)

- **P4-R7:** The air mount system developer was a German company. Cultural differences and the way the two organizations approach to project execution was completely different. Lack in alignment of the two companies lead to many risks on grounds of time management and the cost management of the project.
- **P4-R8:** Since the air mount system development lacked good developmental skills, the process of specification, designs, investigations, concept designs, and detailed designs were completely lacking. The developers viewed the tasks to be more in series, one after the other than parallel. Hence the project fell out of schedule.
- **P4-R9:** The fact that the project leader of the air mount system developers was also the chief project architect from the developers end proved that each individual in the sub vendor end was being overloaded. This led to the risk of lack of resources from the sub vendor end.

Explanation of the different Internal Organization related risks faced are as follows:

- **P4-R4:** The fact that the project was being handled amongst many other projects were always a risk. The dedication of the project engineers and the team members was shared in the different projects. Hence the technical quality would not be at its best. The risk of falling out of the time schedule and cost budget also arose.
- **P4-R5:** The management was extremely stringent and rigid on their demands and budget allocation. The fact that the concept design of the base frames were having to be constantly redone the risk of the project exceeding the predetermined budget always existed.
- **P4-R6:** The management of company C had already made prior selection of the suppliers without realizing the knowledge gap of the suppliers. The risk of the suppliers not being able to attain the technical precision of the subcomponents arose. The suppliers were not selected upon their technical competence. Even the third tier suppliers of primary base frame and air mount supplier developers were also internally decided at company B. The risk of not choosing technically adept suppliers always rose to the situation.

ANALYSIS OF COMPANY B, QXT MACHINE DESIGN PROJECT

(QXT, 450mm Machine)	RISKS	RISK MANAGEMENT STRATEGY	Extent of Application	QUALITY	COST	TIME	EXPLANATION	TAG
TECHNICAL RISKS	1. The complete system has a number of subsystems	1. Discussions and interactions between Inter-functional silos, A strong F.M.E.A carried out on the product realization.	0.8	(I), 0.8	(N), 0.6	(I), 0.8	1. Interactions, team meetings, and communications are process management mechanisms which influence the Quality of the products in terms of technical unclarities being resolved. 2. More the interactions better the time management. 3. A strong F.M.E.A helps to solve technical complexities and hence the quality of the product is improved.	P3-RA1, P3-RA2, P3-RA3
	2. Extremely difficult to deliver the hardware	1. A strong F.M.E.A analysis was carried out on the product after the concept design was achieved.	1	(I), 0.8	(N), 0.4	(I), 0.6	1. A strong F.M.E.A helps to solve technical complexities and hence the quality of the product is improved. 2. Solving technical unclarities further helps to initiate the project in the scheduled time.	P3-RA2, P3-RA3
	3. The designers of the air mounts had a lot of technical expertise in manufacturing but they lacked the capabilities of developing.	1. B tried to streamline the supplier's process of working as much as possible in tune of company B's working process(Specification---Designs---Investigations--Concepts design---Detailed design)	0.8	(N), 0.4	(I), 0.8	(I), 0.8	1. Trying to shape the suppliers in terms of B's process helps to build the supplier for future projects as well it definitely improves the cost management and the time management of the project.	P3-RA4
	4. The project had three main units the Mechatronics unit, the Mechanical unit, and the Electronics department. The mechatronics department did not receive any electrical technical inputs as the the required technical inputs were imbibed by rthe electronics unit from external agents.	1. Proper knowledge management by imbibing knowledge from external bodies.	0.6	(I), 0.6	(N), 0.4	(D/ I), 0.6	1. Resorting to external knowledge can either decrease or increase the time or schedule of the project, since dependence on an external body of knowledge can either speed up procedures or it might also slow down process	P2-RA17
INTERNAL ORGANIZATION	1. The project was being handled with many simultaneous development projects.	1. Deputation of Dedicated Engineers	0.6	(I), 0.6	(N), 0.2	(I), 0.8	1. Having dedicated engineers tends to have more precision on the work 2. Hence Quality tends to increase, and further dedicated engineers means that the time management also enhances. The cost tends to remain nuetral.	PA3-RA6
	2. The management was extremely stringent and rigid on their demands and budget allocation.	1. B tried to adopt a pragmatic project management approach. 2. B followed a milestone based payment system.	1	(N), 0.2	(I), 1	(N), 0.6	1. A stage gate based payment mechanism would definitely mean that the cost management would be improved. 2. A stage gate based payment mechanism would also ensure that the suppliers make on scheduled lead time deliveries which would further initiate the project within the stipulated time frame.	P3-RA7, P3-RA8
	3. The management had made prior selection of the suppliers without realizing the knowledge gap of the suppliers . Ther management did not judge the competence capabilities of the suppliers.	1. Specify the specifications, to suppliers, complete technical support provided to the suppliers.	0.8	(N/I), 0.6	(N), 0.2/0.4	(I), 0.8	1. Specifications provided to the suppliers tends to improve the quality of the product on a component level. 2. Hence better coordination with the suppliers would ensure that the project time management would improve.	R3-RA9
	4. The third tier suppliers of the air mount system also had to be internally decided at company B. It was not evaluated properly if they can support the main supplier. However the contract was signed.	1. Interactions, team meetings, complete technical support provided to suppliers with an aim to develop them for future use.	0.6	(N/I), 0.6	(N), 0.4	(D/ I), 0.6	1. Interactions, team meetings, and communications are process management mechanisms which influence the Quality of the products in terms of technical unclarities being resolved. 2. More the interactions better the Time Management	P3-RA10

EXTERNAL ORGANIZATIONAL RISKS (SUPPLIERS AND VENDORS)	1. Definite lack of resources from the IDE or air mount suppliers end.	1. A strong risk register in which both parties filled their risks, High priority: Weekly Risks, Not so High priority : Monthly Call 2. Immediate action and updation of risk list	1	(I), 0.8	(I), 0.8	(I), 0.8	The Risk Register helped to attain a master document which further helped to bring all the actors on the same platform	P3-RA13
	2. Interfacing with IDE suppliers of the air mounts was the biggest challenge.	1. A strong risk register in which both parties filled their risks, High priority: Weekly Risks, Not so High priority : Monthly Call 2. Immediate action and updation of risk list 3. Designers from the air mount system developers also came down to carry out the technical drawings with company B.	1	(I), 0.8	(D/I), 0.6	(I), 0.8	1. The Risk Register helped to attain a master document which further helped to bring all the actors on the same platform 2. Suppliers and designers coming over to their clients place would ensure that the technical unclarities are erased, therefore the quality would enhance . 3. This would further ensure that the time management of the project will improve.	P3-RA13, P3-RA14
	3. Major cultural differences were faced while interacting with the suppliers.	1. Interactions, team meetings, and strong communication.	0.8	(N), 0.4	(N), 0.6	(I), 0.6	1. Interactions, team meetings, and communications are process management mechanisms which influence the Quality of the products in terms of technical unclarities being resolved. 2. More the interactions better the time management.	P3-RA10
	4. IDE viewed the tasks to be more series than parallel.	1. Company B tried to frame the tasks more parallel than series	0.6	(D), 0.2	(N), 0.6	(I), 0.8	1. A more parallel than a series work schedule definitely propels the functions and the stage gates of the project at a much faster rate. Hence the scheduled project tenure is abided by. 2. A more parallel than a series work culture tends to depreciate the quality of the product.	P3-RA11
	5. Both the parties ASML as well as IDE, was kind of black box to each other. The parties were unaware of each other's functional processes.	1. Interactions, team meetings, and strong communication. 2. A strong risk register in which both parties filled their risks, High priority: Weekly Risks, Not so High priority : Monthly Call 3. Immediate action and updation of risk list	1	(N), 0.6	(N/I), 0.6	(I), 0.8	Interactions, team meetings, and communications tend to improve the clarity of technicalities, not sure how much it influences the quality. Hence I keep it neutral.	P3-RA1, P3-RA10, P3-RA13
	6. Project Leader of IDE was also the project architect. Too much of work load for the same individual.	1. The project manager of the air mount system had recruited more people into their team.	0.8	(N,I), 0.6	(N), 0.4	(I), 0.8	More resources would mean better knowledge management and hence better time management.	P3-RA15

4.5 Explanation of Risks faced in “Automotive Seat Manufacturing” projects.

Explanation of the technological risks risks faced.

- P5/P6-R1: In both projects the end clients demanded seating system with a new technology. Hence C faced the complexity to come up with a concept design considering the new technology. Therefore the risk of producing a concept design , which does not keep up to the standards and expectations of the end clients or OEM always existed.
- P5/P6-R2: In the automobile industry , in order to win or acquire the project , the organization needs to offer the concept design or the solutions to the OEM. Hence the engineering team was always under the pressure of producing successful engineering designs before the tender is finalized. Moreover the seating system designed by C needs to be technically adjusted to the space allocated for the car manufactured by the OEM. Hence the technical designs needs to abide by pre-requisites which leads to technical complexities.
- P5/P6-R3: Technical hindrances always arose since the final system is realized due to the integration of a number of subsystems . Each subsystems had their own technical criticalities.
- P5/P6-R4: At times new testing methods are adopted which might be extremely critical and complex and time taking. The tests ended up taking three to four months and this lead to the risk of placing the project completely out of time schedule.

Explanations of the Risks faced: Appendix

- P5/P6-R5: The job functionalities being extremely streamlined amongst different functional units at times lead to the risk of information asymmetry. Too much of interdependence on each other lead to the risk of not meeting milestones and deadlines.
- P5/P6-R6: At times the quality team realized that the project team was facing serious man power shortage problems and hence resource allocation became a major complexity.
- P5/P6-R7: At times the budget exceeded and fell out of estimated range since the exchange rates across the countries fluctuated. This lead to the risk that the price decided during the tendering process fell out of estimates.

Explanation of the different risks faced on grounds of suppliers and vendors:

- P5/P6-R5: At times the suppliers tended to face lack of certain resources. This lead to huge amount of delays in the product realization due to bottlenecks from the suppliers ends.
- P5/P6-R6: At times the second tier suppliers were dictated by the OEM’s themselves. This lead to the risk of company C having less governance over the second tier suppliers and vendors. Though they definitely needed to interact with each other on technical terms, the fact that the specifications and the budget were determined by the OEM lead to certain complexities and risks. The specifications of the subsystems needed were better understood by the Johnson Control, but they lacked the power to dictate terms.
- P5/P6-R7: At times the suppliers lacked the technical capabilities of realizing the product. This lead to the delay in the time management of the entire product realization.

ANALYSIS OF COMPANY C, AUTOMOTIVE SEAT MANUFACTURING PROJECT

(BMW/GMJ)	RISKS	RISK MANAGEMENT ACTIVITIES	Extent of Application	QUALITY	COST	TIME	EXPLANATION
TECHNICAL RISKS	1. In the automobile industry , inorder to win the project or aquire the project, you need to offer the concept design or the solution needs to be given to the OEM.	1. A subject material technical expert, who provides solutions and works closely with the technical and R&D center. 2. A strong process management , team meets on Monday---Plans and actions decided on--- Meetings conducted again on Fridays ---- Achievements are discussed. 3. Strong discussios and interactions/ negotiations with the OEMs and the suppliers.	1, 0.8, 0.8	0.6/0.8(I, N)	0.6/0.4(N)	0.8(I)	Process management tends to improve the time management of the project.
	2. Sometimes the engineering team is not able to realize the drawing concept or the solution within the stipulated time of the project tendering.	1. A strong dedicated engineering team. 2. A strong process management , team meets on Monday---Plans and actions decided on--- Meetings conducted again on Fridays ---- Achievements are discussed. 3. Strong discussios and interactions/ negotiations with the OEMs and the suppliers.	1,0.8, 0.8	0.8(I)	0.6/0.4(N)	0.8(I)	The involvement of the technical expert tends to improve the quality of the project and specially the dedicated engineering team.
	3. Technical hindrances often obstruct the flow of the project since the final system is realized due to integration of a number of susbsystems. Each susbsystem has its own technical criticalities.	1. Consultation with the subject material technical expert helps to propel the project ahead. 2. If Jc doesnot have the technical expertise on the subsystem or the component , they ensure that they choose a supplier with strong technical expertise. 3. A strong root cause analysis is done to judge and find the reasons for the project falling out of schedule/ budget on technical grounds.	1, 0.8, 0.6	0.8(I)	0.4/0.6(N)	0.8(I)	Involvement of a Subject material technical expert helps to clarify techical complexities and hence the quality enhances. Root cause analysis, helps to identify the origin of the risks mostly on the technical grounds, which in turn helps to initiate the progress of the project in the right direction.
	4. At times the product is designed by JCI needs to be technically adjusted within the space allocated by the car OEM. The product or the design needs to play around the allocated space which leads to technical complexities.	1. A strong process management , team meets on Monday---Plans and actions decided on--- Meetings conducted again on Fridays ---- Achievements are discussed. 2. Strong discussions and interactions and negotiations with the OEM and the suppliers. 3. A subject material technical expert actively helps, particularly since he works closely with the technical and the R&D center. 4. New testing methods are adopted to test the prototype	1, 0.8, 1	0.8(I)	0.4/0.6(N)	0.8(I)	1. Interactions, team meetings, and communications are process management mechanisms which influence the Quality of the products in terms of technical unclarities being resolved. 2. More the interactions better the Time Management
	5. At times new testing methods are adopted which might be extremely critical and complex and time taking. The tests might take three to four months and this destroys the complete project timeline.	1. Strong discussions/ interactions and negotiations with the OEMs. 2. A strong F.M.E.A analysis is carried out on the product, then the process and then design level.	0.8, 0.8	1(I)	0.6(N)	0.8(I)	Failure Mode effects analysis is primarily involved in addressing and identifying the risks invoved with the technical level of the product.

Risk Management activities which tends to cater to the technical risks, improves the quality of the product, removes technical unclarity, hence speeds up process, but costs are not too altered.

INTERNAL ORGANIZATION	1. To realize the complete solution , interaction amongst a lot of functional silos are extremely necessary, and hence milestones are not met.	1. Application of a strong IT software (PLUS): Product Launch System. Plus helps to keep a strong track and estimate of the stage gates of the project progress in terms of Cost Estimates, and milestones achieved. 2. A strong process management , team meets on Monday---Plans and actions decided on--- Meetings conducted again on Fridays ---- Achievements are discussed.	1, 0.6	0.4/0.6(N)	0.8(I)	1(I)	IT management system tends improves the overall cost and time management of the projects. Quality is almost neutral.
	2. Job functions are extremely streamlined and too specific.	1. A responsibility assessment matrix is followed to dedicate specific functions for specific people. 2. A strong process management , team meets on Monday---Plans and actions decided on--- Meetings conducted again on Fridays ---- Achievements are discussed.	0.8, 0.8	0.4/0.6(N)	0.8(I)	0.8(I)	Process management tends to improve the time management of the project.
	3. At times the quality team realizes that the project concerned is facing serious man power shortage problems and hence resource allocation becomes a major complexity.	1. For problems related to resource or man power shortage , the primary form of managing this risk is escalations to the directors of the company.	0.8	0.2(N)	0.6(I, N)	0.8(I)	Escalations have direct effect on the cost management and the time management of the projects but they donot have any effect on the quality of the product, since quality is primarily delt with the technical experts.
	4. At times the budget exceeds and the budget falls out of estimated range since th exchange rate fluctuates. The risk that the price decided on the RFQ tends to fluctuate massively.	1. Budget is also a resource and in that case the crisis is always escalated to the higher management. 2. The PLUS software also helps to keep a constant check on the budget.	0.8,1	0.2(N)	0.8(I)	0.8(I)	ICT Management brings about a better co-ordination amongst all the functional units. Hence better cost manageent and time management.
EXTERNAL ORGANIZATIONAL RISKS (SUPPLIERS AND VENDORS)	1. There are huge amounts of delays in the product realization due to cross functional activities and mainly due to suppliers.	1. Buffer time is considered during the planning phase and mainly during the Front End Loading. 2. Schedule the delivery from the suppliers , inhouse in two weeks prior to scheduled date of integartion and assembly of the final product.	0.6	0.2(N)	0.4(N)	0.8(I)	Primarily improving the time management of the project.
	2. At times the second tier suppliers are dictated by the OEMs themselves , in that case case JCI does not have complete control and dominance over their suppliers.	1. The sales team directly deals with the suppliers. 2. The purchase team doesnot come into the picture since they are not dealing with the complete solution.	0.6, 0.6	0.4(N)	0.8(I)	0.6(N)	In non dictated suppliers where the Oem directly governs the suppliers , the fact that the sales team only interacts and is concerned about the capacity of the supplier proves that ther is a better cost management structure of the project.
	3. Sometimes the project faces delays due to bottlenecks from the suppliers.	1. A dedicated risk management team is present which deals and interacts with suppliers inorder to ensure that the suppliers have sufficient cash to withstand the Economic downturn. 2. A strong application software (VONTIK) is used where the suppliers are needed to upload their balance sheets twice a year inorder to ensure that they are not under financial depts.	1, 1	0.4(N)	1(I)	1(I)	The Risk Management Team and the Vontik software will primarily indulge in the faster working of the processess and hence will improve the cost management structure and the time management.
	4. Sometimes when new products are used , it needs to be validated and the validation of the product might take a long time . Hence the project tends to fall out of schedule.	1. Inorder to ensure a faster validation process , the PLUS software tends to speed up the process. 2. The subject material technical expert also helps in the right validation of the components and the subsystem components.	1, 1	0.6(I)	0.6(N)	0.8(I)	ICT Management brings about a better co-ordination amongst all the functional units. Hence better cost manageent and time management.

Risk management strategies that effect the internal organization processes, like software tools and escalations have little effect on the quality of the products, but it rather tends to speed up processes and have a bettercost management structure.

Risk management strategies related to the Suppliers tends to improve the componnet level qualities and also initiates that the project remains in the schedule.

	5. Sometimes the suppliers donot have the capabilities for product realization or production expertise.	1. JC makes their suppliers go through the Production Part Approval process. Before going into a series production with the supplier and choosing the supplier, the supplier is made to perform the Run at rate test with the suppliers . This helps to ensure the technical and the production capabilities of the suppliers.	1	1(I)	0.6(N)	1(I)	The PPAP process ensures that the quality is completely improved since it validates the production capabilities of the suppliers.
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CHAPTER 5

5.1 Process of consolidation to arrive to 27 Risk management activities.

FINAL TAG	RISK MANAGEMENT ACTIVITIES	RISK MANAGEMENT ACTIVITY TAG	CONTEXT
FA-1	Team meetings, Interactions, discussions, amongst all the stakeholders(the end clients, cross- functional units like production and planning, Supply chain, Engineering, Manufacturing, and Suppliers and Vendors). A Process management approach where the team meets up on Monday to decide on the agenda of work, or action plans, and then meets up again on Fridays to decide upon the achievements.	INTERACTIONS/DISCUSSIONS	TH, IO, SV
FA-2	Try to achieve a closer proximity with the suppliers in terms of distance , and also by deputing project engineers stationed in supplier workplace	CLOSER SUPPLIER PROXIMITY	TH,SV
FA-3	Complete technical assistance, and appropriate/ streamlined and correct specifications provided to suppliers.	TECHNICAL ASSISSTANCE	TH, SV
FA-4	Re-evaluation of the project critical path, and Re-Design of the project breakdown structure, Stronger front end loading, allocate more budget for executional procedures.	RE-EVALUATION	IO
FA-5	Re-think, Re-do, Re-design the concept, and Re-design of the Engineering	RE-DESIGN	TH, IO
FA-6	Testing conducted on the individual subsystem, the complete system as a whole , in an artificial environment, or using new methodologies of testing. Run sample simulations	SYSTEM TESTING	TH, IO
FA-7	Inclusion of a specific project manager, or recruiting more people to maintain the balance of the team, in terms of team members as well as knowledge management . Imbibe knowledge from external bodies.	KNOWLEDGE MANAGEMENT	IO
FA-8	Conducted technical risk workshops and business risk workshops.	RISK WORKSHOPS	TH
FA-9	Formation of individual dedicated functional units (like assembly and integration), and deputation of dedicated engineer(dedicated to a particular job), or use a dedicated RACI matrix to allot specific functions for specific people.	TASK SPECIFICATION	IO
FA-10	Tasks are carried out more parallaly than series inorder to speed up processes.	PARALLEL ACTIVITIES	IO
FA-11	Involve the project engineers and the suppliers from the very concept design phase and hence streamline the suppliers process of working, which also helps them to realize the complexity of the project.	INITIAL INVOLVEMENT OF ENGINEERS/SUPPLIER	TH,SV
FA-12	A strong failure mode effects analysis is carried out after the concept design(product) and also a F.M.E.A carried out on the project level (process)	FAILURE MODE EFFECTS ANALYSIS	TH, IO
FA-13	A specific technical supervisor/ technical expert/ subject material technical expert, responsible for providing technical solution, and works closely with the technical and R&D center to find solutions of technical complexities.	TECHNICAL EXPERTISE	TH,IO

FA-14	Brainstorming different technical solutions.	BRAINSTORMING	TH
FA-15	Resort to escalations to higher management in order to ensure that the resources are allocated on time, or convince the management by means of a business case.	ESCALLATIONS	IO
FA-16	Build up a strong risk register in which all parties fill up their respective risks, and immediate actions and updation of risk list is done depending on high priority or Not so high priority (Risk Impact). Hence a master document is maintained consisting of things gone right and things gone wrong.	RISK REGISTER	TH, IO, SV
F-17	Adopting a pragmatic approach by adopting a milestone based payment system to suppliers.,decide budget after each stage gate, have alternatives and back up options to resort to in order to stick to deadlines, and adapt time/cost if scope and plan changes.	PRAGMATIC APPROACH	IO
F-18	Involvement of a system architect who is responsible for the integration and assembly of the entire system.	SYSTEM ARCHITECT	TH,IO
F-19	Resorting to back up resources from other projects	BACK-UP RESOURCES	IO,SV
F-20	Application of a strong ICT software to keep track of past records of suppliers, or even use of a ICT software to keep a track and estimate of the stage gates of the project progress in terms of Cost estimates and milestones.	APPLICATION OF ICT	IO
F-21	Prove the usefulness of the product, by proving a high net present value of the investments, or by proving that the product can have wider applications.	WIDER PRODUCT APPLICATION	TH
F-22	Root cause analysis is done to judge and find the reasons for projects falling out of schedule, due to budget, or time, or technical grounds	ROOT CAUSE ANALYSIS	TH, IO
F-23	Schedule the delivery of the suppliers a couple of weeks prior to assembly, and consider buffer time during the planning phase or front end loading.	PRIOR DELIVERY OF COMPONENTS	SV
F-24	Incase of not having complete technical expertise on the component or subsystem, ensure to choose a supplier with strong technical expertise on that subject, or check with other companies to understand their developmental capabilities.	COMPETENT SUPPLIERS	SV, TH
F-25	Follow the Production Part approval process where the suppliers are made to undergo a Run at rate Test--- to have an idea of the production capabilities of the supplier.	PPAP PROCESS	SV
F-26	The sales team and not the purchase team directly deals with suppliers incase of non-dictated suppliers (Tier-2)	SUPPLIER CONTROL	SV
F-27	A dedicated Risk management Team is Present which deals and interacts with suppliers in order to ensure that suppliers have sufficient cash to withstand economic breakdown.	RISK MANAGEMENT TEAM	SV

CONSOLIDATION PROCESS OF 27 RISK MANAGEMENT ACTIVITIES

<p>INTERACTIONS</p> <ol style="list-style-type: none"> 1.Team meetings. 2. Discussions amongst cross functional units. 3. Scheduled meetings across the week.(Process management) 	<p>SUPPLIER PROXIMITY</p> <ol style="list-style-type: none"> 1. Select suppliers as close as possible in terms of geographical distance. 2. Deputation of project engineer in supplier workplace and vice versa. 	<p>TECHNICAL ASSISSTANCE</p> <ol style="list-style-type: none"> 1. Complete technical support to supplier. 2. Streamlined scope. 3. Correct technical specifications provided to suppliers. 	<p>RE-EVALUATION</p> <ol style="list-style-type: none"> 1. Re-evaluation of project critical path. 2. Re-design of project break-down structure. 3. Stronger front end loading. 4. More Budget for execution. 	<p>RE-DESIGN</p> <ol style="list-style-type: none"> 1. Re-Think the entire concept. 2. Re- design the entire concept. 3. Re-think and Re-do the entire engineering. 	<p>SYSTEM TESTING</p> <ol style="list-style-type: none"> 1.Test individual subsystems. 2. Complete system testing. 3. Test in an artificial environment. 4. Run sample simulations.
<p>KNOWLEDGE MANAGEMENT</p> <ol style="list-style-type: none"> 1. Inclusion of Project manager. 2. Recruit technical experts. 3. Knowledge acquisition 	<p>RISK WORKSHOPS</p> <ol style="list-style-type: none"> 1. Conduct technical risk workshops. 2. Conduct business risk workshops. 	<p>TASK SPECIFICATION</p> <ol style="list-style-type: none"> 1. Individual functional units. 2. Dedicated project engineers. 3. Use a dedicated responsibility assessment matrix. 4. Tasks specified depending on the technical presion. 	<p>PARALLEL ACTIVITIES</p> <ol style="list-style-type: none"> 1. Tasks are carried out in parallel. 2. Different functional units carry out tasks simultaneously. 	<p>INITIAL INVOLVEMENT OF SUPPLIERS</p> <ol style="list-style-type: none"> 1. Involve the project engineers and the suppliers from concept design phase. 2. Streamline the suppliers process of working. 	<p>F.M.E.A</p> <ol style="list-style-type: none"> 1. F.M.E.A is carried out after the concept design of the product is achieved. 2. F.M.E.A is carried out on the project level (process management)
<p>TECHNICAL EXPERTISE</p> <ol style="list-style-type: none"> 1. A specific technical supervisor . 2. A technical supervisor. 3.. Subject material technical expert. 	<p>ESCALLATIONS</p> <ol style="list-style-type: none"> 1. Route to higher management. 2. Ensure that resources are allocated on time. 3. Convince the management by means of business case. 	<p>RISK REGISTER</p> <ol style="list-style-type: none"> 1. Documentation process in which all parties fill up their respective risks. 2. Immediate action and updation the risk list. 3. Prioritization on impact. 	<p>PRAGMATIC APPROACH</p> <ol style="list-style-type: none"> 1. Milestone based payment. 2. Budget decided after each stage gate. 3. Have alternatives . 	<p>SYSTEM ARCHITECT</p> <ol style="list-style-type: none"> 1. Involvement of a system architect. 2. Integration and assembly of entire system.(supervision) 	<p>BACK UP RESOURCES</p> <ol style="list-style-type: none"> 1. Resorting to back up resources from other projects.
<p>APPLICATION OF ICT</p> <ol style="list-style-type: none"> 1. ICT software to keep track of past records of suppliers. 2. To keep track and estimates of the stage gates of project. 	<p>WIDER PRODUCT APPLICATION</p> <ol style="list-style-type: none"> 1. Prove a high net present value of the investment. 2. Prove that the product can have wider applications. 	<p>ROOT CAUSE ANALYSIS</p> <ol style="list-style-type: none"> 1. To find reasons for projects falling out of time schedule. 2.Reasons for projects falling out of budget, time and technical grounds. 	<p>PRIOR DELIVERY</p> <ol style="list-style-type: none"> 1.Prior delivery of components from suppliers. 2. Buffer time added in the planning schedule for lead delivery time. 	<p>TECHICAL COMPETENCE OF SUPPLIERS</p> <ol style="list-style-type: none"> 1. Choose a supplier with strong technical expertise. 2. Check up on past executed projects of suppliers. 	<p>PPAP PROCESS</p> <ol style="list-style-type: none"> 1. Make the supplier undergo Run at rate test.
<p>SUPPLIER CONTROL</p> <ol style="list-style-type: none"> 1. Direct control : technical as well as commercial governance. 2. Indirect control : Only commercial governance. 	<p>RISK MANAGEMENT TEAM</p> <ol style="list-style-type: none"> 1. Creation and supervision of a master data document of suppliers. 	<p>BRAINSTORMING</p> <ol style="list-style-type: none"> 1. Experts finding best possible solutions. 2. using the delphi technique. 			

5.2 Determining the type of Risk Activity

ANALYSIS OF THE RISK MANAGEMENT ACTIVITIES (whether they cater to technological grounds, or Internal organizational grounds, or External organizational grounds)

The analysis of how the above consolidated Risk management activities helps to manage Risks on grounds of Technology, Internal organization structure and the External Organization has been explained below :

1. **Interactions and Discussions** : Interactions and discussions are the most basic form of process management to manage and counter risks on all aspects. Interactions and discussions amongst all the cross functional silos, the board of management, the end client , or the suppliers and vendors help to find solutions for complexities related to technology, or internal clashes or the requisites of the suppliers and the vendors.
2. **Closer Supplier Proximity** : Closer proximity to the supplier helps to pass on the appropriate message of the exact specific requirements on technical grounds. Moreover deputation of a project engineer at the client end ensures that the design and the development of the subsystem or the software proceeds in the right technical direction. Closer supplier proximity ensures that the suppliers or the external market is strongly knit to the organization. Closer supplier proximity caters to the technological risks and the external organizational risks.
3. **Technical Assistance**: The risk management activity of technical assistance complements the previous risk activity of Closet supplier proximity. If the company has certain technical expertise on certain subsystems, rendering help to the suppliers ensures that technological complexities at the supplier end is being taken care of . It also improves the level of interaction between the organization and the external market (suppliers and vendors). Technical assistance of the parent company to the suppliers and the vendors helps to manage risks on grounds of technology and the external market.
4. **Re-Evaluation** : Re-evaluation primarily caters to redefining the critical path of the project. Re-evaluation brings about changes in the front end loading of the project. It brings about better awareness amongst all the functional units involved in the project, of the changes in the project critical path. Hence it brings all the functional units involved on common terms. Re-evaluation of the project critical path helps to manage risks on grounds of Internal organization.
5. **Re-Design** : Re-design ensures the correctness of the concept design to be achieved. It paves the way to achieve a technically correct product or system. In the process of redesign the culminated efforts of the experts of the different functional units like the R&D , the engineering and the design and the assembly unit ensures that the different functional units of the organizations are on a common platform. Re-design helps to manage risks on Technological grounds and Internal organizational grounds.
6. **System Testing**: System testing ensures the correctness of the integration of the various subsystems to realize the final system or product. System testing helps to manage the complexity on technological grounds since it helps to test if the required functionalities of the system are successfully achieved. The testing is achieved with the culminated efforts of the different functional units namely the assembly and testing unit, the manufacturing unit, the design and engineering unit and the suppliers and vendors. System testing brings all the units of the organization on a common platform. Therefore system testing helps to manage technological risks, as well as internal organizational risks.
7. **Knowledge Management**: Knowledge management helps to manage risks related to the internal organizational complexities by ensuring that the right balance of technical expertise, innovative abilities as well as project management capabilities are maintained.

8. **Risk Workshops:** Risk workshops help to make the project execution team well aware of the various technological risks that are possible. Risk workshops help the project execution team prepared to manage the technological complexities. The technological risks faced in past executed projects are discussed in the risk workshops.
9. **Task Specifications:** Appropriate task specifications according to the technical expertise of the units helps the internal organization to be well aware of the limits and the extent of responsibilities in the different stages of the product realization. Task specifications primarily helps to manage the risks and complexities of Internal organization on grounds of clarity of responsibility and functional expertise of the units.
10. **Parallel activities :** Parallel activities is a risk management activity that complements the activity of task specification. Parallel activities helps to manage the risks and complexities related to internal organization. Different functional units starts different tasks parallel. Parallel activities primarily helps to manage the time and the cost management of the project within the different functional units of the organization.
11. **Initial Involvement of Suppliers and vendors:** Initial involvement of the suppliers and the vendors in the design stage of the project helps to manage the risks on Technological grounds as well as external market. Involvement of the suppliers and the vendors at an early stage helps them to realize the complexity of the project as well as brings the suppliers and the vendors closer to the organization.
12. **Failure Mode Effects analysis(F.M.E.A):** F.M.E.A helps to manage risks on Technical grounds as well as on grounds of Internal Organization. F.M.E.A is used on two levels. A failure mode effects analysis carried out on a product level helps to find a solution for technical complexities. An F.M.E.A carried out on a project level helps to manage risks of the time management and the cost management of the Internal organization.
13. **Technical Expertise:** The technical expertise of the employees help to find solutions and realize a technically correct system. It helps to propel the product development at a faster rate. Technical expertise helps to manage risks on technical grounds as well as manages the risk of time management of the internal organization.
14. **Brainstorming:** Brainstorming amongst all the technical experts helps to find plausible solutions for a technical complexity. Brainstorming primarily caters to managing Technological risks.
15. **Escalations:** Escalations is a risk management activity primarily carried out within the organization as a faster route to the board of management or higher authorities for approval of budget or resources. Escalations primarily helps to manage the complexities of the internal organization.
16. **Risk Register:** Risk Register is the most common documentation process which helps in registering risks related to technological grounds, the internal organization structure as well as the external market viewed as the suppliers and the vendors. The risks are prioritized depending on risk impacts and the plan of actions to mitigate the risks are also documented.
17. **Milestone based payment system:** A milestone based payment system helps to manage risks related to the cost management within the internal organization. A payment mechanism as per stage gates ensures that budget is utilized optimally, since it takes care that suppliers and vendors are paid only upon deliverables as well as certain targets of the project is achieved. This takes care that there are less sunk costs associated to the project.
18. **A System Architect/Subject Material technical expert:** Involvement of a system architect ensures correctness in the process of assembly of the entire system. The subject material technical expert also ensures that the product is stripped down correctly to the sub-components. They help to specify the correct requirements for the subcomponents, which further leads to the correctness of the product realized. A system architect or a subject material technical expert primarily helps in managing technological complexities. However they also help to bring the project team members

and the executives of the various functional units on a common platform of the technical requirements of the system. Hence they are also involved in bridging the gap between the different functional silos, and manage the various internal organizational complexities.

19. **Back up resources:** Back up resources primarily helps to manage risks related to internal organization and the suppliers and vendors. It ensures that in case of a sudden crisis in the inventory, or availability of resources then back up options from other projects helps in the time and cost management of the project in the context of the internal organization and the external market.
20. **Application of ICT:** A common ICT platform amongst all the actors related to the project helps in bringing about better coordination amongst all the functional units. It establishes a better mechanism of following the updates along the proceedings of the various stage gates of the projects. It primarily caters to the management of the risks related to the internal organization.
21. **Wider product application:** Wider application of the product or the system, brings better acceptability of the product or the system at the client end on technological grounds. Wider product applications help in managing technological risks of acceptability of the system to the client.
22. **Root Cause Analysis(R.C.A):** R.C.A helps to manage risks on Technical grounds as well as on grounds of Internal Organization. R.C.A is used on two levels. Root cause analysis carried out on the product level helps to find a solution for technical complexities. A root cause analysis carried out on a project level helps to manage risks of the time management and the cost management of the Internal organization since it primarily analyses on the perspectives of man, material, method and the environment.
23. **Smart delivery planning:** Smart delivery planning or prior delivery of components is a risk management activity which helps to manage the risk of the suppliers and the vendors not being able to deliver by the scheduled lead times. A buffer of a couple of weeks before the integration and the assembly of the entire system is considered as the due date for the delivery of the sub-components and the sub-systems. The risk management activity is adopted to streamline the time management related to the external organization.
24. **Selecting technically competent suppliers:** The technical competence of the suppliers becomes a very crucial factor for selecting the right suppliers for the project. The technical competence of the suppliers has a strong influence on how easily they can cope with the technical complexities of the sub-systems. Selecting technically competent suppliers helps to manage risks related to the technology as well as the external market.
25. **Production Part Approval Process(PPAP):** Before the supplier is selected, the supplier is made to undergo a Run at Rate test, where they have to produce one complete shift for the company abiding to the company specifications. PPAP helps to manage the risks of the external organization by selecting the right competent suppliers and vendors.
26. **Supplier Control :** Supplier control also helps to manage the risks of the external organization by exerting their governance over the suppliers. If the organization has direct control over their suppliers then they interact on technical as well as commercial terms. However if the suppliers are governed by the end clients or the OEMs then the interaction of the organization related to suppliers is only on commercial terms.
27. **Dedicated Risk Management Team:** A dedicated risk management team helps to manage the risks of the external organization by selecting the right competent suppliers and vendors. The risk management team helps to maintain a master document of the database of all suppliers with their present financial conditions. They analyse if the supplier would be able to withstand economic downturn.

5.3 Master data sheet for fsQCA analysis

CASES	OUTPUTS			RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9	RA10	RA11	RA12	RA13	RA14	RA15	RA16	RA17	RA18	RA19	RA20	RA21	RA22	RA23	RA24	RA25	RA26	RA27
	QUALITY	COST	TIME																											
Applus RTD - 1	0.8	0.8	0.4	0.8	1	0.8	0.6	0.8	1	1	0.8	0.4	1	0	0	0.4	0.4	0.6	0.4	0.2	0	1	0	0.8	0.6	0.4	0.6	0	0	0
ASML-1	0.8	0.6	0.8	0.8	0.6	0.6	0	1	0.2	0	0.2	0.6	0.8	0.6	1	0.6	0.6	1	0.8	0.6	0	0	0	0	0	0.2	0.4	0	0	0
ASML-2	0.6	0.8	0.4	1	0	1	0.6	0.6	0.2	0.6	0.2	0.6	0.6	1	1	0.4	0.4	0.4	1	1	0	0	0	0	0	0.2	0.2	0	0	0
Applus RTD-2	0.6	0.8	1	0.8	0	0.8	0.6	0.8	0.8	0	0.4	0.6	0.2	0.8	0	0.8	1	0.4	0.4	0.6	1	0	0	1	0.6	0.4	0.4	0	0	0
Johnson Control-1	0.8	0.6	0.8	1	0	0.2	0	0.4	0.6	0	0	1	0	0.4	0.8	1	0	0.8	0.6	0.8	0	0	1	0	0.6	1	0.8	1	1	1
Johnson Control-2	0.8	0.6	0.8	1	0	0.2	0	0.4	0.6	0	0	1	0	0.4	0.8	1	0	0.8	0.6	0.8	0	0	1	0	0.6	1	0.8	1	1	1

- RA1= Interactions
- RA2= Closer Supplier proximity
- RA3= Technical Assistance
- RA4= Re-Evaluation
- RA5= Re-Design
- RA6= System Testing
- RA7= Knowledge Management
- RA8= Risk Workshops
- RA9= Task Specification
- RA10= Parallall Activities
- RA11= Initial Involvement of Suppliers/ Vendors
- RA12= Failure Mode Effects Analysis
- RA13= Technical Expertise
- RA14= Brainstorming
- RA15= Escallations
- RA16= Risk Register
- RA17= Pragmatic Approach
- RA18= System Architect
- RA19= Back-up Resources
- RA20= Application of ICT
- RA21= Wider Product Application
- RA22= Root Cause Analysis
- RA23= Prior Delivery of Components
- RA24= Competent Suppliers
- RA25= PPAP Process
- RA26= Supplier Control
- RA27= Risk Management Team

1. Company A Project1: 0.8 for the Quality since they achieved their main goal which was to make their system more robust, 0.8 for cost because they efficiently managed their cost and made a management approve more budget by means of an efficient business plan.0.4 for time since they underestimated the complexity of the project which was responsible for the main delay.

2. Company B Project1: 0.8 for Quality since they manufactured systems which are responsible for the safety and protection of the lithography system'0.6 for cost, since costs were managed well, by resorting to escallations, however the budget issues were not out of proportion. 0.8 for the time since they are more of ancillary support systems , they ensure that they stick to time inorder to maintain the scheduled shipment of the primary shipment

3. Company B Project2: 0.6 for Quality because they were able to just achieve the successful concept design, however since the prototype was not developed the technical assurance was low. 0.8 was scored for the cost since the cost management was excellent where the suppliers were paid on a stage gate and milestone pro rata. 0.4 for time since having to work with premature suppliers pushed the realization of the concept design out of schedule.

4. Company A Project1: 0.6 for the Quality since the main aim was to penetrate the market and hence the prototype was not the best possible quality that Applus could deliver. However the time management was excellent since the project was successfully executed within the time frame and the product was delivered to the end client. Cost management was also crisp since the budget was decided upon the stage gates. the expenditure of the next phase or activity and even the estimate of the entire project.

5. Company C Project 1 &2 : Johnson Controls gets 0.8 for Quality since they cater to one of the biggest OEMs like BMW and hence the quality they attained in the projects were of optimum level. Moreover they acquired the projects on grounds of providing an innovative seating solution. 0.6 for cost management since they primarily managettheir costs by means of escallations. Time management of the projects for Johnson Controls is higher of 0.8, resoting to an ICT based solution which brings about faster co-ordination amongst all the stakeholders.

5.4 Fuzzy data sets as an input to fsQCA analysis

TECHNOLOGICAL RISK MANAGEMENT ACTIVITIES (FUZZY DATA SET)

COMPANY	RA1	RA2	RA3	RA6	RA5	RA8	RA11	RA12	RA13	RA14	RA16	RA18	RA21	RA22	RA24	Quality	Cost	Time
APPLUS1	0.8	1	0.8	1	0.8	0.8	0	0	0.4	0.4	0.4	0	0.8	0.6	0.6	0.8	0.8	0.4
ASML1	0.8	0.6	0.6	0.2	1	0.2	0.6	1	0.6	0.6	0.8	0	0	0	0.4	0.8	0.6	0.8
ASML2	1	0	1	0.2	0.6	0.2	1	1	0.4	0.4	1	0	0	0	0.2	0.6	0.8	0.4
APPLUS2	0.8	0	0.8	0.8	0.8	0.4	0.8	0	0.8	1	0.4	1	1	0.6	0.4	0.6	0.8	1
JC1	1	0	0.2	0.4	0.4	0	0.4	0.8	1	0	0.6	0	0	0.6	0.8	0.8	0.6	0.8
JC2	1	0	0.2	0.4	0.4	0	0.4	0.8	1	0	0.6	0	0	0.6	0.8	0.8	0.6	0.8

INTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITIES (FUZZY DATA SET)

COMPANY	Quality	Cost	Time	ra1	ra4	ra5	ra6	ra7	ra9	ra10	ra12	ra13	ra15	ra16	ra17	ra18	ra19	ra20	ra22
Applus1.	0.8	0.8	0.4	0.8	0.6	0.8	1	1	0.4	1	0	0.4	0.6	0.4	0.2	0	1	0	0.6
ASML1	0.8	0.6	0.8	0.8	0	1	0.2	0	0.6	0.8	1	0.6	1	0.8	0.6	0	0	0	0
ASML2	0.6	0.8	0.4	1	0.6	0.6	0.2	0.6	0.6	0.6	1	0.4	0.4	1	1	0	0	0	0
Applus 2.	0.6	0.8	1	0.8	0.6	0.8	0.8	0	0.6	0.2	0	1	0.4	0.4	0.6	1	0	0	0.6
Johnson1.	0.8	0.6	0.8	1	0	0.4	0.6	0	1	0	0.8	0	0.8	0.6	0.8	0	0	1	0.6
Johnson2.	0.8	0.6	0.8	1	0	0.4	0.6	0	1	0	0.8	0	0.8	0.6	0.8	0	0	1	0.6

EXTERNAL ORGANIZATIONAL RISK MANAGEMENT ACTIVITIES (FUZZY DATA SET)

COMPANY	Quality	Cost	Time	RA1	RA2	RA3	RA11	RA16	RA19	RA23	RA24	RA25	RA27
Applus 1.	0.8	0.8	0.4	0.8	1	0.8	0	0.4	1	0.4	0.6	0	0
ASML1.	0.8	0.6	0.8	0.8	0.6	0.6	0.6	0.8	0	0.2	0.4	0	0
ASML2.	0.6	0.8	0.4	1	0	1	1	1	0	0.2	0.2	0	0
Applus2.	0.6	0.8	1	0.8	0	0.8	0.8	0.4	0	0.4	0.4	0	0
Johnson1.	0.8	0.6	0.8	1	0	0.2	0.4	0.6	0	1	0.8	1	1
Johnson2.	0.8	0.6	0.8	1	0	0.2	0.4	0.6	0	1	0.8	1	1

5.5 Results of Technological Risk management activities fsQCA solutions.

Conditions chosen are:

- **Quality: Re-Design (ra5), F.M.E.A (ra12), Interactions (ra1), Root Cause Analysis (ra22) to determine the bottleneck.**

ra1	ra5	ra12	ra22	number	quality	raw consist.	PRI consist.	SYM consist
1	1	1	0	2	1	1.000000	1.000000	1.000000
1	1	0	1	2	1	1.000000	1.000000	1.000000
1	0	1	1	2	1	1.000000	1.000000	1.000000

The solution:

```
*****
*TRUTH TABLE ANALYSIS*
*****
```

```
File: C:/Users/Asus/Desktop/fsQCA3.csv
Model: quality = f(ra1, ra5, ra12, ra22)
```

```
Rows:      3
```

```
Algorithm: Quine-McCluskey
  True: 1
  0 Matrix: 0-CL
```

```
--- TRUTH TABLE SOLUTION ---
Frequency cutoff: 2.000000
consistency cutoff: 1.000000
Assumptions:
```

	raw coverage	unique coverage	consistency
ra1*ra5*ra12*~ra22	0.500000	0.318182	1.000000
ra1*ra5*~ra12*ra22	0.363636	0.272727	1.000000
ra1*~ra5*ra12*ra22	0.272727	0.090909	1.000000
solution coverage:	0.863636		
solution consistency:	1.000000		

This shows that the most used combination of risk management strategies are ra1,ra5, ra12 since it has a raw coverage of 0.50 and unique coverage of 0.3181.hence most used risk management strategies from the perspective of Technical risks trying to improve the quality in terms of Technology are Interactions, Root Cause Analysis, F.M.E.A.

Set and Subset Analysis:

terms	consistency	coverage	combined
ra1*ra5*ra12*ra22	1.000000	0.181818	0.424264
ra1*ra12*ra22	1.000000	0.272727	0.519615
ra5*ra12*ra22	1.000000	0.181818	0.424264
ra1*ra5*ra12	1.000000	0.500000	0.703562
ra1*ra5*ra22	1.000000	0.454545	0.670820
ra12*ra22	1.000000	0.272727	0.519615
ra1*ra12	0.882353	0.681818	0.800568
ra1*ra22	1.000000	0.545455	0.734847
ra5*ra12	0.916667	0.500000	0.696419
ra5*ra22	1.000000	0.454545	0.670820
ra1*ra5	0.947369	0.818182	0.895443
ra12	0.833333	0.681818	0.770183
ra22	1.000000	0.545455	0.734847
ra1	0.814815	1.000000	0.911043
ra5	0.900000	0.818182	0.886259

Combined ra1*ra5 with 0.895443 is the most sufficient condition, which states that Interactions with Redesign. However Redesign can be implemented only by means of combinations of ra1*ra12 (0.800568) and ra1*ra22 (0.73487). Hence we can conclude that the re-design can be implemented only by means of a strong root cause analysis and F.M.E.A.

- **Cost:** the conditions chosen are Interactions (ra1), System Architect (ra18), Re-Design(ra5), System Testing(ra6).

ra1	ra5	ra6	ra18	number	cost	raw consist.	PRI consist.	SYM consist
1	1	0	0	2	0	0.909091	0.750000	1.000000
1	0	0	0	2	1	1.000000	1.000000	1.000000
1	1	1	1	1	1	1.000000	1.000000	1.000000
1	1	1	0	1	1	1.000000	1.000000	1.000000

```
*****
*TRUTH TABLE ANALYSIS*
*****
```

```
File: C:/Users/Asus/Desktop/fsQCA3.csv
Model: cost = f(ra1, ra5, ra6, ra18)
```

```
Rows: 4
```

```
Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL
```

```
--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 1.000000
Assumptions:
```

	raw coverage	unique coverage	consistency
ra1*ra5*ra6	0.666667	0.428571	1.000000
ra1*~ra5*~ra6*~ra18	0.380952	0.142857	1.000000
solution coverage: 0.809524			
solution consistency: 1.000000			

The results of the analysis are:

The results of the analysis shows that the combination of Interactions, Re-Design, System testing has the maximum coverage and unique coverage .

Set and Subset analysis:

terms	consistency	coverage	combined
ra1*ra5*ra6*ra18	1.000000	0.190476	0.434248
ra1*ra5*ra18	1.000000	0.190476	0.434248
ra1*ra6*ra18	1.000000	0.190476	0.434248
ra5*ra6*ra18	1.000000	0.190476	0.434248
ra1*ra5*ra6	1.000000	0.666667	0.812404
ra1*ra18	1.000000	0.190476	0.434248
ra5*ra18	1.000000	0.190476	0.434248
ra6*ra18	1.000000	0.190476	0.434248
ra1*ra5	0.947368	0.857143	0.916515
ra1*ra6	1.000000	0.666667	0.812404
ra5*ra6	1.000000	0.666667	0.812404
ra18	0.800000	0.190476	0.390360
ra1	0.777778	1.000000	0.860233
ra5	0.900000	0.857143	0.907115
ra6	0.933333	0.666667	0.808290

The above set and subset analysis shows that the combination of ra1*ra5 that is Interactions, and Re-design is the sufficient conditions.

Condition ra1*ra6 is (0.81) and ra5*ra6 is (0.81)-----→ hence the actual coverage ra1*ra5*ra6 is 0.66

Hence in terms of cost also redesign and Interactions should be backed by system testing.

- Time : Conditions chosen are Closer Supplier Proximity (ra2), Initial Involvement of Engineers and Suppliers (ra11), Full blown Risk Register(ra16), and Technical Assistance(ra3)

ra2	ra3	ra11	ra16	number	time	raw consist.	PRI consist.	SYM consist
0	0	0	1	2	1	1.000000	1.000000	1.000000
1	1	1	1	1	1	1.000000	1.000000	1.000000
1	1	0	0	1	0	0.750000	0.000000	0.000000
0	1	1	1	1	0	0.727273	0.500000	0.750000
0	1	1	0	1	1	1.000000	1.000000	1.000000

The main analysis and solutions are :

```
*****
*TRUTH TABLE ANALYSIS*
*****
```

```
File: C:/Users/Asus/Desktop/fsQCA3.csv
Model: time = f(ra2, ra3, ra11, ra16)
```

```
Rows: 5
```

```
Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL
```

```
--- TRUTH TABLE SOLUTION ---
```

```
frequency cutoff: 1.000000
```

```
consistency cutoff: 1.000000
```

```
Assumptions:
```

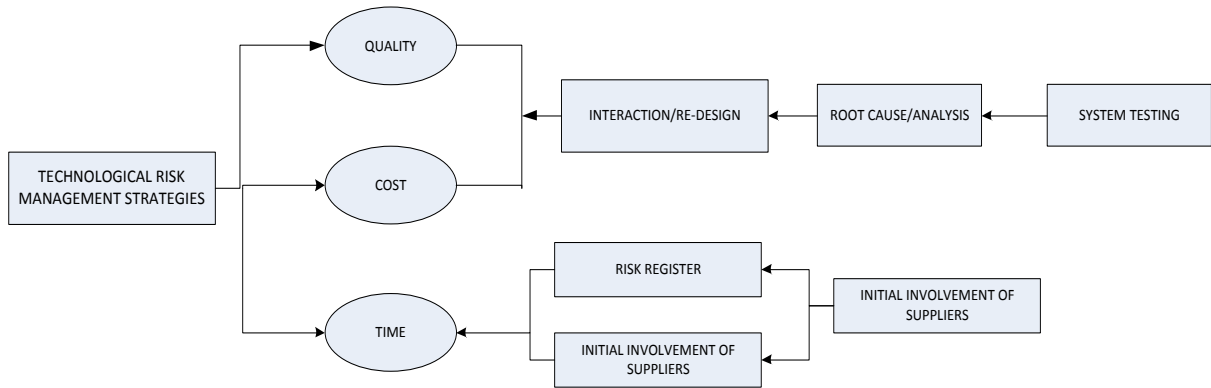
	raw coverage	unique coverage	consistency
~ra2*~ra3*~ra11*ra16	0.428571	0.190476	1.000000
~ra2*ra3*ra11*~ra16	0.285714	0.095238	1.000000
ra2*ra3*ra11*ra16	0.142857	0.047619	1.000000
solution coverage:	0.571429		
solution consistency:	1.000000		

. The above solution gives the result that risk register is the most essential documentation procedure which helps to keep track of the most crucial and highly prioritized risks. The set and subset analysis is as follows:

terms	consistency	coverage	combined
ra2*ra3*ra11*ra16	1.000000	0.142857	0.376070
ra2*ra11*ra16	1.000000	0.142857	0.376070
ra3*ra11*ra16	0.750000	0.428571	0.531843
ra2*ra3*ra11	1.000000	0.142857	0.376070
ra2*ra3*ra16	1.000000	0.238095	0.485504
ra11*ra16	0.785714	0.523810	0.630948
ra2*ra11	1.000000	0.142857	0.376070
ra2*ra16	1.000000	0.238095	0.485504
ra3*ra11	0.785714	0.523810	0.630948
ra3*ra16	0.785714	0.523810	0.630948
ra2*ra3	0.714286	0.238095	0.361873
ra11	0.812500	0.619048	0.712474
ra16	0.842105	0.761905	0.818826
ra2	0.625000	0.238095	0.223607
ra3	0.722222	0.619048	0.594018

The set and subset analysis also shows that the ra16 is the most sufficient condition, but has to be backed up by the other two combinations ra3*ra11 (That is Technical assistance and Initial Involvement of Suppliers).Initial Involvement of Suppliers (ra11) also has a huge importance of 0.712474.

The Model for Technological Risk Management activities (fsQCA solution):



5.6 Results of Internal Organizational Risk management activities (fsQCA solutions).

Conditions chosen are:

- Quality: Interaction (ra1), Clear task Specification(ra9), System Architect (ra18), Technical Expertise(ra13)

ra1	ra9	ra13	ra18	number	quality	raw consist.	PRI consist.	SYM consist
1	1	0	0	3	1	0.882353	0.818182	1.000000
1	1	1	1	1	1	1.000000	1.000000	1.000000
1	1	1	0	1	1	1.000000	1.000000	1.000000
1	0	0	0	1	1	1.000000	1.000000	1.000000

Though the first condition has a consistency of 0.88 the frequency is extremely high and hence I cannot really neglect it. Hence all the conditions are chosen.

```

*****
*TRUTH TABLE ANALYSIS*
*****

File: C:/Users/Asus/Desktop/fsQCA5.csv
Model: quality = f(ra1, ra9, ra18, ra13)

Rows: 4

Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL

--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 0.882353
Assumptions:

              raw          unique
              coverage      coverage      consistency
-----
ra1*~ra18*~ra13  0.727273    0.454545    0.888889
ra1*ra9*ra13     0.454545    0.181818    1.000000
solution coverage: 0.909091
solution consistency: 0.909091

```

The result of the analysis declares that the first set of conditions that ra1*-ra18*-ra13 has the biggest raw coverage of 0.7272 and unique coverage of 0.4545. However interaction forms the primary basis for risk management. Hence we choose the second condition that is interactions, clear task specifications and the technical expertise of the employees which will help to improve the Quality of the product as seen from the context of Internal Organization structure.

Set and Subset Analysis:

terms	consistency	coverage	combined
ra1*ra9*ra18*ra13	1.000000	0.136364	0.367423
ra1*ra18*ra13	0.750000	0.136364	0.300000
ra9*ra18*ra13	1.000000	0.136364	0.367423
ra1*ra9*ra18	1.000000	0.136364	0.367423
ra1*ra9*ra13	1.000000	0.454545	0.670820
ra18*ra13	0.600000	0.136364	0.143019
ra1*ra18	0.750000	0.136364	0.300000
ra1*ra13	0.909091	0.454545	0.660578
ra9*ra18	1.000000	0.136364	0.367423
ra9*ra13	1.000000	0.454545	0.670820
ra1*ra9	0.904762	0.863636	0.910544
ra18	0.600000	0.136364	0.143019
ra13	0.833333	0.454545	0.628852
ra1	0.814815	1.000000	0.911043
ra9	0.904762	0.863636	0.910544

The subset and set analysis concludes that the most crucial and important conditions are the combination of ra1*ra9. This signifies that the combination of Interactions and Task specifications are the most important.

However a proper task specification will only be successful if the specified task is carried out by the employees with proper technical expertise. Hence Interactions and task specifications must be supported by ra13 that is the technical expertise of the employee. The technical expertise will enable him to foresee risks in a more effective way. This is also proved by the combination ra9*ra13.

- Cost : The combinations that are selected are Interactions(ra1), Application of ICT(ra20), Escalations (ra15), Milestone based approach (ra17).

ra1	ra20	ra15	ra17	number	cost	raw consist.	PRI consist.	SYM consist
1	1	1	1	2	0	0.750000	0.500000	1.000000
1	0	0	1	2	1	1.000000	1.000000	1.000000
1	0	1	1	1	1	1.000000	1.000000	1.000000
1	0	1	0	1	1	1.000000	1.000000	1.000000

In the above truth Table Analysis we specify the frequency cut of to be 1 and the raw consistency to be 1.

The results of the analysis are:

```
*****
*TRUTH TABLE ANALYSIS*
*****
```

```
File: C:/Users/Asus/Desktop/fsQCA5.csv
Model: cost = f(ra1, ra20, ra15, ra17)
```

```
Rows: 4
```

```
Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL
```

```
--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 1.000000
Assumptions:
```

	raw coverage	unique coverage	consistency
ra1*~ra20*ra15	0.476191	0.095238	0.909091
ra1*~ra20*ra17	0.523810	0.142857	0.916667
solution coverage:	0.619048		
solution consistency:	0.866667		

The analysis gives a twofold answer. The first answer is the possibility of application of ra1 and ra15 and not the application of ra20. This means that interactions should be combined with escalations. This has a raw coverage of around 0.4761. The other possible solution is ra1 and ra17, which means that the Interactions should be combined with ra17 that is milestone based approach. The raw coverage of this combination is 0.523810.

The Set and Subset analysis:

terms	consistency	coverage	combined
ra1*ra20*ra15*ra17	0.750000	0.285714	0.434248
ra20*ra15*ra17	0.750000	0.285714	0.434248
ra1*ra20*ra15	0.750000	0.285714	0.434248
ra1*ra20*ra17	0.750000	0.285714	0.434248
ra1*ra15*ra17	0.875000	0.666667	0.787401
ra20*ra15	0.750000	0.285714	0.434248
ra20*ra17	0.750000	0.285714	0.434248
ra15*ra17	0.875000	0.666667	0.787401
ra1*ra20	0.600000	0.285714	0.207020
ra1*ra15	0.842105	0.761905	0.818826
ra1*ra17	0.850000	0.809524	0.853564
ra20	0.600000	0.285714	0.207020
ra15	0.800000	0.761905	0.780720
ra17	0.850000	0.809524	0.853564
ra1	0.777778	1.000000	0.860233

Since both ra1*ra15 and ra1*ra17 have an equal sufficiency value of around 0.818826 and 0.853564...we can conclude that the most important set of conditions are the value of ra1*ra15*ra17, which is 0.75.

Hence Interactions combined with Escalations and Milestone based approach should be adopted.

- Time: the combinations chosen are Interactions (ra1), Milestone based approach (ra17), Clear task Specification (ra9), and parallel activities (ra10).

ra1	ra17	ra9	ra10	number	time	raw consist.	PRI consist.	SYM consist
1	1	1	0	3	1	1.000000	1.000000	1.000000
1	1	1	1	2	1	0.875000	0.750000	0.750000
1	0	0	1	1	0	0.833333	0.666667	0.666667

In the above truth table the raw consistency is 0.875 with a frequency cut off of 2

The analysis specifies that:

```

*****
*TRUTH TABLE ANALYSIS*
*****

File:  C:/Users/Asus/Desktop/fsQCA5.csv
Model: time = f(ra1, ra17, ra9, ra10)

Rows:      3

Algorithm: Quine-McCluskey
  True: 1
  0 Matrix: 0-CL

--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 0.875000
Assumptions:

                raw          unique
                coverage      coverage  consistency
                -----      -
ra1*ra17*ra9    0.809524      0.809524    0.944444
solution coverage: 0.809524
solution consistency: 0.944444

```

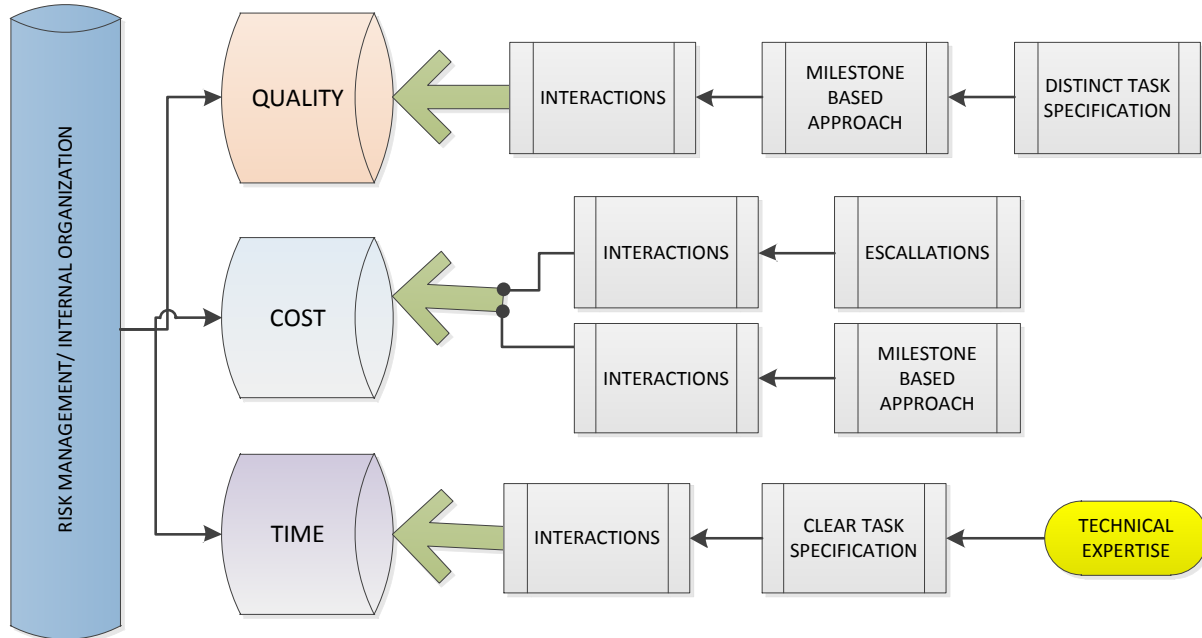
The above analysis gives an extremely unique answer which says that risks related to the time management of the project can be dealt by means of combination of ra1 with ra17 and ra9. The solution has a very significant coverage of 0.809.

Set and Subset analysis:

terms	consistency	coverage	combined
ra1*ra17*ra9*ra10	0.875000	0.333333	0.556776
ra1*ra17*ra10	0.875000	0.333333	0.556776
ra17*ra9*ra10	0.875000	0.333333	0.556776
ra1*ra17*ra9	0.944444	0.809524	0.890693
ra1*ra9*ra10	0.888889	0.380952	0.601585
ra17*ra10	0.875000	0.333333	0.556776
ra1*ra17	0.850000	0.809524	0.853564
ra1*ra10	0.750000	0.428571	0.531843
ra17*ra9	0.944444	0.809524	0.890693
ra9*ra10	0.888889	0.380952	0.601585
ra1*ra9	0.857143	0.857143	0.883176
ra17	0.850000	0.809524	0.853564
ra10	0.692308	0.428571	0.448808
ra1	0.740741	0.952381	0.774597
ra9	0.857143	0.857143	0.883176

Even the set and the subset analysis shows that the most sufficient condition is the combination of $ra1*ra17*ra9$. The value of Sufficiency is 0.89063.

Hence the conditions which help in the most effective risk management strategies in terms of internal organization structure are:



5.7 Results of External Organizational Risk management activities (fsQCA solutions).

The below mentioned are the risk management strategies related to:

- Quality: The conditions which are most relevant are Interactions (ra1), Risk Management Team (ra27), and PPAP process (ra25), Competent Suppliers (ra24).

ra1	ra27	ra25	ra24	number	quality	raw consist.	PRI consist.	SYM consist
1	0	0	0	3	1	0.916667	0.833333	1.000000
1	1	1	1	2	1	1.000000	1.000000	1.000000
1	0	0	1	1	1	1.000000	1.000000	1.000000

The results of the analysis are:

```

*****
*TRUTH TABLE ANALYSIS*
*****

File: C:/Users/Asus/Desktop/fsQCA7.csv
Model: quality = f(ra1, ra27, ra25, ra24)

Rows: 3

Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL

--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 0.916667
Assumptions:

              raw          unique          consistency
              coverage      coverage      -----
ra1*~ra27*~ra25*~ra24  0.500000    0.500000    0.916667
ra1*ra27*ra25*ra24    0.363636    0.363636    1.000000
solution coverage: 0.863636
solution consistency: 0.950000

```

The results of the analysis is a little ambiguous since the first solution clearly signifies that only Interactions without the presence of the other conditions are responsible for a sufficient condition for maintaining quality of the product pertaining to risk management related to suppliers and vendors. However this is the disadvantage of a qualitative judgement being made on quantitative grounds.

Though the first solution has coverage of 0.50 we discard it since the other combinations are more useful that is the Interactions being combined with Risk Management Team, PPAP process, Technical competence of suppliers.

Set and Subset analysis:

terms	consistency	coverage	combined
ra1*ra27*ra25*ra24	1.000000	0.363636	0.600000
ra27*ra25*ra24	1.000000	0.363636	0.600000
ra1*ra27*ra25	0.800000	0.363636	0.539360
ra1*ra27*ra24	1.000000	0.363636	0.600000
ra1*ra25*ra24	1.000000	0.363636	0.600000
ra27*ra25	0.800000	0.363636	0.539360
ra27*ra24	1.000000	0.363636	0.600000
ra25*ra24	1.000000	0.363636	0.600000
ra1*ra27	0.800000	0.363636	0.539360
ra1*ra25	0.800000	0.363636	0.539360
ra1*ra24	1.000000	0.727273	0.848528
ra27	0.800000	0.363636	0.539360
ra25	0.800000	0.363636	0.539360
ra24	1.000000	0.727273	0.848528
ra1	0.814815	1.000000	0.911043

The above analysis signifies that the combination ra1*ra24 that is Quality of the product when related to the suppliers and the vendors is the most sufficient combinations of conditions with a value of 0.848.

However conditions with combinations of ra27 /ra25 with ra24 have consistency of 1, with quite a high sufficiency value of around 0.60. Hence we can conclude that Technical competence of the suppliers should be backed up with a strong risk management team and also the PPAP process.

- Cost: The conditions which are most crucial from the perspective of cost management of the project in the context of external suppliers and vendors are Interactions, back up resources, competent suppliers.

ra2	ra19	ra24	ra1	number	cost	raw consist.	PRI consist.	SYM consist
0	0	1	1	2	0	0.846154	0.600000	1.000000
0	0	0	1	2	1	1.000000	1.000000	1.000000
1	1	1	1	1	1	1.000000	1.000000	1.000000
1	0	0	1	1	1	1.000000	1.000000	1.000000

The results of the analysis is

```

*****
*TRUTH TABLE ANALYSIS*
*****

File: C:/Users/Asus/Desktop/fsQCA7.csv
Model: cost = f(ra1, ra2, ra19, ra24)

Rows:      4

Algorithm: Quine-McCluskey
True: 1
0 Matrix: 0-CL

--- TRUTH TABLE SOLUTION ---
frequency cutoff: 1.000000
consistency cutoff: 0.846154
Assumptions:

           raw      unique
           coverage  coverage  consistency
-----
ra1*~ra19*~ra24    0.571429    0.047619    1.000000
ra1*~ra2*~ra19     0.761905    0.238095    0.761905
ra1*ra2*ra19*ra24  0.142857    0.142857    1.000000
solution coverage: 0.952381
solution consistency: 0.800000

```

The first two results are not valid since both signify that only interactions are sufficient enough for the desired result. Hence we discard both the solutions and we accept the third one which is the combination of all the conditions.

Set and Subset solution:

terms	consistency	coverage	combined
ra1*ra2*ra19*ra24	1.000000	0.142857	0.376070
ra1*ra19*ra24	1.000000	0.142857	0.376070
ra2*ra19*ra24	1.000000	0.142857	0.376070
ra1*ra2*ra19	1.000000	0.190476	0.434248
ra1*ra2*ra24	1.000000	0.238095	0.485504
ra19*ra24	1.000000	0.142857	0.376070
ra1*ra19	1.000000	0.190476	0.434248
ra1*ra24	0.875000	0.666667	0.787401
ra2*ra19	0.800000	0.190476	0.390360
ra2*ra24	1.000000	0.238095	0.485504
ra1*ra2	1.000000	0.333333	0.574456
ra19	0.800000	0.190476	0.390360
ra24	0.875000	0.666667	0.787401
ra1	0.777778	1.000000	0.860233
ra2	0.875000	0.333333	0.556776

The combination of ra1 and ra24 has the most sufficient condition which signifies the technical competence of the suppliers along with constant interaction with the suppliers from the perspective of the organization gives the best outcome as far as cost management is concerned. Closer supplier proximity could be seen as a back up condition which helps in the cost management since we see that the combination of ra1*ra2 also has a high significance.

- Time Management: The conditions which are applicable are Interactions with the suppliers (ra1) which is always extremely important, Initial Involvement of Suppliers and Vendors (ra11).

ra1	ra11	number	time	raw consist.	PRI consist.	SYM consist
1	1	3	1	0.812500	0.727273	0.888889
1	0	3	1	0.846154	0.750000	0.857143

Since the most important conditions are mentioned by the expert validation units to be Interactions with the suppliers and the vendors only these two units are fed into the software.

The results of the analysis are:

```

*****
*TRUTH TABLE ANALYSIS*
*****

File: C:/Users/Asus/Desktop/fsQCA7.csv
Model: time = f(ra1, ra11)

Rows:      2

Algorithm: Quine-McCluskey
  True: 1
  0 Matrix: 0-CL

--- TRUTH TABLE SOLUTION ---
frequency cutoff: 3.000000
consistency cutoff: 0.812500
Assumptions:

      raw      unique
      coverage  coverage  consistency
-----
ra1    0.952381  0.952381  0.740741
solution coverage: 0.952381
solution consistency: 0.740741

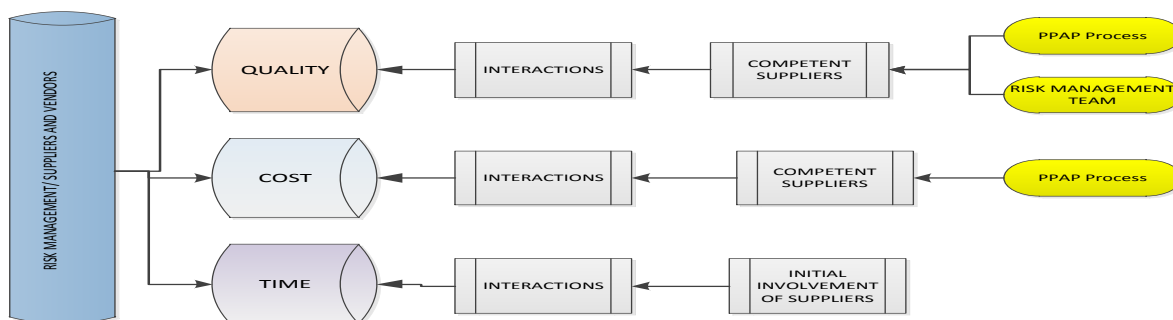
```

The obvious result of the solution is 0.952381.

The set and the subset solution is:

terms	consistency	coverage	combined
ra1*ra11	0.812500	0.619048	0.712474
ra11	0.812500	0.619048	0.712474
ra1	0.740741	0.952381	0.774597

Hence combination of both ra1 and ra11 conditions are very important from the perspective of risk management.



5.8 Sample Interview Transcripts

The table below depicts the interviews that have been conducted.

COMPANY	CASES	EXPERTS INTERVIEWED
Company A	Project 1. (Rayscan Mk2)	Research Scientist
	Project 1. (Rayscan Mk2)	Project Manager
	Project 2 (Riser Inspection Tool development)	Project manager
	Project 2 (Riser Inspection Tool development)	Technical Head
	Project 3 (Tooling, Handling, Hoist development)	Project Lead
Company B	Project 3 (Tooling, Handling, Hoist development)	Chief Design Architect
	Project 4 (QXT, Machine Development)	Project Lead
	Project 4 (QXT, Machine Development)	Chief Design Architect
	Project 5(BMW/500 series, seat manufacturing)	Purchase Manager
Company C	Project 5(GM/J300 series, seat manufacturing)	Purchase manager
	<i>4 expert validation interviews to determine and choose 6 most important risk activity conditions from the first level of fsQCA answers.</i>	

CASE-I

COMPANY A RAYSCAN INTERVIEW DISCUSSION(01.05.2014)

Research Scientist, Project manager

1. What is the main aim and scope of the project? What were the major drivers of the project? Describe the product?

The main aim of the RTD Rayscan MK2.0 project is to improve the generation one Digital radiography system that Applus had come up with. The main perspective was to develop the scanner

from the Mechanical and Electrical perspective and also to have an adequate software that backs up the mechanical and electrical devices.

The scope of the project was primarily to :

- Device a digital inspection tool that is roughly more dedicated to the scanning area. The aim was to improve the sensitivity of the device and make the device tougher to endure extreme temperature gradients.
- The project aimed at piloting five prototypes. Hence the scale of the project was quite huge compared to the usual.
- The first generation was more dedicated to a specific temperature, but the new project wanted the RTD to be functional in extreme tropical climates, and also work in corrosive water tight conditions. Hence the detector cooling area was one of the concerns too.

2. What was the composition of the design, engineering and development team? Did the team face any sudden crisis due to sudden changes in the composition of the team?

The team consisted of mechanical, electrical and electronics engineers. The team also composed of radioactive testing engineers.

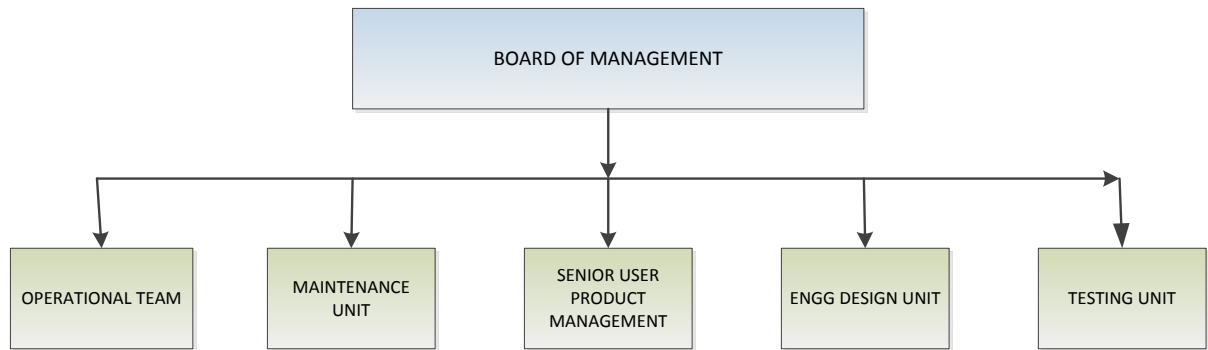
The generation one RTD Rayscan prototype being a great success, the design improvements which were necessary to be implemented was visualized to be an easy task. The project was conceptualized to be relatively simple. Initially the team was completely technically driven and there was a definite lack of project management skills. The project was being executed on a formal planning. However as the project graduated complexities arose and it was realized that the project was extremely high risk driven. This called for the inclusion of experts like Dr Wassink and Mr Marcel who were technically adept with high expertise and also had crisp project management skills. Hence the project had to be shifted from mere technical focus to be aligned by means of proper project management.

3. How did the board of management govern the entire project? Was there a clash in interest of the management and the project execution team? If so how did they come down to a common consensus?

There were certain clashes initially, however the fact that the first generation prototype was a great success, the management realized that the project would definitely reap benefits for the operational units in the future. The development of the Rayscan device would help A climb higher as an organization and also take up the major market share in the Non-destructive testing arena, particularly with only GE and Shaw being the other competing companies. The benefits of the business were perceived by the management board and they even approved of an excess budget when, the re-evaluation of the project was done.

The effective strategy of the team being that they presented a business case to the board of management from the perspective of the operational units, which further clarified the positive effects and the benefits that company A would reap in the future.

4. What were the complexities faced by the team to interact with the functional units in the organisation? How did the team manage these complexities?



The organisational structure of A creates the complexity for the project. The operational unit can also be seen as the client for the RTD Rayscan devices. A does not sell their Radio Active Testing Devices to the market. They develop their own testing devices for their own services. The research and development unit finds solutions to improve the radioactive testing devices for their own services. Hence they cater to the needs of the operational units. The senior User Product management Team was rather involved with the procurement of components with the suppliers. They were the primary interface with the external market. Some of the major complexities that were faced during the execution of the project were:

- The Operational team demanded a new RTD device with incremental features necessary for their own inspection services. The major clash was due to the fact that the operational team failed to realize the technical complexities of the new design to be realized. The lead times of procuring the essential components, the interfacing of the software with the mechanical structure was itself a high risk intensive action. The operational team pushed the Engineering , Design Team , Senior Product development team to commit to their deliverables. To realize a Radioactive testing device of high complexity with technical precision was indeed complicated and time taking.
- a did not have any formal assembly unit. The maintenance department was expected to do the assembly since, integrating all the components together would provide them a vivid knowledge of the technical aspects and complexities of the device. However the maintenance unit was not prepared to take up the responsibility of the assembly. The maintenance unit had a definite lack of resources to perform the assembly of the system.
- The organisational structure also lacked definite resources to arrange logistics. There was no definite unit which took up responsibilities to arrange logistics.

ACTIVITIES INCORPORATED:

The basic activity implemented was intense process management by means of lot of communications between the product development team and the operational teams. The aim was to bring all the parties to a common platform of understanding. The operational team was made to realize the complexities of design, and the fact that operational success of the prototype depended heavily on the successful procurement and functioning of the sub systems would definitely lead to the extension of the execution tenure.

5. **What were the budget constraints for the engineering, manufacturing and testing units? How did they identify the cost management risks?**

Major faults committed:

The project was visualized to be much simpler than it actually is. The design complexities were too high and the cost estimation needed to be reviewed once again. Re-evaluation of the budget was done considering the complexities and the higher request of the delivery. The integration of the software which was being developed by the software developer was extremely complex to be integrated with the system. The hours that were shown in the budget for the software improvements had a high risk of exceeding the stated amount. The time considered for the mechanical designs as well as the software improvements and the implementations were insufficient. Considering the risks extra hours were considered in the planning, which meant that the cost estimation as well as the time scheduling needed to be re-evaluated.

However the technical reasoning for the design complexities was quite valid and the approach was extremely pragmatic.

ACTIVITIES:

- A business case which scaled up the complexities with an aim to show the management of the clear benefits from the perspective of the operational team was presented to the management.
- The senior management took up the issue with upmost priorities and the extra budget was granted.

6. What were the difficulties faced by the team to keep the project on schedule(Time Management)? How did the team manage these difficulties ?

The scale of the project was much larger. The project aimed to pilot 5 prototypes, which meant that there was huge management which was necessary for managing the suppliers for successful procurement of all the components. The complexities that lead to the risk of the project falling out of schedule were as follows:

- The fact that the project under estimated the technical complexities, the designs done at the beginning of the project were not appropriate. Hence in order to do rectification, the design needed to be redone.
- The project breakdown structure needed to be reconstructed again.
- The critical path which was determined surfaced out to be faulty. Hence the critical path of the project was once again determined considering the complexities.
- The clash between the functional units as described in the previous segment also lead to major delays. Moreover the lack of adequate logistics was also a major deterrent.

ACTIVITIES ADOPTED:

Company A started dedicated Assembly and Manufacturing units. Dedicated assembly units for future projects would ensure that the integration of the system is done by an individual unit with appropriate resources and expertise. Each functional unit has dedicated work, and would not lead to any sort of information asymmetry and overdependence of any particular functional unit.

Engineering and procurement was done parallel. The design and engineering of the device occurred on side and simultaneously the procurement occurred at the other side. This also created immense clash since changes in certain design aspects also changed the components that were required. However to speed up the project and to abide by the second planning schedule the parallel work segregation was indeed necessary.

7. What were the technical complexities of the design, engineering of the new prototype? How did the team manage the above complexities?

The fact that the project was highly underestimated in the front end was a major cause of concern. The aim was to design a technically sound product and hence create a good quality product. However some of the technical difficulties faced were:

- Making the RTD device robust enough for a wide gradient of temperature.
- The integration of the software drivers and the detectors with the physical mechanical device was extremely complex.

The software developer was the chosen developer of the software and the drivers. The task was extremely crucial since the successful functioning of the detector and the software were pivotal for the successful functioning of the entire system. Hence the critical subsystems needed to be perfected in order to achieve precision for the entire device. There were certain contractual agreements signed between software developer and company A, in order to ensure the governance of company A over the software developers. However as strategized by company A was too strong contractual terms and conditions between the two parties would definitely spoil the relations. Damaged relations would definitely not secure success for the prime motive.

The technical complexity was definitely too high in the project. There was a good reason for the engineers to take time to deliver results. Hence A realized that in order to have a successful project they had to make a trade-off between Quality and Time. In order to achieve precision it was necessary and urgent that the project was slowed down.

Anyways A was a relatively smaller client to the company of software developers. Hence in order to speed up the work in the vendor end, A ensured that they had deputed their engineers in person in the vendor end. Presence of an A's representative would ensure that a closer bond was developed with the software developers. This would also ensure that there was stronger communications, no information asymmetry, and appropriate technical developments were made.

8. How did the team choose the appropriate suppliers or vendors taking into account the various supplier risks(The decision making process)? Did the project face any supplier risk?

The software developers was probably the only company with the technical expertise that could develop the required detectors and software. Moreover A was recommended by a knowledge institute. The various risks face in the interaction process with the software developers has been discussed above.

Looking further ahead at the future business, A is looking forward to developing other suppliers in parallel. Moreover A has also interacted with software developers for possible development and deliverables for future projects which has different scopes and objectives.

ACTIVITY: This is an extremely smart strategy deployed by A since they are not only expanding their network of the suppliers by trying to **build up other developers**, but they are also locking in their pivotal developer with lucrative projects in the pipeline.

9. Did the project face any obstacles due to lack of resources or failure of machines? If so how did they manage them?

Some of the major issues faced by Applus in arranging their resources were the complexities in arranging the high voltage umbilical cable. The suppliers faced huge difficulty in sufficing to the technical requirements for the proper functioning of the system. The umbilical was a specially dedicated cable. Hence the cable issues took sufficient amount of time. Moreover the electronics and the cable types as decided earlier on were changed later on.

ACTIVITIES DEVELOPED:

- The fact that A has high precision and knowledge in cable testing proved to be extremely beneficial. They co-ordinated with their suppliers for the exact technical requirements by means of repeated cable testing. Moreover dedication of the team members also proved to be a major aspect to arrange for the exact requirements.
- The Rayscan MK.2 project needed to be backed by resources from other projects. Hence the project needed to be partially filled up with resources of other projects which did hamper and affect the schedule of the other projects.

10. What were the day to day management activities or the decision making process in order to reduce the identified risks?

Some of the major risks faced by A in the Rayscan M.K.2 project being:

- The feasibility of the environmental temperature constraints and the proper functioning of the system in extremely hazardous conditions.
- Extended research needed to be done in order to test the temperature effects of the detector.
- The overall technical complexities from the mechanical and electrical point of view was initially given low priority since the team had past experiences in developing the main design.
- Updating and coordinating with the external software and detector developers were one of the prime concerns. Hence the day to day management of coordination was the main point of concern.

ACTIVITIES DEVELOPED:

A conducted Business Risk Workshops and technical Risk workshops. However to cater to the above identified risks a strong day to day management of activities was extremely important for the effective success of the project. The following were some of the some actions taken by A:

- A increased the frequency of team meetings and they even focussed on weekly and daily activities and issues.
- A kept a constant track of actions and team progress.
- The teams indulged in a lot of team interactions and communications amongst all the stakeholders.
- The team closely kept a track of all the hours spent on each stage gate of the project and the materials spent.
- Team update meetings with the clients were organised on a weekly basis.
- Documentation of project procedures for future references and maintaining records were made mandatory and were also given high priority.

11. How did the team identify the risks associated in integration and assembly of the various subsystems/components to achieve the final product? How did they manage the risks?

There were separate tests conducted in order to satisfy the mechanical perspectives, the electrical perspectives, the software perspectives and even the complete system was tested on a whole. A abided by the standard range of testing procedures. In order to ensure that the integration was perfect the testing was conducted on a component level. Individual testing of each component and software would ensure the correctness of the designs and functionality of the individual components. The tacit knowledge and the expertise of the engineers was a great advantage indeed. The strategies which were used for managing the risks of assembly and integration of the entire system were:

ACTIVITIES USED:

- Each and every subsystem was tested individually in order to find the faults on individual component level. Correctness of individual components would ensure that the total system functions correctly.
- Endurance testing of the complete system was carried out in artificially created environment and climate chambers.
- During the planning session the lead time required for the testing was calculated. Testing of the components and the subsystems were started halfway through the design phase. Hence the project was executed in fragments. Parallel tasks were also conducted in order to maintain the speed of the project.

12. How did the teams prioritize the risks or complexities related to the project?

Though the project definitely needed project management skills to abide by a scheduled time plan and cost budget, the core of the project was highly technically driven. Hence the technical impacts of the risks were given high importance.

The tacit knowledge of the experienced members in the group were of utmost importance. The experience of the past projects and the knowledge of the product helped to foresee the future technical risks. However since a product or system based manufacturing project is highly stage gate oriented, although some risks can be identified in the future, actions cannot be immediately taken upon, since the project proceeds upon completion of individual parts. The risks can be acted upon when experienced.

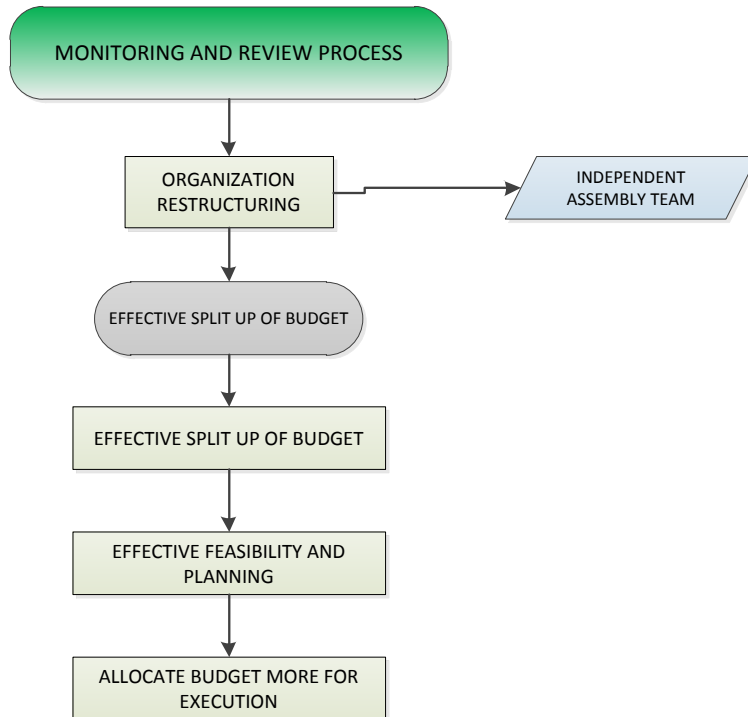
- Risks were prioritized looking at categories and frameworks of systems. Risks were also identified and prioritized based on the critical planning of the schedule.
- Company A has adopted the strategy of formulating three or four approaches to the project in the feasibility phase. Hence the project phasing is done henceforth with utmost importance.

13. What were the risk management outcomes and how did they influence the project?

The fact that front end loading, business planning and risk workshops were conducted for the better execution of the project, the communication as a whole within the team and outside the team improved. The fact that adequate project management was missing initially was recognised and soon the control and the governance over the project was managed by means of process management amongst all the major actors of the project. The basic mantra of success for the project was the fact that the team should keep in constant touch and interaction with the clients. Constants interactions help in delineating major organisational functional issues. In the Rayscan MK2 project the major complexities were to make their clients which was their own Operational team realize the complexities of the design and the reasons for the delay in the deliverables. On the other hand on the downstream the complexity of interacting with

software developers was also extremely crucial. Not only did the vendor need to be managed appropriately, but also make the developer develop the software with required technical functionalities was of utmost importance. This was finally achieved in the context of the project, leading to the development a very strong and convincing vendor or developer for future projects.

14. How does the organisation review and monitor the identified risks to prevent any further mal function of the same risks in the future?



The execution of the Rayscan MK2 project was a great success. The project was a success in the perspective of solving technical complexities as well as from the perspective of finding new dimensions in the project management skills. Risks faced in the past project are mainly catered to in the future projects by means of lessons learnt sessions. Lot of stress is put on the front end loading of the project. The initial feasibility and planning of the project is done with careful consideration. The budget is split more accurately, especially considering the fact that most of the budget is kept for the execution process of the project. Though the project fell out of time schedule and minor cost management plans had to be implemented, the project on a whole was a great success. Thirty successful systems have been built and company A is still manufacturing more of the Rayscan MK.2 prototype. The project is definitely still expanding and a great asset to the Operational team.

COMPANY A (Riser Inspection Tool development Project) DISCUSSION(10.06.2014)

Discussion with: Chief Scientist, Team Leader: technical head

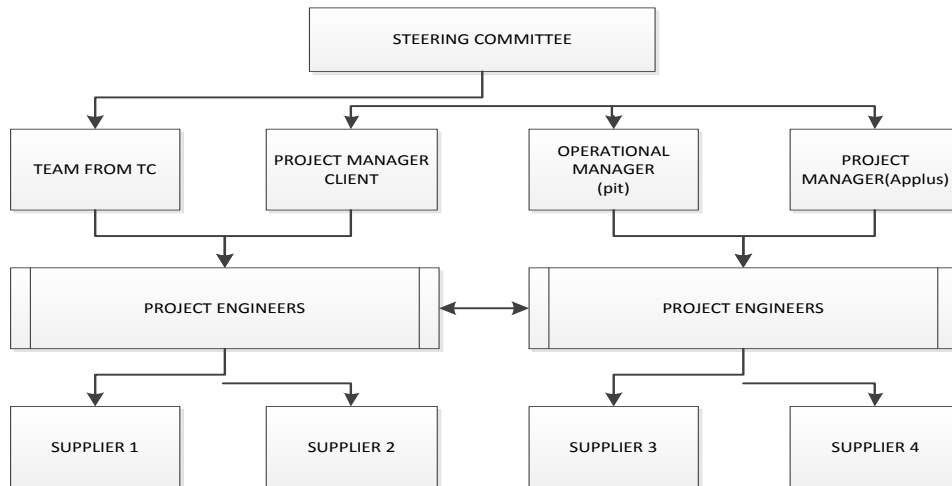
**15. What is the main aim and scope of the project? What were the major drivers of the project?
Describe the product?**

The main objective of the project is to produce or manufacture an instrument or testing device to inspect risers and specially the welds which connects the platforms to the bottom of the sea.

- The main challenge was to find fatigue cracks. The complexity being that the fatigue cracks allows the ultrasound radiation to pass through and hence the cracks remains unnoticed.
- The main objective of the project was to save the costs from the perspective of the client since the mal operation of the riser would signify that there would be loss of billions of Euros. The advantage of a proper inspection mechanism would signify that the lifetime of the riser would be extended.
- The mechanism would signify a real time sensing of the welds and pull up all the data for the welds. The real time sensing of the welds would also mean that it is possible to get an actual idea of the deformation.
- Hence the main aim was to provide or develop an inspection tool with an algorithm that is able to accurately sense the fatigue crack and size the defect of the crack.
- The inspection tool needed to function under high pressure (due to depths of 2000m beneath the sea) and high temperature.

16. What was the composition of the design, engineering and development team? Did the team face any sudden crisis due to sudden changes in the composition of the team?

The main challenge was to have a team which is technically equipped and balanced to carry out and find a complex solution. The project demanded to think of different options . The project needed to make the correct choices to make an impact on the quality and cost of the solution. Hence the team consisted of a team of physicists from the technology centre, project manager from client, Operational manager from the Pipeline Inspection Department, Project manager from company A. The project manager of company A would be primarily responsible for all the results and outcomes.



As such the team was extremely stable and did not face any obstacles as such.

17. What were the major risks that were faced in the project?

There were quite a few risks that were faced by the project:

- “From client’s perspective the estimation of the project were rather from the perspectives of repair, rather than inspection.”
- “ Shutting down the riser for an hour or any mal operation would lead to loss of billions of Euros for the market. Hence there is a high set of risks associated. Company A tried to sell themselves from the perspective of the fact that the solution or the application mechanism would extend the lifetime of the operation.
- On a technical level the project was extremely complicated since the solution was a combination of techniques. It was a combination of Diffraction and Refraction theories. The combination of methods used were Time of Flight Diffraction(TOFD), Phased Array, P.E echo, Creeping waves. The complexity on technical grounds was immense which tested the skills of the engineers to the optimum level.

18. How did the board of management govern the entire project? Was there a clash in interest of the management and the project execution team? If so how did they come down to a common consensus?

The following were the views :

“ There wasn’t any major clash between the board of management and the project execution team. However the major clash of interests were between client and company A. It was extremely difficult to manage the expectations of the client”.

Client kept asking for more applications for the same solution. Moreover shell was not convinced with the fact that the solution was for nearly 4 million.

ACTIVITIES ADOPTED:

- “ Company A adopted the activity of a cost benefit analysis, and we convinced shell that the inspection methodology would actually have a better Net Present Value, since constant inspection would increase the lifetime of the riser.”

- “ We provided shell with a wider application of solutions from 18 inches to 8 inches by manipulating the combinations of the techniques used”.
- “ We even broke down the cost structure to show that each device would cost around 300 k, which looked more realistic than 4 million.”
- “ Constant communications with the client to convince them on the application of the solution”

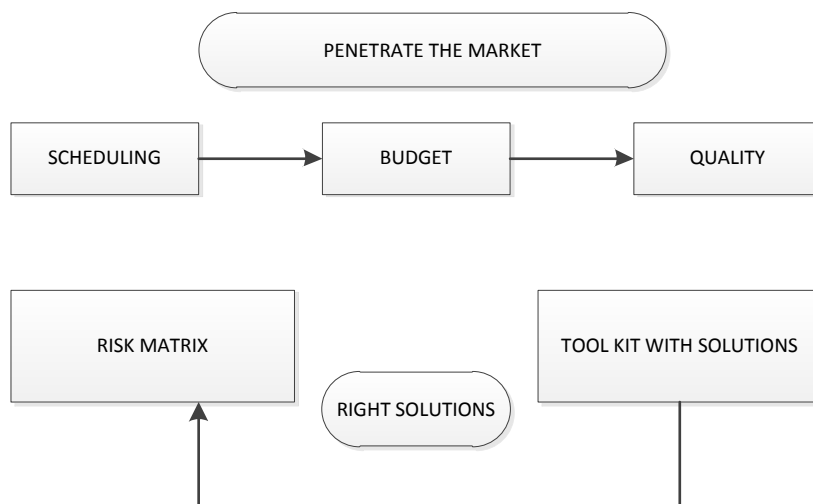
19. What were the complexities faced by the team to interact with the functional units in the organisation? How did the team manage these complexities?

The fact that the mechanical configuration of the system needed to work on strong concepts of Physics like diffraction and refraction, increased the complexity of the project.

“ It was extremely difficult to get equipment’s and also to arrange the right equipment from the operations to the measurements division.”

“ To realize the solution different functional units, the physics department from the technical centre , the project engineers, the project manager of applus, the project manager of shell, had to come together and carry out dedicated brainstorming sessions to come up with different solutions. It was very important to discuss with the clients to scope the project perfectly”

The Operations department was involved in the steering committee. This ensures that the testing of the device is more accurate and hence the Quality is not substandard.



20. What were the budget constraints for the engineering, manufacturing and testing units? How did they identify the cost management risks?

Budget was decided on a stage gate perspective. Cost estimates were done after each stage for the next stage as well as for the whole project.

“ the engineers were involved from the beginning in order to get a better understanding of the technical complexities.”

“ the costs were managed in work packages. Engineers were aware of their responsibilities they needed to carry out within the budget constraints”.

“ As a project manager you need to push your engineers. If scope and specifications are changed the cost estimates are also needed to be carried out. Spread sheets were maintained to keep track of the budget. It is very important to stick to scope and be very specific. It is very important to be sure of your requirements from beginning . Any alteration in estimates or scope should be communicated beforehand”

21. What were the difficulties faced by the team to keep the project on schedule(Time Management)? How did the team manage these difficulties ?

“ One of the biggest risks faced by the project was the fact that the end client took a lot of time to send approval but the times for the deliverables did not change. The approval and the clients perspectives keeps the project on hold and puts the project out of schedule. Strategies incorporated in order to keep the project on schedule.

- “Allocate resources on time. If the plan changes , the time for the project execution also changes”
- “ We tried to have appropriate back up options”
- “ We tried to be as realistic as possible in our planning. We tried to manage our deadlines”
- “ In order to manage the deadlines it was important to have a better co-operation and co-ordination between all the functional units. It was extremely essential to be pro-active in nature”
- “ It is very crucial to have the project managers of the clients on your side”

22. What were the technical complexities of the design, engineering of the new prototype? How did the team manage the above complexities?

“ The main complexity on technical grounds was the combination of different techniques to find the optimum solution. The complexity was due to the nature of the cracks , which are transparent to ultrasonic radiation. The integration of the hardware with the different concepts of physics along with the hardware caused the main difficulty”.

“ Huge amounts of data needed to be analysed .hence it was important to compare different techniques and come up with different options. For proper inspection it is important to have the best possible solution with minimum requirements.”

ACTIVITY:

“We overcame the technical complexities by means of Discussions, technical expertise, simulation and prototyping”

23. How did the team choose the appropriate suppliers or vendors taking into account the various supplier risks(The decision making process)? Did the project face any supplier risk?

“ The main complexity in dealing with the suppliers is the fact that A has a very short time to market. Hence the suppliers need to deliver within the scheduled time period.”

Activities : “It is important to keep the suppliers and the vendors in close proximity and to communicate the right requirements.”” It is crucial to make the suppliers realize the complexity of the project. Involve the suppliers and the vendors in the team from the beginning of the project”

“ The suppliers and the vendors should deliver the demonstration since some of the components are extremely precise and technically challenging”

24. Did the project face any obstacles due to lack of resources or failure of machines? If so how did they manage them?

“ At times there were lack of resources from the operational units. Hence at times in order to keep to the time schedule measurements had to be done by ourselves”. This proves that there were lack of testing capabilities and to certain extent quality was compromised.

“ Most important resources were also arranged by means of intense communications and manage the expectations of the client”

25. What were the day to day management activities or the decision making process in order to reduce the identified risks?

Some of the day to day risk management activities adopted by company A were as follows:

- “Intense brainstorming sessions were conducted amongst all the cross functional units at the beginning of the week. The risk list is created and we adopt the funnel method to prioritize the risk depending upon its impact”
- “We run through the risk list and we try to generate the solutions. We prioritize the risks depending on the delivery time and the budget ”
- “ Risks are prioritized in a risk matrix format. What’s urgent needs to be incorporated first”. Hence risk prioritization was conducted depending on the time, budget and then urgency.
- “ A strong front end loading is carried out, by designing a practical Project Critical path”

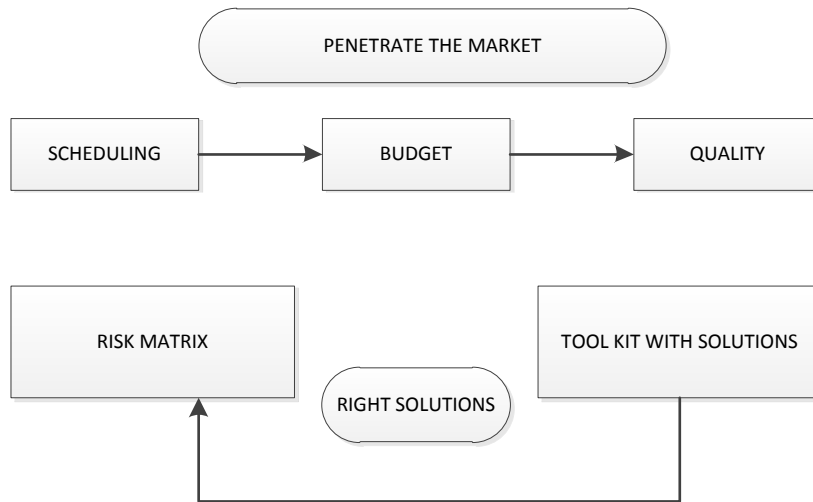
26. How did the team identify the risks associated in integration and assembly of the various subsystems/components to achieve the final product? How did they manage the risks?

“ The project had a dedicated system architect who was responsible for the overall system integration. The system architect is involved from the beginning of the project to look if all the components match the future expectations”

“ We tried to carry out as many simulations as possible for the algorithm since the simulation tests actually help to realize the drawbacks of the working of the device”

“ However the prototype is not the final product. We principally aim to penetrate the market and we heavily depend on future iterations to improve the prototype.”

27. How did the teams prioritize the risks or complexities related to the project?



“The main aim of A is to penetrate the market. Hence the risks are also prioritized on the Time, followed by the Budget and then the Quality. It is extremely important to have a tool kit of solutions where the prioritized risks are addressed with the different alternatives and solutions from the tool kit with solutions. Under Estimation of risks might prove to be extremely disastrous “

28. What were the risk management outcomes and how did they influence the project?

The following were the project outcomes as per the vision of the project manager:

- “ There were strong lessons learnt sessions where the experiences faced in realizing the prototype were documented”
- “ The technical complexity of the project was so intense that it pushed the engineers to a higher level of expertise”
- “ Some of the solutions that were achieved in the project were used into other projects”

The most important added value that can be realized from the above project is the fact that A realized a technical solution for inspecting cracks in the weld which extends the lifetime of the riser, which has huge financial savings. They realized a solution which is not prevalent in the market.

29. How does the organisation review and monitor the identified risks to prevent any further mal function of the same risks in the future?

“The main mechanism used was to discuss with the project managers and document the experiences. A also follows in-depth lessons learnt sessions Though you tend to know the risks you tend to repeat the risks. At times you know the risks that might come up but you cannot act upon it unless it actually occurs. “

“ It was an extremely successful project in a whole and value added to the technical knowledge of the engineers was immense, which would also be extremely fruitful for the future projects”.
