Understanding the causal relations in organizational structures of project teams

How simulations can contribute to better work processes

Master Thesis

Olivier Kooy

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Research thesis details

Understanding the causal relations in organizational structures of project teams

How simulations can contribute to better work processes

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Preface

This research report is the result of my graduation at the Technical University Delft in cooperation with ePM and also serves as the thesis report for the Master Systems Engineering, Policy Analysis and Management.

The goal of this thesis project was to explore the possibilities of simulation modeling in creating new insights into work processes for project-based organizations. By applying ePM's simulation program SimVision® in the project department of DSM, relationships between actions that are embedded in the work process of their engineering, procurement and construction (EPC) phase were researched from an organizational perspective. The research has designed a conceptual model that can act as a base for specific cases on learning about organizational complexities in work processes during the EPC phase of a project. Furthermore, the research has provided ePM with an outline of a process of how simulation modeling can be successfully utilized, and has given rules of thumb to ensure acceptance of the modeling results.

For a quick read, I refer to the executive summary on page vi. For the research definition and knowledge that form the foundation of the research, I refer to chapters 2 and 3. For a detailed view on the designed conceptual model, including the first steps of the simulation modeling process, I refer to chapters 4 and 5, with the evaluation via a case study in chapters 6 to 8. The viewpoint on using simulation modeling on work processes of a project-based organization and its implications can be found in chapter 9, with the conclusions and reflections listed in chapter 10. The appendices of the report contain additional information and analyses that contributed to the thesis.

At the end of my study I kindly thank my supervisors from the TU Delft for the guidance they have provided and for their assistance: Sander van Splunter, Hans Bakker and graduation professor Alexander Verbraeck. They helped me focus on the essence of my study and provided me with the support to frame the correct scope of the subject: a task that turned out to be quite tricky knowing both the width and depth that work processes can contain.
During my thesis I have also received support from, and have developed a pleasant working relationship with, ePM. I would like to thank my supervisor Mark Triesch for his endless support and advice during my project. Our conversations were both insightful and motivating.

I would like to thank Charles van Gisbergen, Roel Keijser, Will Deckers, Harrie van Linssen and Ben Sartorius of DSM for taking the time to discuss with me the work processes of DSM in their field of work and how simulation modeling can be fitted in. Lastly, I am grateful for the support and help from my family and friends, especially the efforts of Josje Hofland who went through the thesis to spot my fuzzy logic and correct a lot of grammar.

I hope you will enjoy reading the results.

Olivier Kooy
Delft, January 2012

Executive Summary

Research context

Project-based organizations (PBOs) structure projects around temporary assemblies of in-house specialist staff and executing business within a fixed time limit. Projects are defined as temporary organizations to which resources are assigned to undertake a unique, novel and transient endeavor that involves managing the inherent uncertainty and need for integration in order to deliver beneficial objectives of change.
Three types of complexities need to be managed in projects: External, Organizational and Technical complexities. This thesis focuses on organizational complexities, as they are influenced by characteristics of structures of project teams. Project teams are formalized, as PBO's aim to provide a robust structure that results in a positive project performance. This formalization is defined as a work process containing a collection of interrelated actions in response to an event that achieves a specific result.

This research assumes a lack of knowledge on how the different organizational complexities relate to one another. Therefore the research objective is to learn about the relationship between actions of work process of project-based organizations that entail characteristics which partly influence organizational complexities, resulting in the following research question:

> How can simulation modeling of the work process of project-based organizations support the understanding of organizational complexities?

Research approach

To answer the research question the research uses a design science approach, see figure 1. The design science paradigm is based on the development of scientific knowledge by inspecting unresolved problems and solving them through a rigorous process. This approach provides the structure that the research requires because of its twofold objective of developing an innovative artifact and creating knowledge.

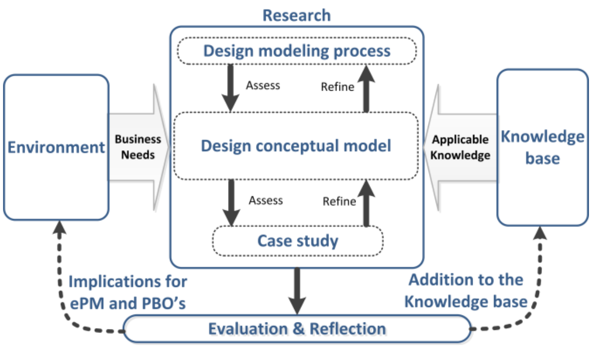


Figure 1 - Research methodology

Research process

Part I: Theoretical foundation: Creating the context

Knowledge Base

As work processes state how and by whom actions need to be executed, work processes contain information on how the project team is structured and thus influence the likelihood of some organizational complexities occurring. To successfully design a simulation model of work processes, the characteristics of work processes and project teams need to be taken into account, while further requirements derive from a simulation modeling perspective. Together they form the requirements of the knowledge base that the conceptual model needs to meet.

R1. The simulation technique needs to be able to model the four dimensions of work processes: level of detail, generality, formalization and quality
R2. The simulation technique needs to be understandable by the end user for it to produce results that can be accepted
R3. The simulation results can provide knowledge of organizational complexities within the modeled work process

Environment

The environment for this research contains a consultant company ePM and its customer base of PBOs. The needs of PBOs for simulating work process are twofold: decision making speed and predictability of outcomes. Simulation modeling speeds up the decision making through its calculating powers and aids with the need of predictability of outcomes by modeling the causal relations between the interrelated actions. This combination of needs made by the environment result in the following requirements:

R4. The simulation technique can model the different organizational structures
R5. The simulation technique can model PBO's work processes
R6. The simulation technique can create conceptual models to be applicable for different projects
R7. The simulation technique produces project performances as output

Part II: Design challenge: Designing a conceptual simulation model

The system definition for this research is provided by the environment: work processes of PBOs. The scope is narrowed due to the focus on organizational complexities within project teams. The focus for modeling the project teams lays on the design and execution phases of projects as project team are more structured during these phases compared to the initiation and close-out phases.

As the objective of the conceptual model is to understand how organizational complexities influence project team performance, the project organization and its primary tasks are centered in the model, as is shown in figure 2. To achieve this, the conceptual model requires the creation of a hierarchy of positions in terms of information flows, since the exchange of information is key to managing the project interfaces. As positions are linked to tasks within the EPC phase of the project, a simulation can both identify the tasks that are the bottleneck of the project, and

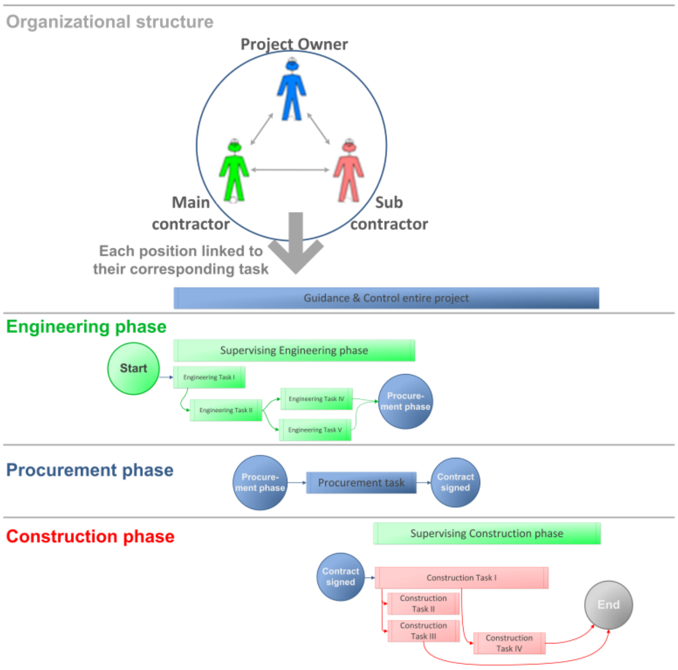


Figure 2 - Conceptual model of work processes in EPC phase

explain how this reflects back to the organizational structure. This way the model tests the fitness of the organizational structure on the work process and thus reflects on the project.

Part III: Evaluation: Testing conceptual mode with case study

Specification of the model

The conceptual model was tested via a case study on projects at DSM. To model the work process of DSM correctly, the conceptual model needed to be made case specific. This specification step brought forth two issues:

1. The choices and the limitations of a conceptual model are conveyed onto the case-specific model. This means that a modeler should be aware that a formulated problem and an objective definition influences the conceptual model and thus also the programmed model.
2. DSM sees work processes as organization-independent, which causes them to miss or ignore important organizational characteristics within work processes. The conceptual model thereby falsely inherits characteristics from these work processes.

Validation of the model

The simulation modeling process, see figure 3, is a good method to evaluate the credibility of the programmed simulation model. The decision moments that are embedded in the simulation modeling process provide structure. This structure aids the modeler and the end user as such, due to the quality checks with diverse validation techniques on various places of the simulation model. The applied validation techniques had shared characteristics: not only do they test a model on a specific aspect, the validation techniques involve the end user of the model. The interaction of the end user with these validation techniques not only increased the quality of the model, as tacit knowledge was used in using the validation techniques, but it also increased the acceptance of the model by the end user.

Acceptance of modeling results

To get the simulated results accepted, an approach needs to be used to structure the final phase of the simulation modeling process. The approach chosen is able to achieve a predetermined successful acceptance of results, and promotes action afterwards. The following issues need to be considered when choosing an approach:

- Goal – To support a design decision or to learn about a specific element?
- Knowledge – How does the end user see project teams and productivity?
- Time constraint – How much time does the end user have?
- Level of interaction – How much interaction is needed for achieving acceptance?

For this research, a workshop was constructed. The goal was to create additional insights in organizational complexities, which creates a high level of interaction in a short time period. Using different scenarios, the participants were able to learn about different modeled organizational complexities, improving their knowledge of the subject of organizational and cultural parameters and their impact on project performances.

Part IV: Conclusion: Contribution to knowledge base and environment

Main conclusion

It is the conclusion of this research that simulation modeling can support the process of understanding organizational complexities by making characteristics that contribute to these complexities testable. A number of identified characteristics of a project-based organization are decided in work processes and those characteristics influence (partially) the likelihood of organizational complexities occurring. By understanding the causal relations of the interrelated actions, knowledge is created on how work processes can be positively influenced by designing fit for purpose project teams and thus improving project execution.

Contribution to Knowledge Base and Environment

The research contributes to the knowledge base with the designed simulation modeling process, as well as with the requirements and checks for designing a conceptual model of work processes. Furthermore, the research has laid out a structure of an evaluation cycle of work processes in which simulation modeling has been given a clear predefined purpose. All of the above was needed to make the final contribution to the knowledge base: a way to create insights into the interaction of characteristics within project team structures that affect organizational complexities.

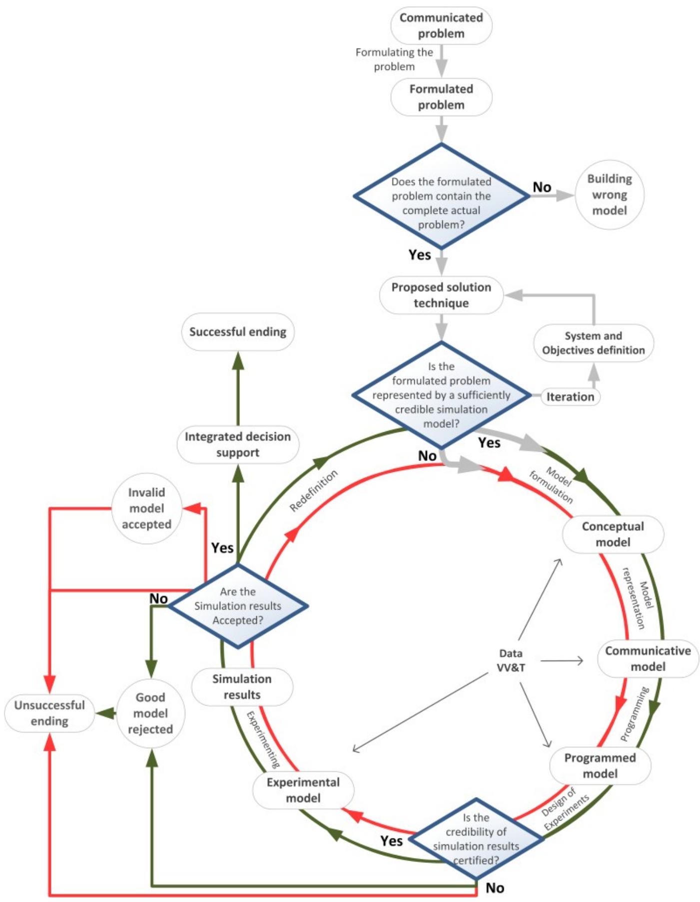


Figure 3 - Simulation modeling process

The research designed a simulation modeling process in which the focus of modeling is shifted two times. Firstly, the focus lies on whether the correct problem is formulated in order to model with the right objective and system. Once defined, the first shift occurs towards the credibility of the simulation technique which models the system. With a credible model the conceptual and programmed models, and finally the simulation results, can be constructed. During the end of the process the focus is shifted one more time towards the credibility and acceptance of the simulation results.

The simulation modeling process aids a modeler to model the right problem and reach a model that is capable of producing acceptable and credible answers to the formulated problem.

The practical aim of this research has been fulfilled: the need of ePM has been fulfilled by supplying the simulation modeling process, while PBOs have been given a method to identify characteristics which (partly) influence organizational complexities by reducing the likelihood of occurring.

Table of contents

1. Research definition

In section 1.1 of this chapter the motivation for this research is elaborated upon, followed in section 1.2 by the main research question and sub-questions. In section 1.3 the methodology that has been used for this research is explained.

1.1 Research motivation

Hierarchical organizations struggle to stay ahead of the competition in innovation and competitiveness in the knowledge-based economy (Sawhney & Prandelli, 2000; Chasbrough, 2003; Haour, 2004). As any advantage on the competition is crucial, some of these organizations transformed into flatter, speedier, more flexible and horizontally oriented structures around teams and projects (Child & McGrath, 2001; Child & Rodrigues, 2003). These project-based organizations (PBOs) are better suited to deal with changing markets and technologies than hierarchically structured organizations (Lundin & Midler, 1998; Hobday, 2000; DeFillipi, 2002; Lindqvist, 2004). The business model of the PBO is to “generate results in response to specific client demands by structuring projects around temporary assemblies of in-house specialist staff and executing business within a fixed time limit” (Kodama, 2007, p. 3). Projects are defined as “a temporary organization to which resources are assigned to do work to deliver beneficial objectives of change” (Turner, 2008 p. 2).

Given the above definitions, a PBO that is able to improve its project performance, would be able to generate a better outcome of its business model. However, what does project performance mean? When is the performance improved? Morris and Hough (1987) distinguishes three dimensions of project success:

1. Project functionality: to what extent does the project perform financially and or technically in the way expected by the project’s sponsors?
2. Project management: implementation of the project to budget, schedule and technical specification?
3. Contractor’s commercial performance: did the contractors have a commercial benefit in either short or long term?

These three dimensions show that the performance of a project depends on the eye of the beholder: the client, the project team and the contractors. To determine whether a project was successful, a choice has to be made on which definition is to be used. This research adopts the viewpoint that besides the iron triangle of project success (costs, schedule and quality), customer’s perspective and their satisfaction with the outcome of the project are part of the project performance (Bakker et al, 2010; Winter & Szczepanek, 2008).

Coming from an ‘one best way’ approach starting in the 1950s (Maylor, 2005), project management nowadays contain a variety of theories that have their origin from different schools (Söderlund, 2011). Researchers within the school of contingency theory suggest that project management should adapt to the context in which the project is performed (Engwall, 2003; Sauser et al., 2009; Shensar & Dvir, 1996; Smyth & Morris, 2007; Williams 2005). They argue that a variety of contingency factors interact with the context and that each project will need a different organization structure.

Donaldson (1996) summarized these contingency factors as: strategy, rate of change, size, task uncertainty and technology. Some literature state that complexity and uncertainty are separate factors that should be added (Pich et al., 2002; Sommer & Loch, 2004). This research, however, follows the definition saying that "complexity is caused by, amongst others but not limited to, uncertainties and risks" (Bosch-Rekveldt, 2011, p.38). Meaning that uncertainty and risk are not separate factors, but contribute to project complexity. This viewpoint further combines the definition of project complexity of Williams (2002), who states that project complexity consists of structural complexity and uncertainty, with softer aspects and influences from the environment (de Bruijn et al., 1996; Jaafari, 2003). The combination of hard and soft aspects lead to a distinction of three project complexities: technical complexity (T), organizational complexity (O) and environmental complexity (E) (Bosch-Rekveldt, 2011).

> "Project complexity is caused by, amongst others but not limited to, uncertainties and risks" (Bosch-Rekveldt, 2011, p.38)
>
> **Project complexity**

Bosch-Rekveldt derived a variety of complexities through both literature and surveys, and placed them in three categories resulting in the TOE complexity framework. Her goal was to support project management, to create awareness of the complexities amongst the involved stakeholder and to be used repeatedly throughout the project, starting in front-end. The relevance of the TOE framework can be illustrated with the following example.

In the front-end of a project the project team is structured. The involved organizations, but individuals as well, bring characteristics to the project team that influence the contingency factors of the structure of the project team (e.g., the *size* of the project team differs per project and the *strategy* used depends on the perceived goal of the project by the involved stakeholders). The decisions that are made in the front-end influence the way the project team executes tasks later in the project. A project team that is aware of organizational complexities, which are related to decisions made in the front-end, is able to reduce the probability of the complexity of occurring. The probability of complexities such as 'a high project schedule drive', 'lack of research and skills availability' and 'lack of trust within project team', can be reduced by discussing during front-end on methods how to negate the likelihood of occurring.

The example above shows that the structure of a project team influences the probability of organizational complexities occurring during the project. Looking at the structure that organizations give their project teams, these structures evolve over time, as past experience can be utilized to positively influence future projects (Fitzek, 2002; Milton, 2010). PBOs can save time and money on a project as well as improve the project's quality if it can avoid making the same mistakes in each project (Shell, 2010). Applying past experiences enables the project teams of PBOs to react faster and be more flexible with respect to new problems (Seningen, 2005).

The structure of project teams differs per organization and per project, but each structure contains a shared base that is derived from years of practice and formalization of team structures. These team structures represent all the individual people and their relations to one another. Together, all these people perform tasks that contribute to the success of a project. Applying a project team that fits the characteristics of the project, not only reduces the likelihood of complexities occurring, but also contributes to a better project performance.

> A project team is a temporary group of people from different organizations who work cooperatively to bring the predefined goals of a project to a successful ending.
>
> **Project team**

As stated above, team structures evolve over time and as PBOs learn from past experiences, they formalize the structure of their project teams. By formalizing the structure, PBOs aim to provide a robust structure that results in a positive project performance. Besides the structure of a project team, the formalization contains what the people need to do, when to do it and who is responsible. This formalization is for this research defined as a work process and defined as follows:

> "A work process is a collection of interrelated actions in response to an event that achieves a specific result." (Sharp & McDermott, 2001)
>
> **Work Processes**

The working definition uses a managerial decision to trigger the execution of an overall work process. Through sub-processes, active on lower levels, actions are initiated and related to one another. The definition holds no restrictions for the type of actions and the type of relationships between the actions.

Work processes standardize interrelated actions to achieve a specific results. However as is said above, contingency theory argues that the standardization of actions is not feasible for projects due to the contingent factors that affect the project. Still, PBOs develop a preferred project team structure, which has proven itself to be successful in past projects. Literature identifies five types of organizational structures (Mintzberg, 2007). As PBOs aim for a horizontal and speedy organization with rotating project teams (Child & McGrath, 2001; Child & Rodrigues, 2003), some elements of Mintzberg's typology are more useful than others. With its focus on functional hierarchy, Adhocracy is a fitting base upon which project teams can be structured. However, the organizations behind the project team can have a different structure resulting in a mix of the typologies that interact between the project team and the organizations that have a role in the project execution.

PBOs have a preferred organizational structure for the project team and with the preferred structure the likelihood of organizational complexities occurring is influenced. These complexities, caused by risks and uncertainties, influence project performances (Hillson & Simon, 2007). Knowing how project complexity occurs and exerts its impact on project performance would enable project management to better understand how complexities can be avoided. The TOE framework of Bosch-Rekveldt (2011) as a checklist seems to be a step towards this goal by creating awareness.
At Stanford University a 'Virtual Design Team' did research to understand decision-making and communication behavior in order to enhance organizational engineering (Jin et al, 1995a & 1995b; Kunz et al, 1998a & 1998b; Christensen et al, 1999). This design team generated theories on the

interaction between actors within project teams, focusing on information flows. By understanding these flows, it is the team's belief, a better understanding is created of the interactions between individuals within project teams and through this understanding project performance will improve (Kunz et al, 1998a). similarly to Bosch-Rekveldt, these researchers state the importance of thinking about the structure of the project team for each project in the front-end phase of each project, instead of relying purely on past successes. The issues of organizational engineering that the Virtual Design Team encountered show a similarity with the organizational complexities of Bosch-Rekveldt (2011). However, no link has been made between designing the organizational structure of project teams using the theories of the Virtual Design Team with the organizational complexities.

In real terms, a lot of effort goes into structuring project teams and into planning the execution of projects (interview Triesch, 2011). External companies are involved to build and analyze computational models of planned organization and its processes to improve the fit of the project team's structure on the project. In workshops the organizational structures are assessed to match the objectives of the specific project.
These activities aim at achieving a higher level of predictability of the project's execution (interview Triesch, 2011). The focus of these workshops is often only on the end goal in mind: how to further improve the project performance. Due to this focus, the underlying relationships between the actions of the work processes are not fully explored. Thus, similar to the scientific approach, the goal is to improve project performance by addressing complexities that possibly could happen during project execution, but not understanding how project complexity exert its influence on project performance.

It is the standpoint of this research that there is a lack of knowledge on how organizational complexities interact with one another. Literature has focused on identifying organizational complexities, but when studied in practice those complexities were dealt with independently. As complexities are caused by uncertainties and risks, understanding how complexities impact project performance aids in improving the project performance. The objective for this research aims to make a step towards that goal and is defined as follows:

> The objective of this research is to learn about the relationship between organizational complexities, which influence project performance through the structure of the project team of project-based organizations.
>
> **Research Objective**

To achieve the scientific objective of this research, theory and practice are combined. The current theory and practice set a foundation upon which the research can continue. As the objective of this research is to get an understanding of the relationship between project team structures and organizational complexities, settings of real projects are used to create the insight.
The practical aim of this research is to create a process in which the scientific goal of creating insight is guided. The practical goal is thus a process that is utilized in this research to achieve the scientific goal. Furthermore, the process can be used outside the research to obtain more insights into how simulation modeling can deliver good and accepted results.

1.2 Research questions

Provided by the research objective and the scientific and practical aim of this research, the main research question is defined as:

> How can simulation modeling of the work process of project-based organizations support the understanding of organizational complexities?
>
> **Main Research Question**

Answering this research question results in a conceptual simulation model which enables the process of learning where organizational complexities influence projects by modeling the project team's structure. The term 'the work process of project-based organizations' is defined for this research as work processes with a high level of aggregation and with a focus on the actions of project team structures and the positions within these structures.

The conceptual model contributes to the literature by making a general model in which organizational complexities are modeled interrelated to each other instead of studied separately. The conceptual model contributes to practice, as project-based organizations can modify the conceptual model to match their specific project team's structure and gain insight into how the modeled complexities influence project execution. Thus while the research question is scientific based, practical methods are applied to test the scientific findings. Before answering the main research question, sub-questions need to be resolved.

RQ 1.1. Which requirements for designing a conceptual simulation model based on work processes can be derived from literature?

RQ 1.2. Which are the needs derived from practice that simulation modeling and modeling work processes of project-based organizations can satisfy?

RQ 1.3. What does a conceptual model that models organizational complexities in project teams of project-based organizations look like?

RQ 1.4. Which methods are able to evaluate whether a conceptual model has been built correctly?

RQ 1.5. Which implications ensue when applying a conceptual model to real-world work processes?

RQ 1.6. Which methods are able to evaluate whether a case-specific model is credible enough?

RQ 1.7. Which approach needs to be used to get a simulation model of work processes to be accepted by its end users?

RQ 1.8. What are the contributions of this thesis, and what are the implications for the environment?

1.3 Research framework

To ensure that the research is done rigorously, a structure is applied that aligns the sub-questions with appropriate methods. As the research aims to answer a scientific question by designing a conceptual model to be used in practice, the structure of this research represents this split.
The research contains a descriptive part and a normative part. The first part of the thesis is descriptive: the elements involved in work processes of PBO's are identified both in theory and in practice. The second part of the thesis is normative: a conceptual model is designed and subsequently tested.

This two-way dilemma is also described by Hevner et al. (2004) as the dilemma to choose between the design-science and the behavioral-science approach, see figure 4. Hevner argues that for information systems both approaches have to be combined. For this research both approaches are present, as the aim of this research is to compare scenarios (learn about the relationships in the work process) and to identify whether the comparison contributes to the current knowledge base and practice (behavioral-science) by constructing a simulation model that allows the insight to be made (design-science), resulting in the research methodology as is shown in figure 5.

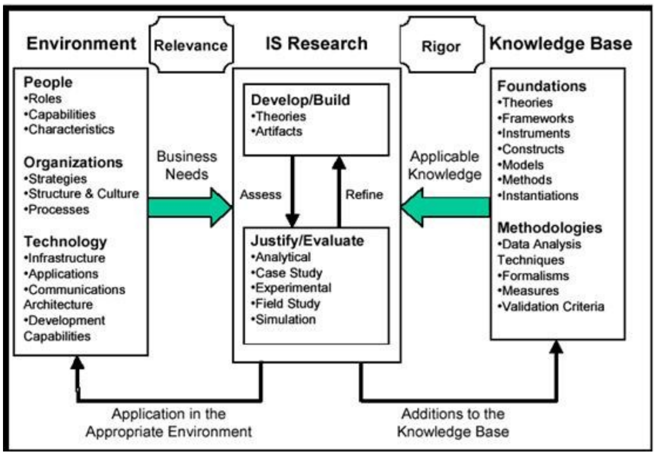


Figure 4 - Methodology of Hevner et al. (2004)

Using the methodology of Hevner et al. (2004), a *knowledge base* is constructed from the fields of project management, knowledge management, process management and from managing organizations. The theoretical knowledge is combined with knowledge from practice. Knowledge from the *environment* is obtained with the help of the company ePM. ePM is a consulting company that advises project-based organizations on the structure of the project teams to improve project performances, such as costs and project duration. ePM seeks a process that has quality checks embedded in the process of modeling their clients projects. These quality checks are required to ensure that the model ePM constructs is given the credibility it deserves and that the results are accepted by the end users. Using the practical knowledge of both ePM and its clients, a practical knowledge foundation is obtained.
With the knowledge from both theory and practice, a modeling process can be designed. Besides being useful for ePM, this process is used to *design* the conceptual model that is the basis for answering the main research question. A case study is added to *evaluate* the conceptual model. The results of this test are input for reflection and lead to *contributing* both to the knowledge base and to ePM's success in improving its services.

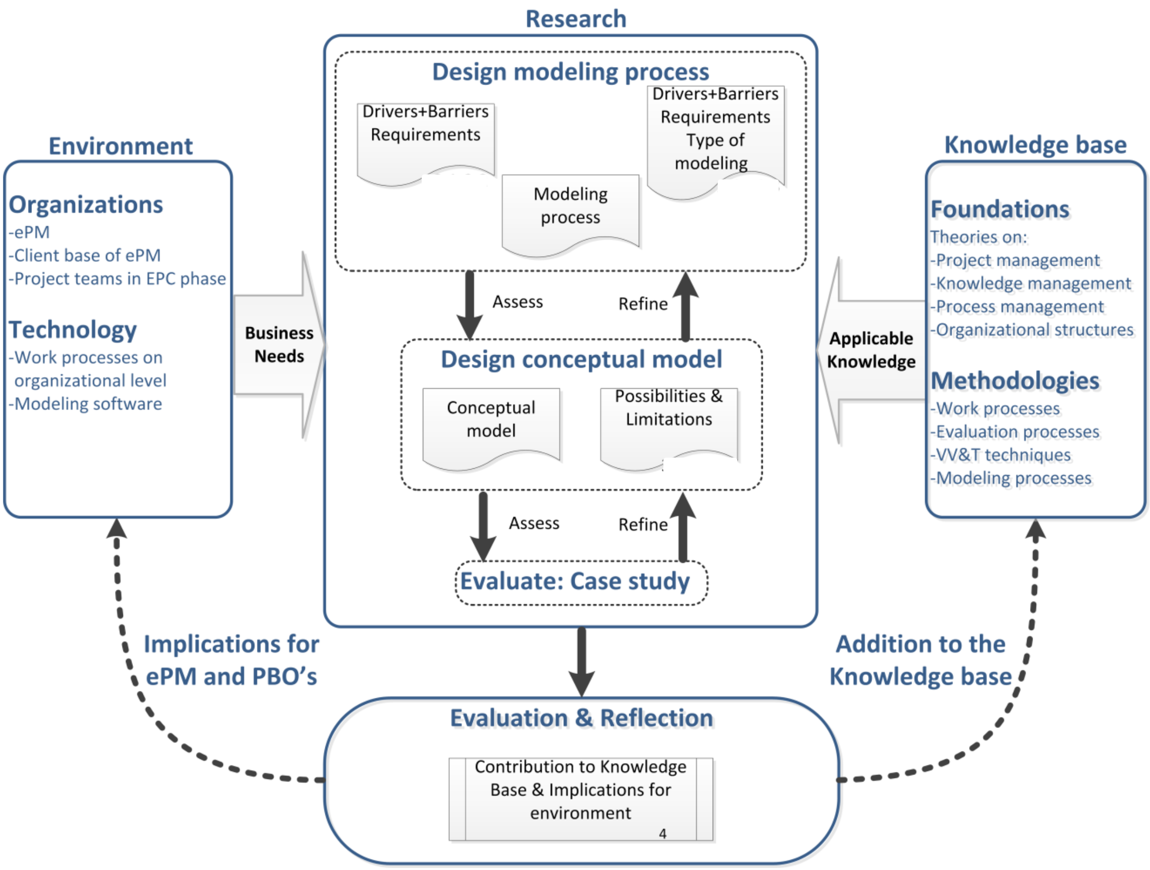


Figure 5 - Research methodology derived from Hevner et al (2004).

Hevner et al. (2004) have introduced the design-science paradigm that adopts the thought that designing and testing artifacts results in additional knowledge and expertise of the problem domain. They propose seven guidelines that, when followed, lead to successful performance of design research. To ensure that this research results into good design-research, attention is paid to these guidelines.

Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation. (Guideline 1)

The research focuses on designing a model that can create insights into how organizational complexities of managing projects influence each other and project performance, as well as provide ePM with a modeling process that enables ePM to design credible models that will be accepted by their customers. The two-model purpose is to directly create utility for its application.

The objective of design-science research is to develop technology-based solutions to important and relevant business problems. (Guideline 2)

The problem domain that is the topic of this research is the domain of project-based organizations. This field has been rapidly growing over the last decade. Creating an artifact that allows insights into organizational complexities aids these organizations in managing their projects more successfully.

The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. (Guideline 3)

Thorough evaluation is incorporated in both design phases with the framework of Balci (1994) by applying an extensive list of verification, validation and testing techniques in the case study. The extensive testing makes it possible to value the models' application and scientific contribution.

Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. (Guideline 4)

The fourth guideline states that the designed artifact should be contributing both to the environment and to the knowledge base. As the goal of this research is to gain a better understanding of organizational complexities the results of this research contribute to the knowledge base. The implications of the research are related to PBO's and the practice of ePM.

Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. (Guideline 5)

Design research must be conducted rigorously. By combining the Hevner et al. framework with the Balci one, the combined framework adds rigor to the research. The many interviews, audits and semi-structured meetings add rigor to the fairly explorative character of design-research. The extensive list of verification, validation and testing techniques finally adds rigor to the artifact.

The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment. (Guideline 6)

Guideline 6 means that the research itself must undergo a search process. The designs of both the conceptual model and the model in the case study are expected to be a search process due to the necessity to reflect on decisions and assumptions, resulting in many iteration steps.

Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences. (Guideline 7)

The practical deliverable of this research is communicated back to ePM who can use the modeling process to embed milestones in its work flows to further improve the credibility of its models to its clients. The scientific findings are communicated back to a scientific audience by presenting the work to a predetermined committee.

1.4 Thesis outline

In order to answer the research question the research is divided in four different phases, see figure 6. Using the derived methodology the four phases for this thesis are:

1. Design modeling process: Using the knowledge base, a simulation modeling process is created that guides a modeler towards a credible model that produces acceptable results and recommendations.

   List design requirements: Using both the theories from the knowledge base and the business needs from PBO's, what are the requirements for a simulation model when modeling work processes of project-based organizations?
2. Construct and test conceptual model: Using the modeling process, a conceptual model is created representing some organizational complexities within a project structure. The conceptual model is designed based on requirements from literature as well as from practice.
3. Evaluate: Using a case study the designed models are evaluated. The findings form the basis for the input into both practice and theory. How well can a work process be fitted in a model given the unique nature of each project?
4. Conclusion: What do the results of this research mean for managing the organizational complexities in work processes and what can both ePM and project-based organizations in general learn from the results?

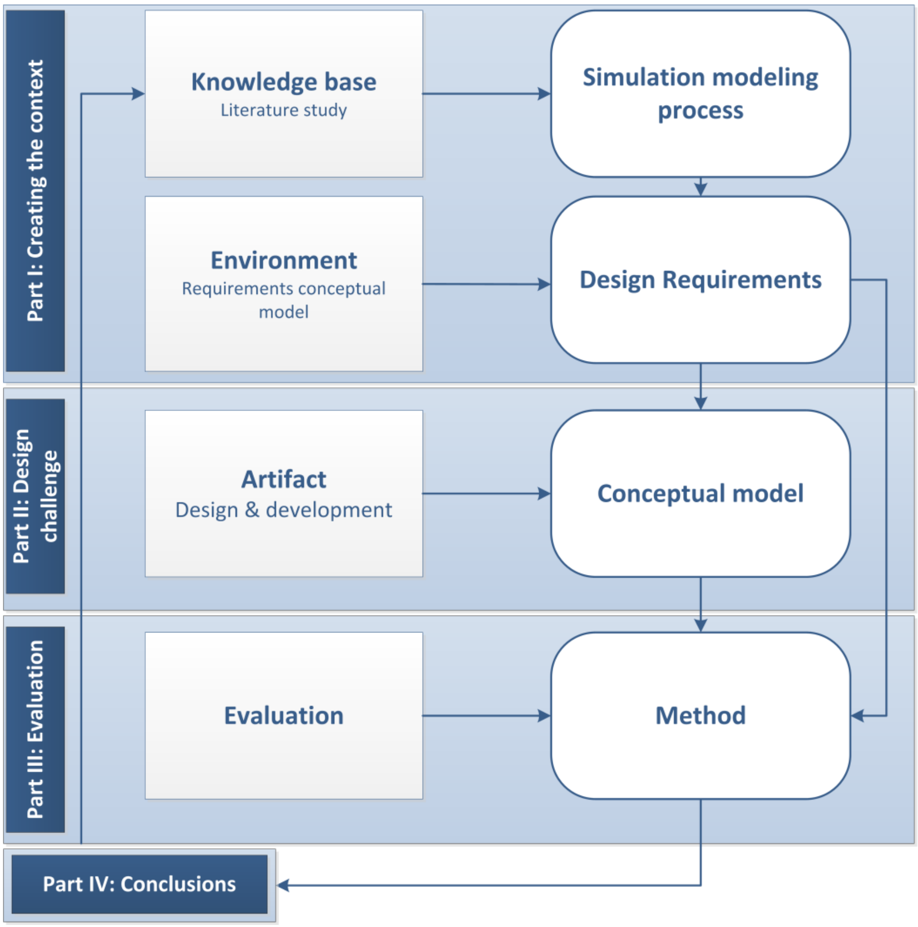


Figure 6 - Thesis outline

The sub-questions from section 1.2 are answered in chapters throughout the thesis. Chapters have been placed within the four parts of the research described above, resulting in the following structure:

Part I: Theoretical foundation: Creating the context

Chapter 2

RQ 1.1 Which requirements for designing a conceptual simulation model based on work processes can be derived from literature?

Chapter 3

RQ 1.2 Which are the needs derived from practice that simulation modeling and modeling work processes of project-based organizations can satisfy?

Part II: Design challenge: Designing conceptual simulation model

Chapter 4

RQ 1.3 What does a conceptual model that models organizational complexities in project teams of project-based organizations look like?

Chapter 5

RQ 1.4 Which methods are able to evaluate whether a conceptual model has been built correctly?

Part III: Evaluation: Testing conceptual mode with case study

Chapter 6

RQ 1.5 Which implications ensue when applying a conceptual model to real-world work processes?

Chapter 7

RQ 1.6 Which methods are able to evaluate whether a case-specific model is credible enough?

Chapter 8

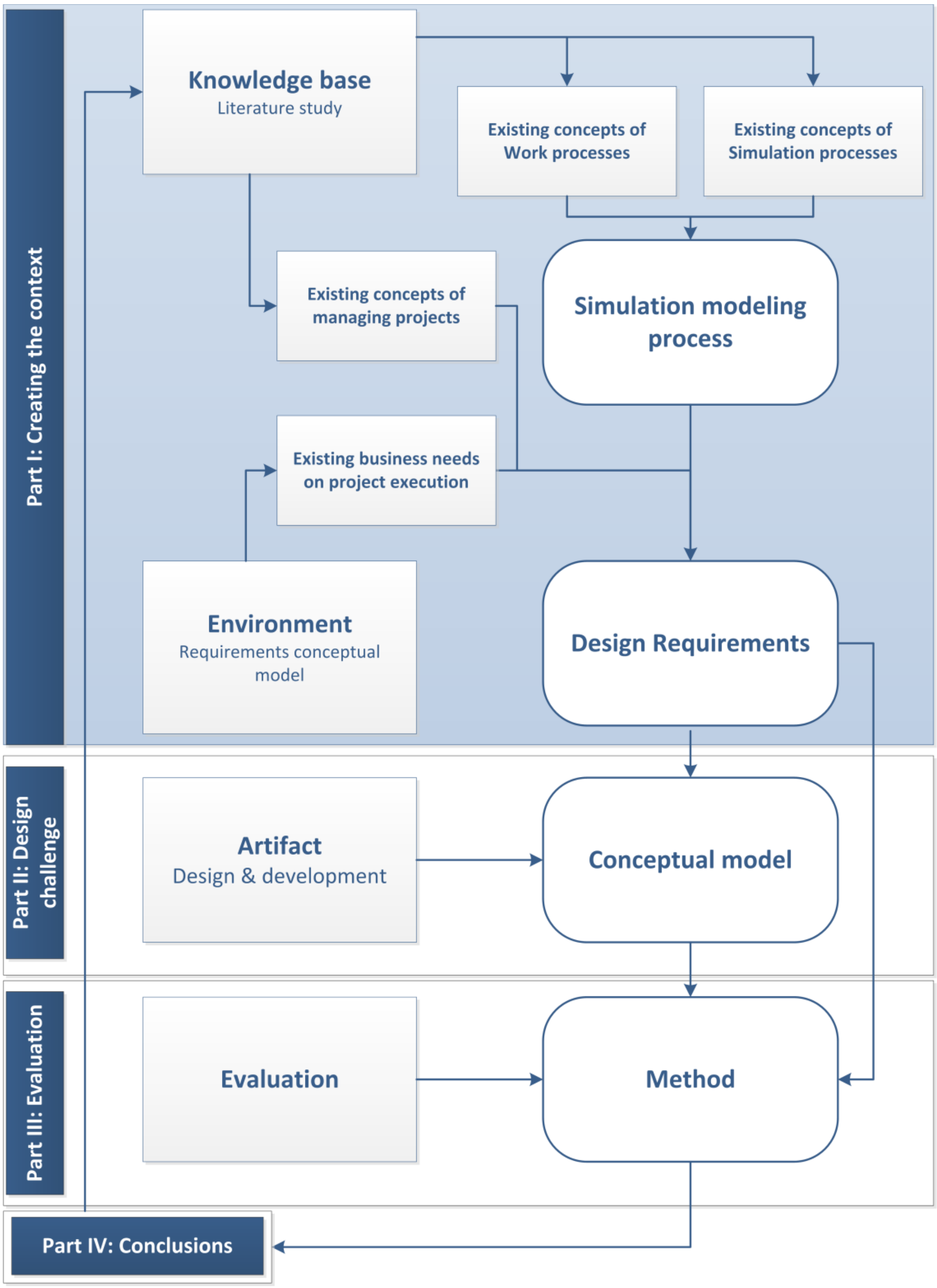
RQ 1.7 Which approach needs to be used to get a simulation model of work processes to be accepted by its end users?

Part IV: Conclusion: Contribution to knowledge base and environment

Chapter 9

RQ 1.8 What are the contributions of this thesis, and what are the implications for the environment?

Part I



Part I: Theoretical foundation: Creating the context

Chapter 2

RQ 1.1 Which requirements for designing a conceptual simulation model based on work processes can be derived from literature?

Chapter 3

RQ 1.2 Which are the needs derived from practice that simulation modeling and modeling work processes of project-based organizations can satisfy?

2. Knowledge base for research

In the previous chapter the reason for, and structure of, this research were described the research question and sub-questions were explained. In this chapter the knowledge base that is used as a foundation for this research is described. By reviewing the knowledge base, an answer is found to the question: Which requirements for designing a conceptual simulation model based on work processes can be derived from literature?

2.1 Work Processes and modeling work processes

In literature, the terms “work process” and “business process” are often used as synonyms. While used simultaneously, “business process” has not got one clear meaning. Davenport (1993) defines it as a “structured, measured set of activities designed to produce a specified output for a particular customer or market.” Another – broader – definition is given by Rummler & Brache (1995). They state that a business process is “a series of steps designed to produce a product or service”. Finally the Workflow Management Coalition (WFMC, 2011), a group containing vendors, users and consultants of workflow management technology, defines business process as a “set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure”.
The general perception is that a business process contains actions, steps or procedures, but the relation between these smaller elements differs per definition. In practice, Workflow Management focuses on recurrent processes on the operative level. Theiβen et al. (2010) conclude therefore that “In consequence, common usage of the term business process is narrowed to highly structured processes as indicated in the definition by Rummler and Brache”.

As described in the research motivation (section 1.1) the research utilizes the definition of Sharp & McDermott (2001) stating that a work process is “a collection of interrelated actions in response to an event that achieves a specific result”. Given the value of a good work process for project-based organizations, diverse procedures have been developed (e.g. Davis, 2001; Phalp, 1998, Sharp & McDermott, 2001). For both designing new work processes and improving existing ones, these procedures share common steps that need to be used in an iterative process, see Figure 7:

1) Identify modeling goals and scope
2) a. Capture the process as currently performed with its strengths and limitations
   b. Make a first draft of what the desired work process should look like
3) Analyze the process and specify an improved version
4) Implement the improved version

Roughly four dimensions can be identified to distinguish work processes from each other when modeling these procedures:

1. *Level of detail* that is put into a work process: The level of detail refers to the amount of information that is incorporated into the work process. The more information has been added to the work process, the better the related actions are explained. This can be done by adding detailed work procedures or through adding examples of best practices.
2. *Level of formalization*: This level refers to the way information is presented. Information can for example be shared through raw data, in diagrams or through story telling.
3. *Level of generality*, which is an indication of the number of work processes that are represented by the model. This dimension distinguishes between modeling a unique activity, modeling projects of a specific type and modeling guidelines describing typical steps.
4. *Quality* of the work process, which is dependent on the quality of the input that is supplied in the first two steps of the modeling procedure for work processes.

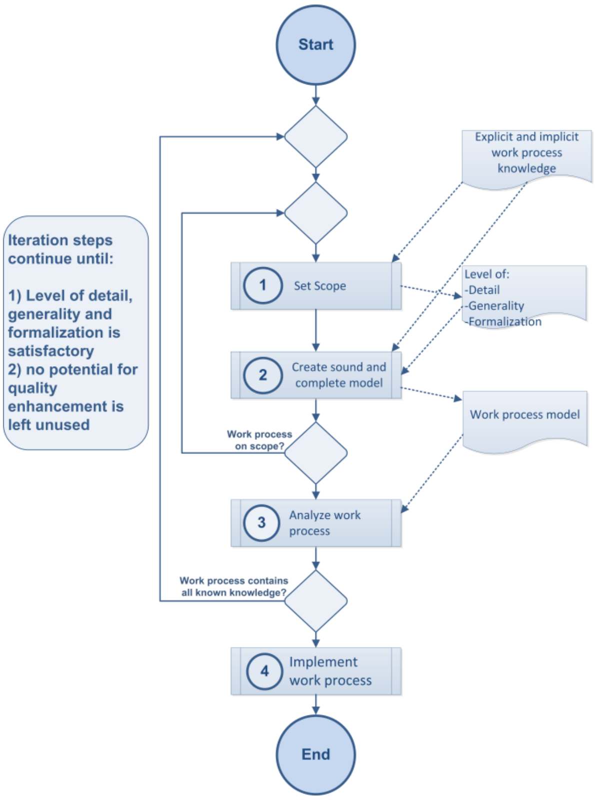


Figure 7 - Modeling procedure for work processes by Theiβen et al. (2010)

Work processes contain a lot of knowledge. Individuals can, by contributing during a modeling procedure, add their personal knowledge to the organization's work process. Knowledge for the people involved in these actions is essential, hence the knowledge base on knowledge management is explored next.

2.2 Knowledge and knowledge management

As stated in the previous section, work processes contain a lot of knowledge. To better understand the importance and influence of that knowledge on work processes a better understanding of knowledge and how knowledge is managed in an organization is required.

When the term knowledge is applied, a differentiation is made between data, information and knowledge. Data refers to "non-interpreted and unprocessed raw data" (Kim & Park, 2003) such as symbols, pictures and numbers. Data is just numbers without meaning until placed within a context, then it becomes information. Depending on the context a number can be positive or negative and thus context shapes the way data transforms into information. Knowledge is defined as: "Knowledge has to do with the process of learning, understanding, and applying information" (Soo et al., 2002). Knowledge is knowing *what* information is to be applied *when*, *where* to apply it, *how* this must be

done and *why* (Ackoff, 1989). As soon as information is actively applied, knowledge is the driving force why it is used, where and how.
Knowledge comes in two shapes: tacit and explicit knowledge (Nonaka & Takeuchi, 1995). Tacit knowledge is knowledge that is created within an individual through daily activities and is used subconsciously. Tacit knowledge cannot be seen or expressed easily and is best capitalized through mentoring (Goffin & Koners, 2011).
While tacit knowledge is hard to document, explicit knowledge is just the opposite: it is knowledge that has been formulated and can be shared easily (Nonaka & Takeuchi, 1995). As tacit knowledge is created by daily activities, explicit knowledge is created by stating tacit knowledge in an explicit form. Because explicit knowledge is easier formulated than tacit knowledge, it is used for guidelines, standards and procedures (Carvalho & Fereira, 2001; Huber, 1999).

Within organizations knowledge is obtained daily through individuals. For these organizations it is important that knowledge of individuals is managed in order for the organization to benefit from it. Knowledge management is defined as:

> "The effective learning processes associated with exploration, exploitation and sharing of knowledge (tacit and explicit) that use appropriate technology and cultural environments to enhance an organization's intellectual capital and performance" (Jashapara, 2004, p. 12)
>
> **Knowledge Management**

As becomes clear from the definition, organizations try to enhance the intellectual capital of the organization, which can contribute to the performance of the organization by using that intellectual capital to refine work processes and practices of the organization (Argote & Ingram, 2000). Knowledge management thus is an important aspect of any organization and needs to be structured in order to be effective. A knowledge management system (KMS) is needed and is defined as:

> "Set of policies, organizational structures, procedures, applications and technologies which defines a systematic social and technological process for creating, valuating, organizing, classifying, storing, maintaining and refining, distributing, accessing, using, and applying organizational knowledge as a resource" (Brink, 2003, p. 8,)
>
> **Knowledge management system**

As the definition states, a knowledge management system consists of multiple parts, of which technology is only one. The relationship between the different elements can be described using Soo et al. (2002) and is visualized in figure 8. A knowledge management system uses a common *language* within an organization (the *network*) to *transfer* knowledge into a *database*. Within these four subsystems three categories can be identified: technology, social and organization.

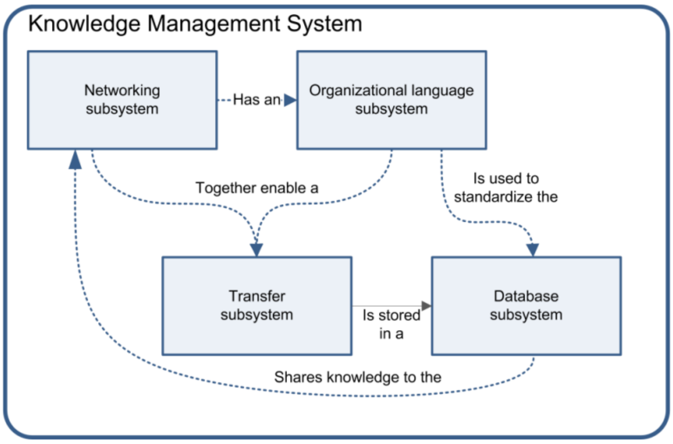


Figure 8 - Schematic representation derived from Soo et al. (2002).

Section 2.1 discussed that work processes can be designed using four dimensions and that work processes transformed individual knowledge into organizational knowledge. The way knowledge is captured and stored was discussed in this section. As people learn new knowledge with each project, this knowledge needs to be infused with the organization on a continuous basis, which is discussed in the next section.

2.3 Evaluation cycle

When combining the need for work processes with the concept of knowledge management a cycle can be identified. This learning cycle facilitates the capturing, storing and retrieving of knowledge. Each step will first be explained shortly.
The first step of such a learning cycle is the capturing of the knowledge (Milton, 2010). This requires some skill of the individual who experienced the lesson, as he needs to transform his tacit knowledge – the experience – into explicit knowledge. There are a number of different methods that aid the capturer with this step such as the use of project reviews (Newell, 2004), management initiatives (Koch, 2004), weblogs (Ras et al., 2005) and learning-based project reviews (Kotnour & Vergopia, 2005).
The second step is storing the knowledge. This step contains two important elements: the first one is to screen whether the knowledge has already been recorded earlier. This is to prevent placing the same knowledge multiple times in the database creating double query hits while representing the same experience (Barney, 2011). The second part is the validation of the quality of the experience. If too little knowledge is captured the transformation from tacit knowledge to explicit knowledge will not succeed, resulting in the retrieval of the knowledge being done partly and a successful retrieval not guaranteed without the capturer filling the gap each time.
Retrieval of the learned experiences is the third and final step of a learning cycle. This step utilizes the knowledge in order for an individual who did not participate in the project that encountered the experience, to learn from it and make the explicit knowledge his own.

To safeguard the usage of the learning cycle, more is needed besides a technical system. Barney (2011) states that two soft elements need to be present for this cycle to succeed. The first one is that organizational institutionalization needs to be designed with process management in mind (Bruijn et al., 2002). The second prerequisite is that individuals need to feel connected with the cycle in order to not only consume, but also contribute.

Thus besides standardization through templates, verification forms and a database, it might even be more important to embed time and resources within each step of a project lifecycle to retrieve as well as capture experiences. Only then can the culture of an organization be shifted to fully utilize the learning cycle (Cooper et al., 2002; Soo et al., 2002; Ajmal et al., 2010; Jasimuddin et al., 2011). Institutionalization plays a key factor in shifting the culture of an organization. Using the definitions of Selznick (1957) institutionalization is defined as infusing the organization with value. This means that institutionalization can be seen as a process: a learning cycle will only work if the organization is determined to use resources for the long run. Its usage and usefulness will have to grow as time progresses. Institutionalization also means that there is not one solution for all organizations. Each organization needs to find its own method of implementing and using a learning cycle according to its own strengths and weaknesses.

Using the four dimensions of Theiβen (et al., 2010), a work process can be categorized on its level of detail, formalization, generality and quality. The level of detail describes a scope on which work processes define the actions that lead to the specified result. An organization makes choices on the four dimensions of Theiβen, that leads to a designed work process, reflecting how actions are structured at that moment.
New experiences or a changing environment may require evaluating the current work process. A process can provide the structure needed to ensure a rigorous and systematic evaluation. Similar to a learning process the process contains three steps (C.I.I., 2007): 1) a gatekeeper who guards the work processes and is chair of evaluation meetings of the work process of his specialty; 2) employees who work with work processes, gain new experiences and provide evaluation processes with new input; and 3) the modification of work processes after the evaluation has taken place resulting in the implementation of the adjustments, see figure 9. Together these steps result in refined work processes that direct actions with the goal of improving organizational performance.

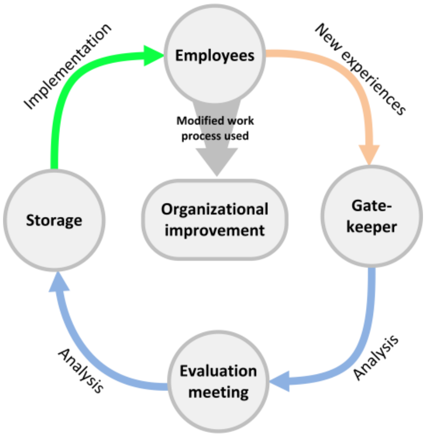


Figure 9 - Evaluation process for work processes

Using experience from past projects to further improve work processes is important, but it only focuses on learning at the end of project execution. Barney (2011) states the importance of ad hoc learning as well lessons learned as prior to the project. With these perceptions in mind, the ability to learn more of the work processes besides executing the lessons learned in projects, would enrich the circle of improving the work process quality.

Work processes are interrelations between actions. Together these actions influence the output, and thus the performance, of the work process. Creating a better understanding of the relationship between the actions will therefore enhance the understanding of how to improve the work process to achieve a better outcome. The main research question is related to pursuing this concept, as simulation modeling might be able to facilitate creating insight into how organizational complexities affect the interrelated actions of work processes. Therefore, an understanding of how modeling processes work is discussed next.

2.4 Modeling process

Using the four dimensions of Theiβen et al. (2010), to successfully model a work process, a simulation model is required to model within the right context (level of detail) and using the right scope (level of generality). The importance of modeling within the correct context and scope is also emphasized by Banks (1998). Banks states that during modeling three different types of errors can occur:

- Type I Results of a credible model are falsely rejected
- Type II Results of a non-credible model are falsely accepted
- Type III Results do not solve the formulated problem

To avoid the three modeling errors, Banks proposes to integrate decision moments during the modeling process, see figure 10. These decision moments take place during the construction of the simulation model starting in the early phase, and guides the modeler until the process is ended. The decision moments should be seen as an iterative sequence, meaning that each decision moment can be done multiple times until a satisfactory outcome is achieved.

From the theory of Banks the importance of modeling the right problem and with the right means is deducted. Focusing on merely the acceptance of the modeling results is not enough and can be more harmful than not accepting them, if the results are answering the wrong question. Having a rigorous modeling process is thus vital to come to a successful ending.

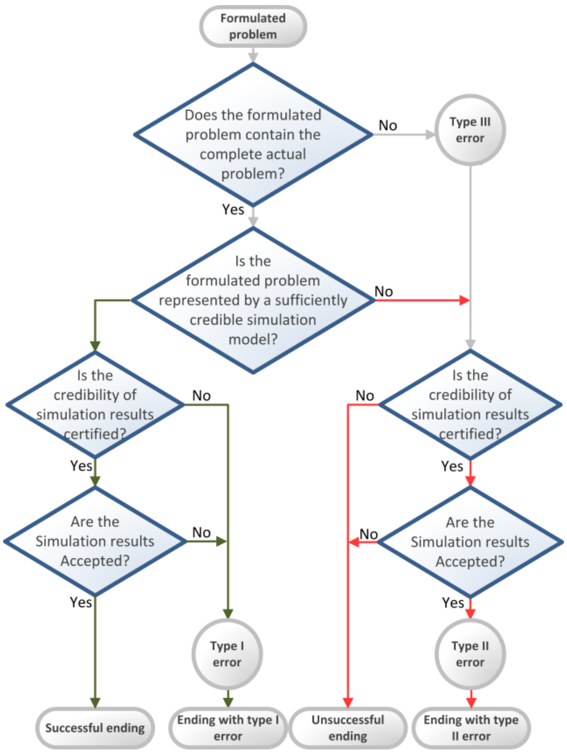


Figure 10 - Decision moments to avoid modeling errors by Banks (1998)

Balci (1994) states that such a rigorous modeling process can be achieved by implementing verification, validation and testing (VV&T) techniques throughout the modeling process. In essence, Balci states that each step towards the results must be evaluated by applying a variety of techniques, see figure 11. For each stage in the process, several VV&T techniques exist (Balci, 1994 p.154). To check if the formulated problem is correctly understood by the modeler, for example, an audit or walkthrough with the end user can be applied. While testing the experimental model, stress testing can be utilized to learn about the model boundaries. With the provided list, a modeler is able to check each stage of the modeling process and be confident that progress allows for venturing to the next stage.

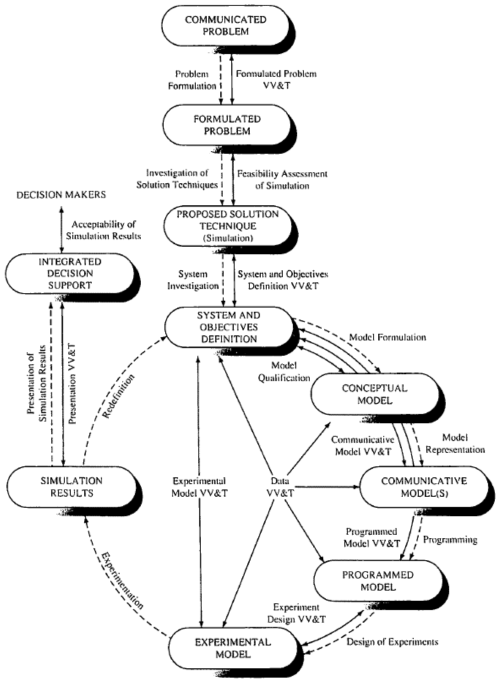


Figure 11 - Modeling process by Balci (1994, p.154)

Balci also describes the modeling process as an iterative process in which the first results are input for modifying the previous modeling steps. A rigorous outcome can only be achieved by going through a series of iterations and abandoning the concept of being right the first time. This concept is in line with the theory of Banks, along with verifying the quality during the process.

Both the concepts of Balci and Banks aim for a successful ending. A successful ending is defined as results that are accepted by their end user which are produced by a simulation model that is credible enough to deal with the problem. Each of the concepts focuses on different elements through which a successful ending can be achieved. Banks aims to give structure to the process by implementing decision moments at which a quality check is performed, whereas Balci emphasizes applying VV&T techniques during the modeling process at various stages. By combining both concepts the modeling process increases its quality checks and therefore makes an successful ending more likely. By enhancing the process, the three types of modeling errors are less likely to occur, while increasing the quality of the end result by applying various VV&T techniques. The modeling process as shown in figure 12 is the result of the merge between both theories.

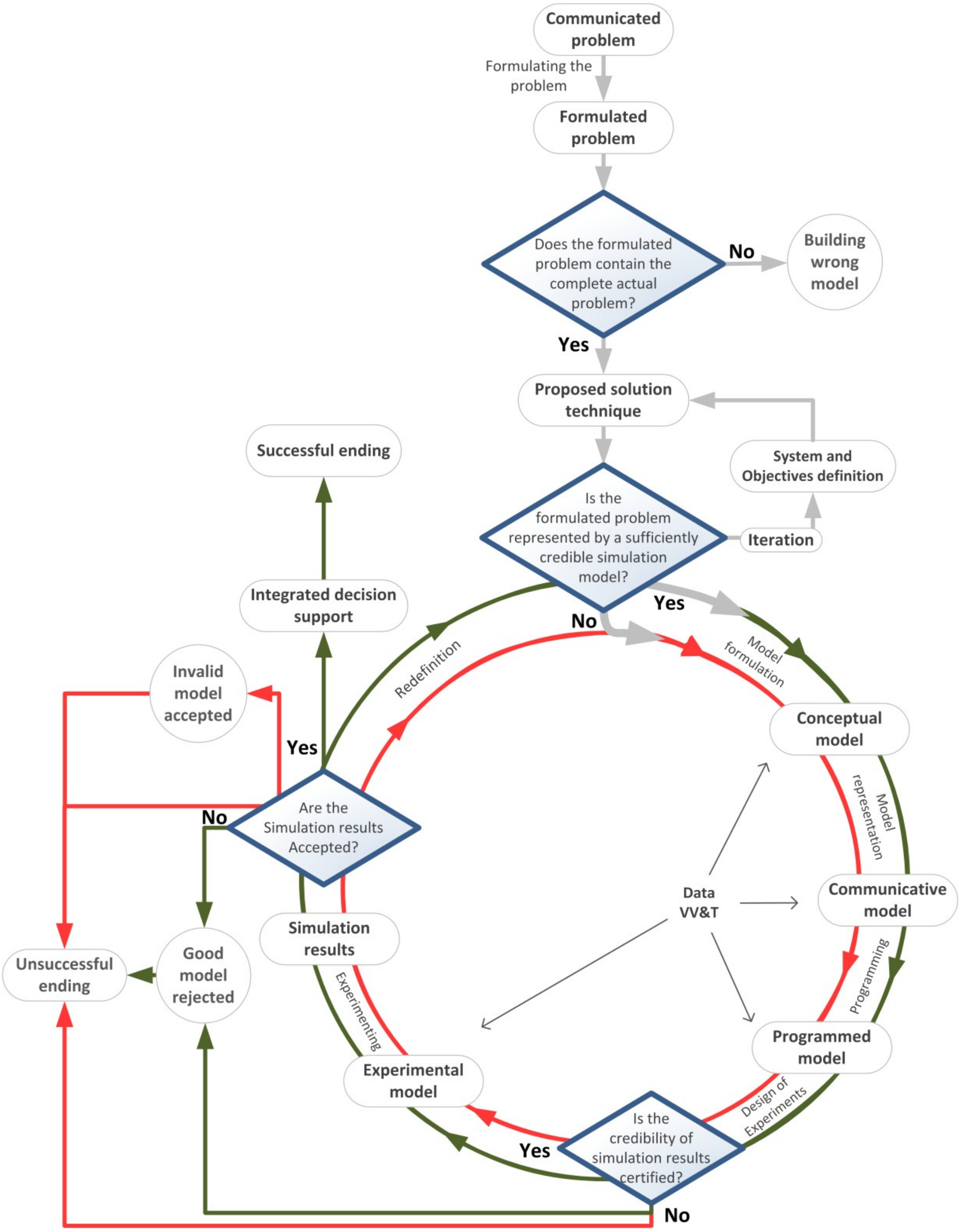


Figure 12 - Modeling process combining Balci (1994) and Banks (1998)

The modeling process shows the different stages that each simulation model needs to undergo in order to achieve a satisfactory ending. It starts with a problem that is communicated by the problem owner to the modeler. The *communicated problem* needs to be transformed into the *formulated problem* which contains a clearly defined system and goals. Before choosing a solution technique, the first decision moment is implemented. To avoid a type III error, solving the wrong problem, the formulated problem needs to be verified with the problem owner. Once the formulated problem is verified successfully, the process can continue.

Choosing a correct *solution technique* is the next stage. Often the technique used is seen as a given, because organizations use the same specific techniques all the time. However, the chosen technique does need to match with formulated *system and objectives definitions*. When the modeler feels comfortable with the match, the second decision moment of Banks can be initiated: is the formulated problem represented by a sufficiently credible simulation model? The chosen simulation technique needs to be able to solve the formulated problem in a structural and believable way. The theory of Banks indicates a split depending whether the simulation model is credible or not. If the proposed simulation technique is not capable of representing the formulated problem, then an unsuccessful ending is the only possible outcome, as is indicated by the red path. Whereas the green path indicates the path of a simulation technique that is able to represent the formulated problem.

After the second decision moment a *conceptual*, *communicative* and *programmed model* can be constructed. The importance of VV&T techniques is stressed during these stages. Data that is used to construct these models needs to be verified and validated. The reason for stressing VV&T is two-fold. Firstly, verifying and validating the data improves the quality of the results as the model represents the system more accurately. Secondly, the problem owner is often involved when applying VV&T techniques enabling the problem owner to relate the mechanisms of the simulation technique to real actions. This involvement is important for the third and fourth decision moment.

Once the programmed model is finished, the next stage is creating the *experimental model*. However, the experimental model can only be of use if the problem owner accepts the basis of the simulation model. The third decision moment is thus a procedural check if the problem owner accepts the foundations of the model and confirms that the outcomes the model thus far produces, are within the line of expectations.

The fourth decision moment determines whether the final *simulation results* are accepted by the problem owner. Only when the formulated problem deals with the actual problem (avoiding type III error), when the model represents the formulated problem and when the model produces credible results, only then do the accepted results lead to a successful ending of the modeling process.

2.5 Simulation modeling on work processes

The modeling process as described in section 2.4 provides a modeler with clear stages and decision moments at which a quality check is performed. By following this process the simulation results are formed rigorously with verified and validated data giving simulation results the credibility to be convincing. As this thesis focuses on understanding the interrelated actions within work processes by using simulation modeling, the modeling process needs to be given a place within the learning process of the work process.

For a simulation model to be able to create insight into the interrelated actions, the model needs to represent the work process accurately. In the previous sections a number of useful techniques and processes on how to build a sound and rigorous tested simulation model (Balci, 1994; Banks, 1998; Theiβen et al., 2010) were discussed. Using the modeling process a conceptual simulation model can be constructed that is able to represent the mechanism of the interrelated actions in a work process. In order to be useful for a project-based organization, however, more than just a conceptual simulation model is required. As is shown in figure 12, after the conceptual modeling phase, the model needs to be catered to a specific work process, and the simulated results needs to be validated to ensure the results can be rightfully accepted. Realizing the above, the simulation model needs to have a place in the learning process to have added value for the work process, as is shown in figure 13.

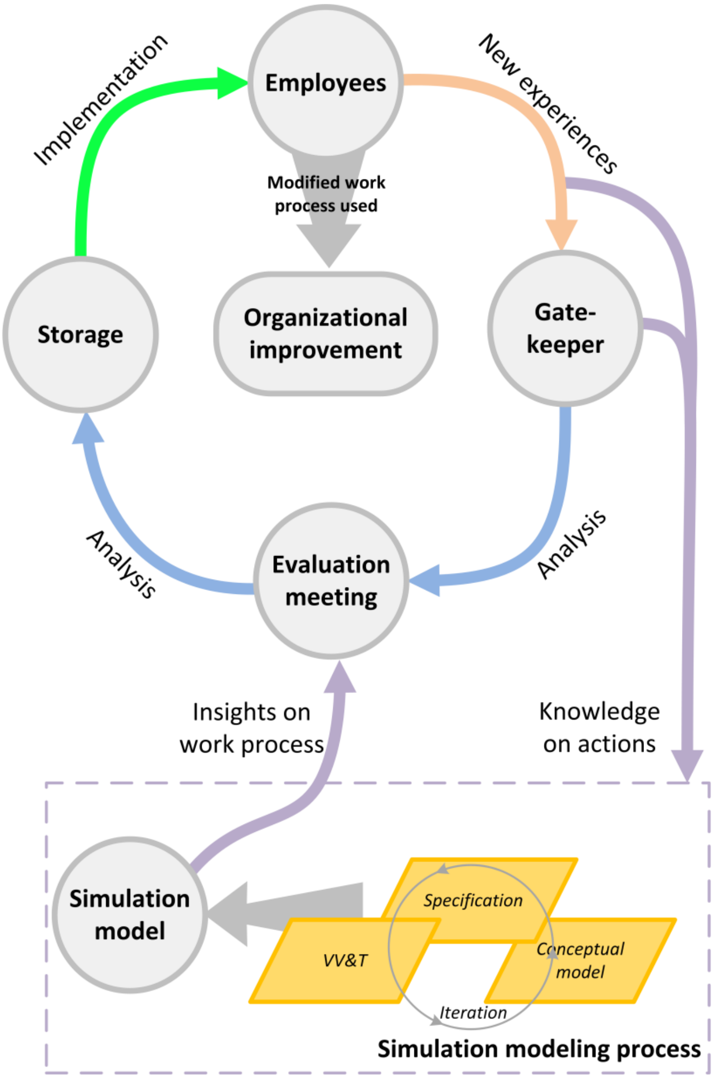


Figure 13 - Placing simulation modeling within the evaluation process

The simulation modeling process in figure 13 assumes two inputs. Firstly, the process assumes that the organization is able to generate a conceptual model of the PBO's work processes. This conceptual model will have a high level of generality with a low level of detail. The conceptual model serves as a foundation upon which a wide variety of work processes can be created. This flexibility avoids repeating stages such as choosing a credible solution technique and identifying the mechanisms that are in place in each work process.

The second assumption of input is (new) knowledge of the actions described in the work process that will be simulated. This input is required to enable the specification and validation of the work process that is evaluated.

2.6 Conclusions

In this chapter the knowledge base on relevant literature has been discussed. Using the knowledge base discussed in the previous sections, research question 1.1 can be answered: "which requirements for designing a conceptual simulation model based on work processes can be derived from literature"?

This question is answered as follows: first, the driver and barrier for using work processes are explained to set the boundaries when work processes should be used. Second, usability of simulation modeling on work processes is set out. Last, a list of requirements which a conceptual simulation model needs to comply with are given.

Work processes

The main driver for using work processes is to achieve specific results by structuring the actions in response to a predetermined event. By providing structure the actions will be executed according to the idea, guidelines or rules stated in the work process. The organization can steer the direction of actions and therefore influence the performance of those actions.

The main barrier for using work processes is that each work process has limited applicability as each work process can be categorized on four dimensions: level of detail, generality, formalization and quality. Using the dimension of 'level of generality' as an example; the more information is placed within a work process, the better specific actions can be explained. However, at the same time the applicability of that work process decreases as other actions cannot directly follow that process due to different characteristics. When the level of generality is high, the work process can be used for many different situations, but explains less how the actions have to be executed. Such a work process thus serves more as a guide than a blueprint.

Another barrier is the amount of resources that goes into the creation of a work process. A work process requires not only a clear concept of the actions and how they relate to each other, it also dictates the way actions need to be executed to achieve the result in mind. Especially in project executions predictability is heavily sought after, but rarely provided. Restricting the maneuverability of project teams by formalizing the actions could work counterproductive in achieving the specified result of the work process (C.I.I. , 2007).

Simulation modeling

Simulation modeling can be used to find a variety of answers, depending on the type of simulation used and the way the simulation is structured. Basically, any type of simulation model can be used for constructing work processes as long as it uses four dimensions: level of detail, generality, formalization and quality. This means that work processes can be modeled using flow charts (e.g., explaining the sequence of steps to perform when starting a project), but plain text stating tips and tricks can be a work process in itself as well (e.g., when giving best practices).

To create simulation results, a process of simulation modeling is conceived in section 2.4. By providing decision moments and laying the emphases on verification, validation and testing techniques the quality of the different stages and the final result are rigorously designed. An additional, and essential, effect of the constructed simulation modeling process is the involvement of the problem owner, increasing the acceptance of the results.

2.7 Answering research question 1.1

From the knowledge base the following requirements can be derived that are needed to create a model based on work processes using simulation modeling, answering research question 1.1:

R1. The simulation technique needs to be able to model the four dimensions of work processes
R2. The simulation technique needs to be understandable by the end user for it to produce results that can be accepted
R3. The simulation results can provide knowledge of the modeled work process

With the answer of the first sub-question and the creation of the simulation modeling process, the theoretical part of the first phase of this research comes to an end. In the next chapter the practical requirements of a conceptual model based on work processes are discussed.

3. Environment: Project-based organization

In the previous chapter theoretical requirements for the conceptual model and a simulation modeling process are discussed based on a literature study. In this chapter the business needs of the environment are elaborated upon. In section 3.1 the company ePM is discussed, followed by a recap of the practical aim of the thesis in section 3.2. Section 3.3 discusses the needs from the client base of ePM, project-based organization. In section 3.4 the requirements from the environment are listed.

3.1 The company ePM

This thesis answers a scientific question by combining theory with practice. While applying the applicable knowledge from the knowledge base, needs and requirements flow from the business environment. For this research the company ePM provides its business needs along with insights on project-based organizations. These needs are described in this section and result in requirements that a simulation model needs to comply with when modeling work processes.

ePM - the organization

ePM is a consulting company that gives advice to project-based organizations globally and to a wide variety of sectors. Over the years it has given advice to companies in sectors ranging from the oil and gas production, computer hardware and software, pharmaceuticals and biotechnology and transportation sectors (ePM brochure, 2011). ePM has specialized in designing the organizational structure of its customers' project teams, the same way companies design products. Designing the structure of a project enables the customer to lower project costs, shorten the product schedule and streamline cooperation between people resulting in higher productivity and lower costs.

> "ePM combines the science of organization design with the discipline of organization development to achieve predictable and profitable performance."
>
> **ePM website**

ePM's approach

In order to facilitate its customers, ePM has developed several tools and processes over the years based upon a learning cycle: Context, Process, Content, Feedback. This approach is holistic and ensures that all organization elements work coherently and reinforce each other. The principle of context is the setting in which the project is placed. The customer operates within a certain field and wants to address (parts of) his organization. The context will then be the specified section of the organization that will be reviewed and all that is connected to it.

Together with the customer ePM works within that context with different processes designed to make the required content explicit. These processes have been developed over the years to create a good setting in which the customer feels respected, trusted and taken seriously. For each service the processes differ but methods such as meetings, workshops, brainstorm sessions and simulation models are used within these processes.

Following the process the result delivers the content, creating better team work, higher predictability of results and placing personnel in the right place at the right time. In essence the content answers the question of the customer.
The final step is feedback. During the actions of context, process and content the customer has reviewed his own personnel and organization and is able to look back on his initial questions. This reflection allows the customer to learn from the experience and gain new insights into how to improve his organization structure.

ePM's need
ePM believes that simulation modeling provides an additional depth, an immersive layer, when going through the learning cycle. SimVision, ePM's simulation environment, is a step towards using simulation in their approach and ePM seeks ways to improve its business approach by answering practical questions such as: when simulation modeling is applied, how can ePM determine what should be modeled and when is the designed model performing correctly for that particularly case? When can the model be viewed as a good model, who determines what a good model is and when is a model finished? In other words, the business need of ePM can be summarized by the following question:

> How do you know that the model that is designed, is a good model and fit for purpose?
>
> **ePM's need**

3.2 Practical goal of research

The practical goal of the research, to create a simulation modeling process in which insights into organizational complexities are facilitated, is the driving force of solving the need of ePM. The simulation modeling process supports the modeler with a rigorous process that defines what a good model looks like for the customer and increases the quality of the model.

Both questions to which ePM seeks answers are dealt with by applying the simulation modeling process, as is shown in figure 14. As a simulation model can represent anything, it is essential that the modeler has a clear view of what the goal of the simulation model is (e.g., modeling organizational structures while the goal is to learn about the waiting time on deliveries will lead to the results not accepted). To avoid producing a model that solves the wrong problem, the problem the model needs to solve has to be clearly defined. Only with a correct formulated problem can the answer on what is needed to model be successfully answered.

With a correctly formulated problem, there are still many options for the modeler to choose from (e.g., determining how in-depth a model should go to answer the formulated problem). Answering the question of what a good model, or satisfactory model for the customer, looks like results in ambiguous criteria. The simulation modeling process deals with this issue by involving the customer in the process of designing the simulation model, resulting in clear criteria for each case as they are created together with the customer. The required level of detail for the model comes from the involvement of the customer during the various stages of modeling. This process raises the credibility of the model and the model is more likely to produce acceptable results when the customer has participated.

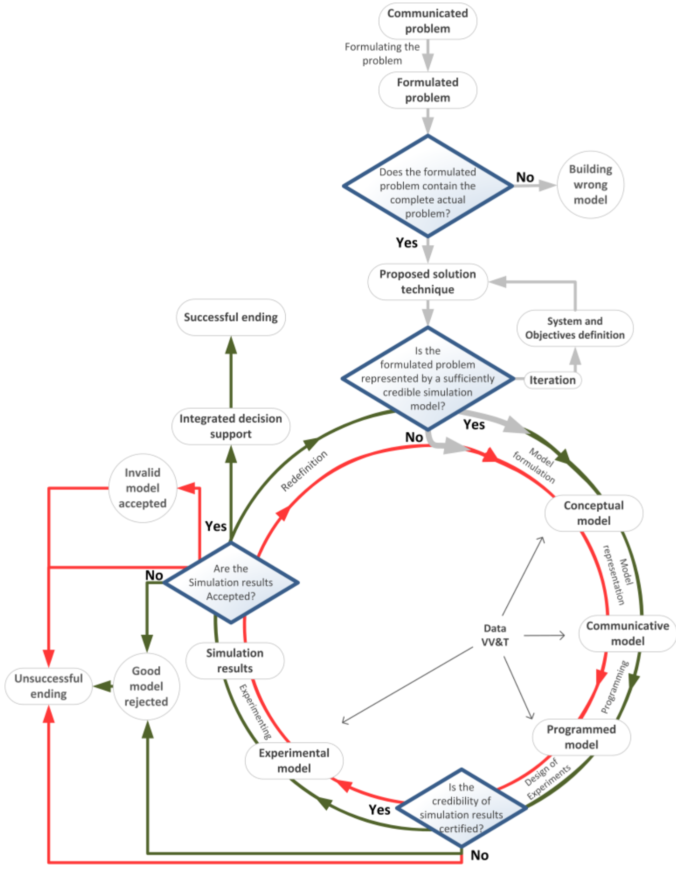


Figure 14 - Simulation modeling process

The simulation modeling process enables ePM to deal with the questions they have when using modeling in its practice. The decision moments create clear evaluation moments in which ePM can check with its customer whether the correct problem is modeled, whether the model is able to produce information that the customer needs, and when the model is finished due to producing accepted simulated results that answers the customer's questions. The simulation modeling process thus seems to answer the need of ePM. To validate this conclusion, the modeling process has to be able to deal with requirements that the customer has when its problems are placed in a simulation model. Before being able to construct a conceptual model by applying the simulation modeling process, the business needs of ePM's customers, project-based organizations, are explored.

3.3 Project-based organizations

The reasons for the PBOs to come to ePM are two-fold. ePM is able to increase the speed of making decisions on project team structures and ePM provides predictability of project outcomes with its simulation modeling program SimVision.

Business needs

Increasing *decision speed* means to improve the speed with which the problem is solved and with which results are discussed. By increasing the pace, ePM can give feedback sooner, leaving more time to improve the quality of the project team structure. SimVision is capable of modeling the organizational structure and identifying bottlenecks of the proposed organizational structure. While

simulation models can calculate results of a range of scenarios, building the models is time-consuming. One way to further improve the speed of work is by having conceptual models ready to be used for different customers. The advantages of using conceptual models are: the basis of the model is already tested before; it saves time compared to working from scratch; and the customer can already recognize his organization with the rough setup and can give feedback based on the mold for further specifications.
ePM foresees a change in the marketplace towards demanding better *predictability of project outcomes* (interview Triesch, 2011). ePM believes that the customer demands that projects are predicted better, thus reducing the probability of negative results. ePM wants to achieve this by enhancing its simulation modeling capabilities. By placing the context of the customer in a simulated environment the customer is able to go through the four steps (context, process, content and feedback) by himself and learn about his organization and personnel. This level of immersion creates a higher level of context and content in which the simulated environment is projected. Instead of hearing the conclusions and advice from an external company, the customer is able to see the results and their effects on the organization himself and test other setups by changing parameters, using a credible and accepted simulation model.

PBO characteristics
Focusing more on the characteristics of project-based organizations (PBOs), a couple of generalities arise. First of all, PBOs execute projects to get things done. Over time, experiences of past projects shape how projects should be executed. Combining these experiences, consisting of formal and informal procedures, can be defined as the work process in which the required interrelated actions are defined to execute a project successfully.
Secondly, experiences obtained during project execution can be divided in two typologies: process and product lessons (interview Wardall, 2011). Whereas the product lessons are unique for each sector as it contains specifics on the product that is being constructed, process lessons can be generalized as they can be described in the procedures of work processes. Examples of issues which process lessons deal with are:

- Communication during project execution
- Structure of the project team
- Utilization of resources

The thesis focuses on organizational complexities and as process lessons could be related to these complexities (i.e. organizational complexities identified by Bosch-Rekveldt such as: 'size of project team' and 'interfaces between different disciplines' could be related to the given examples of process lessons), the findings of this research can shed light on how simulation modeling can aid with the relationship of past experiences and understanding organizational complexities.
Thirdly, a characteristic of today's projects is the required expertise to lead, design and construct a project. To cope with the increase in expertise, PBOs have specialized. Broadly speaking three typical roles can be defined from practice; Project owner, Main contractor and Subcontractor (interview Gisbergen, 2011), as is shown in figure 15. The consequence of this separation is that project teams consist of different organizations that need to work together, thereby increasing the organizational complexities of managing projects (e.g., organizational complexities such as: the number of

contracts, interfaces between disciplines and size of the project team are more likely to occur, when the number of organizations involved in the project team increases).

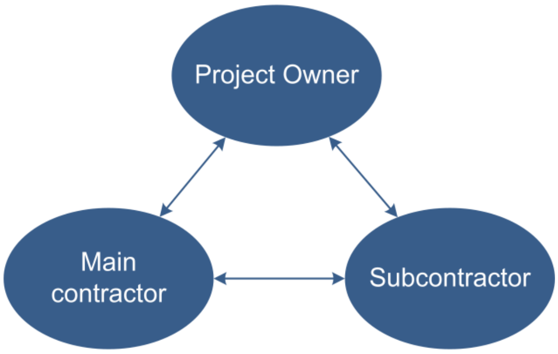


Figure 15 - Generalized project roles

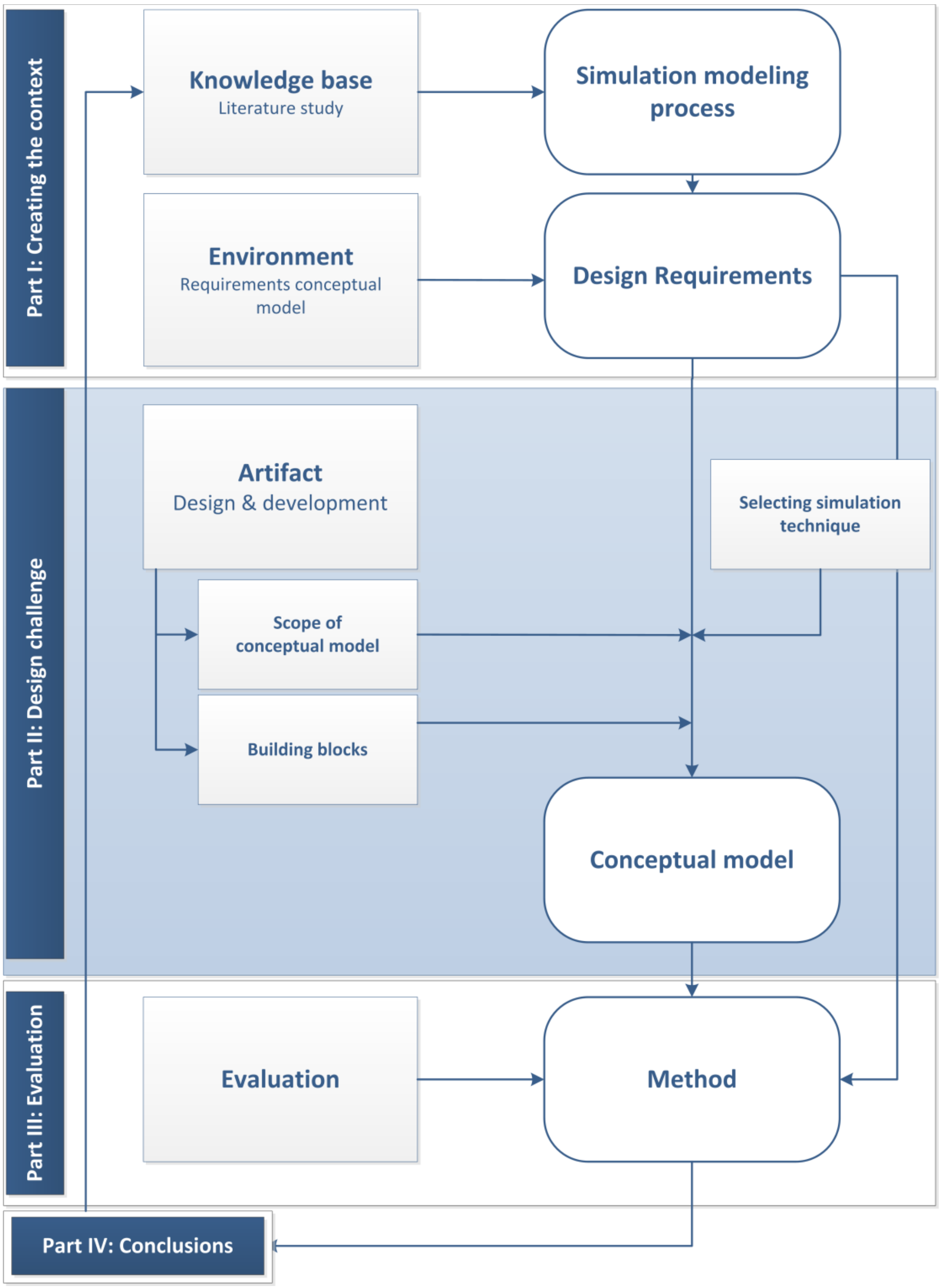
3.4 Answering research question 1.2

In the previous sections the business needs of ePM and project-based organizations have been discussed. The needs have been related to simulation modeling resulting in requirements which the simulation model has to meet to successfully represent the business needs. The requirements are:

R1. The simulation technique can model the different project team structures
R2. The simulation technique can model PBO's work processes
R3. The simulation technique can create conceptual models to be applicable to different projects
R4. The simulation technique produces project performance as output

With the list of requirements that the simulation technique research question 1.2 is answered. With the requirements from both the knowledge base and the environment now known, it is possible to conceptualize projects in the next chapter.

Part II



Part II: Design challenge: Designing conceptual simulation model

Chapter 4

RQ 1.3 What does a conceptual model that models organizational complexities in project teams of project-based organizations look like?

Chapter 5

RQ 1.4 What method is able to evaluate whether a conceptual model has been built correctly?

4. Design: Conceptual model

In the previous chapters the applicable knowledge and the business needs were discussed. As the goal of this research is to learn about the relationship between organizational complexities, which influence project performance through the structure of the project team, a conceptual model of project execution needs to be designed. This process is guided by the simulation modeling process which was designed in section 2.4. The relevant section of that process for this part of the research can be viewed in figure 16. As the first step of the simulation modeling process is defining a formulated problem, the formulated problem for this research is given:

> Organizational complexities are likely to be influenced by the actions and the structure of project teams, which are defined in the work processes of PBOs, but no insight is available into which actions contribute to these complexities.
>
> **Formulated problem**

In this chapter the requirements of a conceptual model are recapped in section 4.1, followed by the scope of what is modeled in section 4.2. In section 4.3 the output of the conceptual model is explained. The question of what should the model be able to tell is centralized in this section. Lastly, the designed conceptual model is elaborated upon in section 4.4.

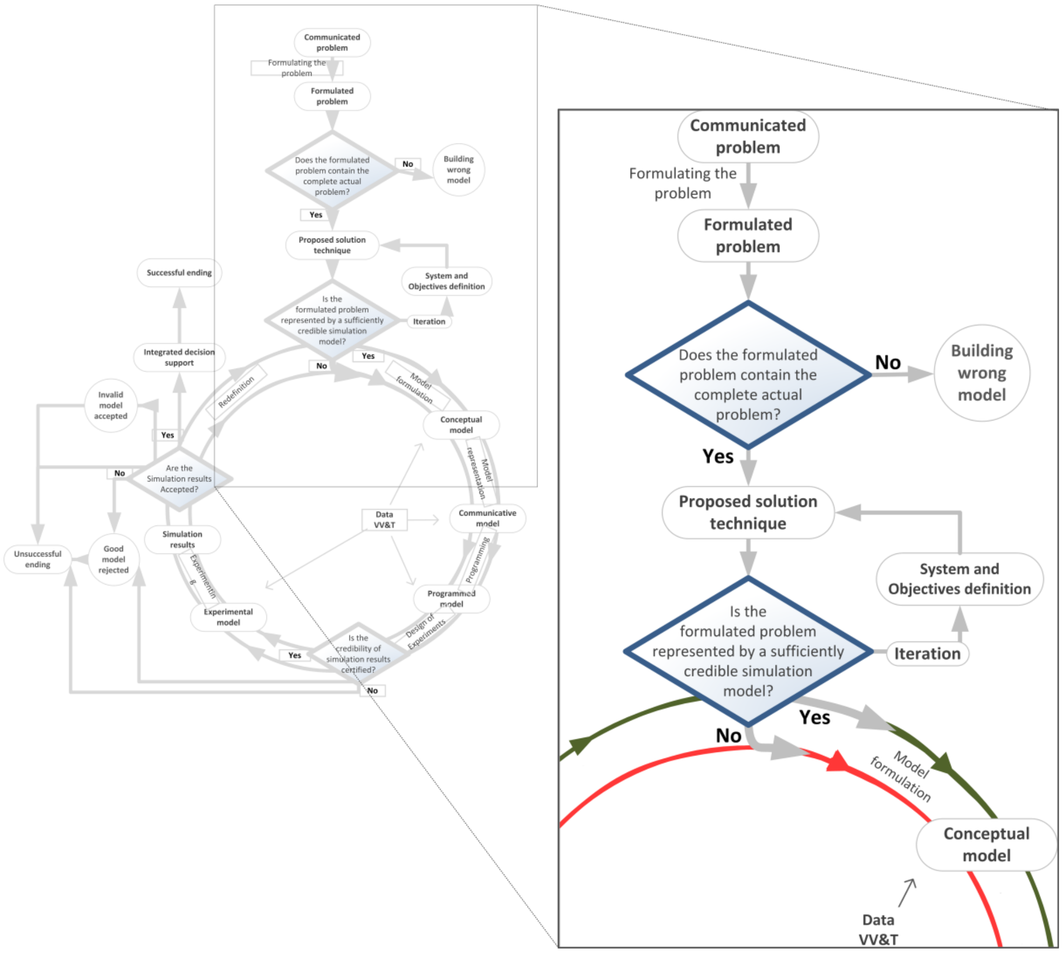


Figure 16 - Relevant section of simulation modeling process for chapters 4 and 5

4.1 Requirements of the conceptual model

From the knowledge base several requirements were derived with which a simulation technique needs to comply if the technique wants to achieve additional contribution. Business needs are summarized from the environment so that the simulation technique can produce useable outputs. Together the requirements are:

R1. The simulation technique needs to be able to model the four dimensions of work processes
R2. The simulation technique needs to be understandable by the end user for it to produce results that can be accepted
R3. The simulation results can provide knowledge on the modeled work process
R4. The simulation technique can model the different project team structures
R5. The simulation technique can model PBO's work processes
R6. The simulation technique can create conceptual models to be applicable to different projects
R7. The simulation technique produces project performance as output

Taking the requirements into account, the conceptual model needs to be able to simulate projects done by PBOs while focusing on modeling the actions and project team structures within the work process that could influence organizational complexities.

> Using simulation modeling, a conceptual model needs to be able to simulate projects done by PBOs while creating insights into the organizational complexities embedded within the work process.
>
> **Objective definition**

4.2 System definition

There are many different ways of constructing a model that represents reality, ranging from modeling every nut and bolt to modeling only the procedures on the highest level. Each model has its pros and cons and justifying the modeler's choice is just as important as the results that the model generates. In this section a select group of choices that have been made is described, while the full list can be viewed in Appendix A.2.

Aggregation level
The model is constructed on a high aggregated level. The main reason for this choice is the goal of the research: test relationships between actions on this aggregation level. Going a level lower would shift the focus from organizational towards operational characteristics. The level of detail and generality of the information and the available time of the parties involved also matches this scope.

Phases of the project within the simulation
Using the given requirements in the previous section with the goal of the research, it is not necessary to model all stages of a project. Viewing projects from a high level, projects consist of the following phases: proposal and initiation, design and appraisal, execution and control, finalization and close

out (Cleland & King, 1983; Leybourne, 2007; Turner, 2008; Murray, 2009). As the interest lays in the organizational complexities of managing projects, the phases of design, appraisal, execution and control are the focus of this research. The proposal and initiation phase is an important period that can exert large influence on the value of a project (Hutchinson & Wabeke, 2006), but is less suitable for modeling. During this phase a project team is often small and tasks are not clearly defined yet, resulting in a simulation model that is a simplification of the phase and does not grasp the essence of it.

The phase of project closing, which includes testing and starting up production, was excluded as data did not suffice to model it with enough certainty. While it would add additional uncertainty to the organizational structure with extra positions that test the interfaces of the different components, the lack of data meant that so many assumptions had to be made that it could undermine the reliability of the conceptual model.

As the project phases ‘proposal and initiation’, and ‘finalization and close out’, were left out of the simulation model, an artificial start and end of a simulated project had to be decided upon. The start of the simulation is when the decision has been made to make a complete detailed plan, and the simulation ends when subcontractors have finished their work.

Reduction of the procurement

An important aspect of project execution is often the procurement of tasks to which subcontractors react and together with the project owner arrange a contract. Similar to the phase of project proposal and initiation, procurement is a vital part that can heavily influence the project performance. However, modeling procurement alongside with the design and construction of a project, would have made the model substantially larger and more complex, as additional team members need to be added with their own tasks, making the identification of relations between actions harder and thus negatively influencing the goal of the research. This research therefore assumed that the procurement phase can be reduced to a singular task, allowing the task to influence other tasks throughout the project, while the research focused on the relationships between the design and construction of the project.

Parts of project team that have been left out

The conceptual model focuses on people that contribute ‘physically’ to the project, meaning the functions that perform a task that do something concrete. Staffing personnel, such as human resources and secretaries, is vital for the project team to do its job, but for modeling purposes these functions cannot be given a place in the modeled project team. People and activities of this kind have therefore been left out of the project team, thus further reducing the project team enabling a clearer overview of the model and focusing on the tasks that aid in constructing the facility. In order to still take the communication between staff and engineers into account a probability function is needed to increase the project information flows.

Tasks

There are two type of tasks in the conceptual model. The first type is ‘work Volume’ tasks. Tasks require a certain amount of work volume to be completed. The dimension is given in time as it

explains how much time one person, a full-time equivalent (FTE), would need to perform the task. Any additional work will add more time to that task before it is considered complete.
The other type of task is the supervisory task. These tasks do not have a work volume, as the supervisor will have to be active from start to finish. As supervising cannot be given a fixed amount of time needed to complete the task, these tasks are expressed in FTEs. Usually a supervisor is not working full time on one supervisory task as the employee needs to have time available to address issues that arise unexpectedly or help a person or sub team who run behind (interview Deckers, 2011).

In this section the boundaries of the elements of a project that needs to be modeled were discussed. Summarized, the system definition of a conceptual model for this research is as follows:

> The model represents a highly aggregated work process in which the project team, its actions and its tasks during the design, appraisal, construction and control phases of a project are described.
>
> **System definition**

4.3 Building blocks of the conceptual model

In the previous section the system definition of the conceptual model was discussed. The choices that form the scope have been elaborated providing the boundaries of what is part of the conceptual model. The context in which the model is built and the content that is incorporated in the model have been made clear. In this section the elements that are within those boundaries, the building blocks of the conceptual model, are described.

Organizational structure

Projects are often structured in such a way that there are three different organizations at work: project owner who initiated the project, a main contractor with engineers that can take the lead on the construction site, and subcontractors that execute the project, as is shown in figure 17.

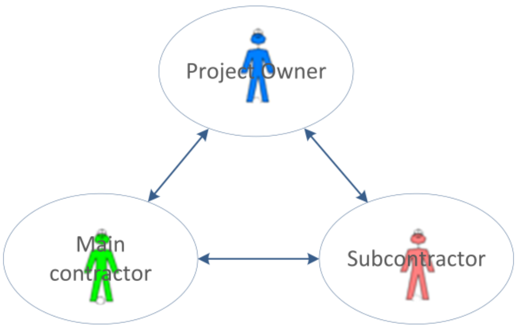


Figure 17 – General organizational roles of projects

Project Owner 

The role of 'project owner' consists of different people that usually work full time on this project on behalf of the PBO that initiated the project. Typical functions that are present in this position are the project manager, project controls manager and independent external experts that oversee engineering elements such as process engineering and mechanical engineering (interview Linssen, 2011). The positions mostly consist of supervisory tasks in the model, as they control the overall progress of the project and guide other positions where necessary. The project owner is required to be present at a lot of meetings with at least one of its people to be updated on the progress of each element in the project to control the interfaces between the elements.

Main Contractor 

In the model, the main contractor engineers the detailed plan and is the leader on the construction site. The main contractor is, therefore, split up into engineering positions and coordinator positions. In all positions more than one person can be involved. In terms of meetings a coordinator is required to attend all meetings on the construction site, while the '*main contractor team leader*' is mainly in meetings with the client team.

Subcontractors 

Different subcontractors that have won the procurement and are now executing their contracts. While not all subcontractors have a major influence on the main tasks (i.e. scaffolding), they were viewed as fundamental to be present in the model during the research (interviews: Triesch, 2011; Linssen, 2011; Sartorius, 2011). Not implementing these positions would directly result in doubt of the reliability of the model. While some subcontractors are not mandatory for the goal of this research, acceptance and a model recognizable to the end user are of major importance: the project owner will place higher value on the product (interview Triesch, 2011).

Meetings

Meetings play an important role in projects as people use them to communication problems and come to decisions (Jin et al, 1995a & 1995b; Kunz et al, 1998a & 1998b; Christensen et al, 1999). Information is shared about the progress of each task, problems that have taken place or interface issues.

As is shown in figure 18, the meetings have been placed in such a way that from top to bottom the meetings represent the level of communication that takes place, meaning that in the top meeting the project owner and the main contractor team leader meet, while at the bottom meetings the construction site coordinator meets with the individual subcontractors.

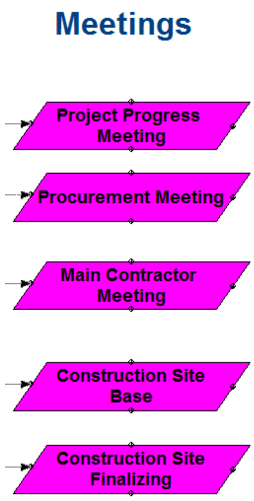


Figure 18 – Meetings in the model

Design (Engineering) phase

The conceptual model begins right after a feasibility study has been approved and the main contractor starts designing the detailed plan. Using the data retrieved from interviews (with employees of DSM and ePM), a waterfall-like structure has been constructed for the engineering phase. Some tasks cannot start before others have reached a certain stage. For example for a chemical plant the process engineers need to have their plans worked out entirely before the piping engineers can start designing as they need to know where specific pipes need to be placed, while the equipment engineers can start a lot sooner as their equipment only need rough estimates from the process engineers. Figure 19 below shows how this phase can be generally structured.

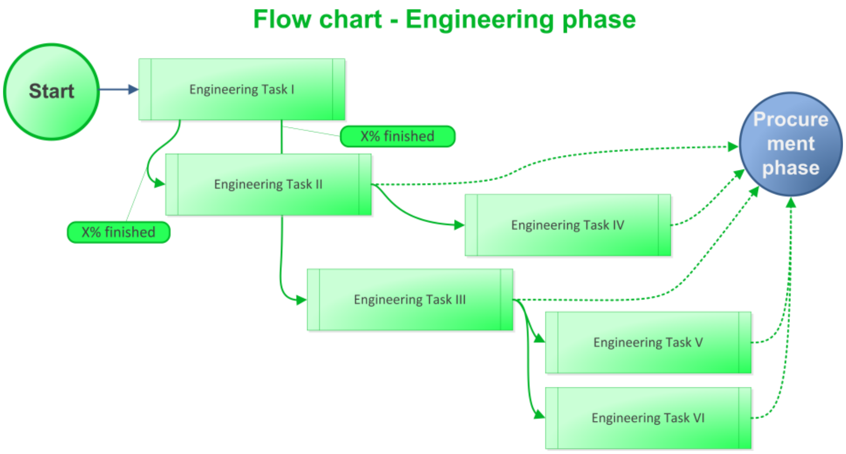


Figure 19 – General representation of engineering phase

Procurement phase

In the previous sections the choice for the design, appraisal, construction and control phases has been elaborated upon. Procurement, a binding element between design and construction, has been reduced to a singular task as has been discussed in the previous section. The process of procurement is very dynamic in time and content: setting up the requirements, receiving and judging the bids from the market, making a contract with the subcontractor. The phase is included in the model, as it has a direct influence on the project's promise of time and without it a structural element of the project would be missed, see figure 20. The task should not be seen as all the individual steps of a real procurement process, but merely as the task of a procurement manager supervising the whole process and reporting back to the client team when attending meetings.

Figure 20 – Procurement phase in the model

Execution (Construction) phase

The model assumes that as soon as the contracts have been signed, construction can start. Similar to the engineering phase, each task has requirements before it can start resulting in a waterfall-like structure, see figure 21. To use the same example of a chemical plant, the installation of electronics and instruments can only start when pipes are in place, while equipment can only be installed if enough of the civil structure has been completed.

The first subcontractor that can start working on the construction site is often a civil contractor. As all the other subcontractors cannot do any work until parts of the foundation have been completed, the time at which the civil subcontractor starts working is crucial for the timespan of the project. As construction can only start when the detailed plan is ready and a contract has been signed, the modeling of the engineering phase is crucial for the rest of the project.

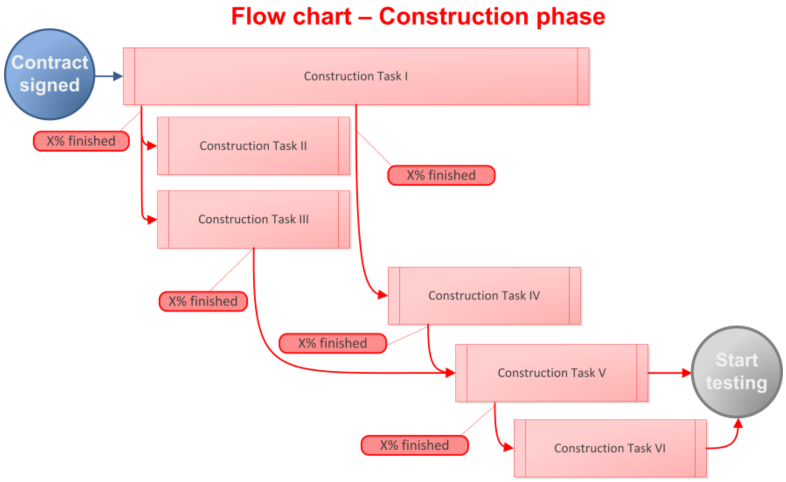


Figure 21 - General representation of Construction phase

The end of the construction phase is also the end of the simulation. In real projects a lengthy testing phase and a start-up phase still have to be performed before production can begin. While it is possible to add those phases to the model, it would make the model more complex and lengthy and does not add integrity to an research. Given the resources of this research, it has been decided to exclude those parts as the goal is to learn about organizational complexities. The model in its current form is capable of doing that and modeling more than that consumes resources that are needed elsewhere in the research. With the mechanical completion, the conceptual model sees the construction management phase, and with that the project, as finished.

Supervisory tasks

Large engineering projects are mainly about managing the interfaces (Miller & Lessard, 2000). A lot of tasks have interdependences with other tasks. To ensure a smooth project, managing those interdependencies is crucial. The conceptual model contains three main supervisory tasks as can be viewed in figure 22: the 'Guidance & Control' task is executed by the project owner, who supervises during the entire project length. The other supervisory tasks are done by the main contractor during the engineering and the construction phases. As the engineering and construction phases overlap, due to the need of design changes during construction, the supervising tasks run in parallel.

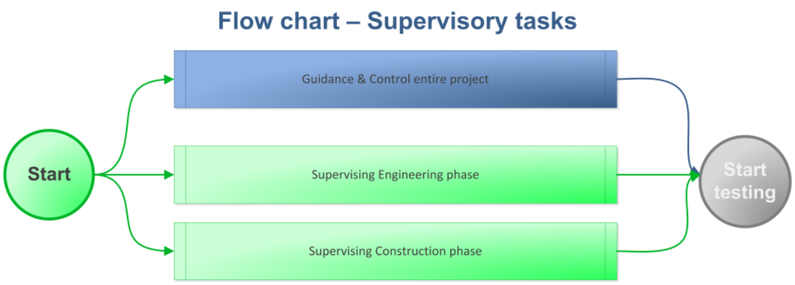


Figure 22 – The three supervisory tasks in the model

In the paragraphs above the building blocks that a conceptual model should entail have been discussed. Using these building blocks is the first step towards complying with the requirements as provided in section 4.1. The building blocks enable a simulation technique to represent actual projects. In the next section the output of a conceptual model for this research is discussed.

4.4 Output of the conceptual model

In the section 4.1 the seven requirements (R1-R7) of a conceptual model have been discussed, and with the building blocks from section 4.3, several of those requirements are fulfilled. The conceptual model can represent different projects (R6) due to the high aggregation level. By separating the project roles of organizations, the model can represent a multitude of organizations involved in the project (R4). Lastly, the conceptual model allows the modeling of work processes of PBOs (R5), because it is focused on modeling formal tasks that embed organizational complexities. To ensure that project performances are produced as output (R7) and that knowledge on work processes can be obtained (R3), the way the conceptual model utilizes the buildings blocks is elaborated upon in this section.

Simulation modeling is used in this research to represent work processes of actual projects. To enable validation of the representation, the simulation model needs to produce outputs that can be related to actual project performances. As the tasks are defined by the amount of time it takes to complete, the total time of project execution (of the phases within the scope of the simulation) is calculated and communicated at the end of a simulation. Together with an overview of the costs (fixed costs plus variable costs defined by cost per time unit times required time) two main performance indicators are summarized for the end user to relate back to.

While these project performance indicators are important to know, little knowledge can be gained from these numbers alone. Understanding the behavior and patterns that lead to the summarized data creates the knowledge this research seeks for. The behavior shows the interactions between the tasks and how these tasks influence and enhance the complexity of project execution. The simulation technique therefore requires that data are provided on the behavior of the modeled tasks in respect to the entire project as well as to other tasks. The result of the above sections is shown on the next page in figure 23.

4.5 Answering research question 1.3

In the previous sections answers to research question 1.3 have been formulated per section. Research question 1.3 is: What does a conceptual model that models organizational complexities in project teams of project-based organizations look like?

The requirements, scope and building blocks of the conceptual model have been discussed. With this information it is possible to use a simulation technique that is suitable for the task to model work processes of PBOs. The simulation technique needs to provide data on how individual tasks, positions and performance indicators progress as the project is being executed, therefore in the next chapter the applied simulation technique is discussed.

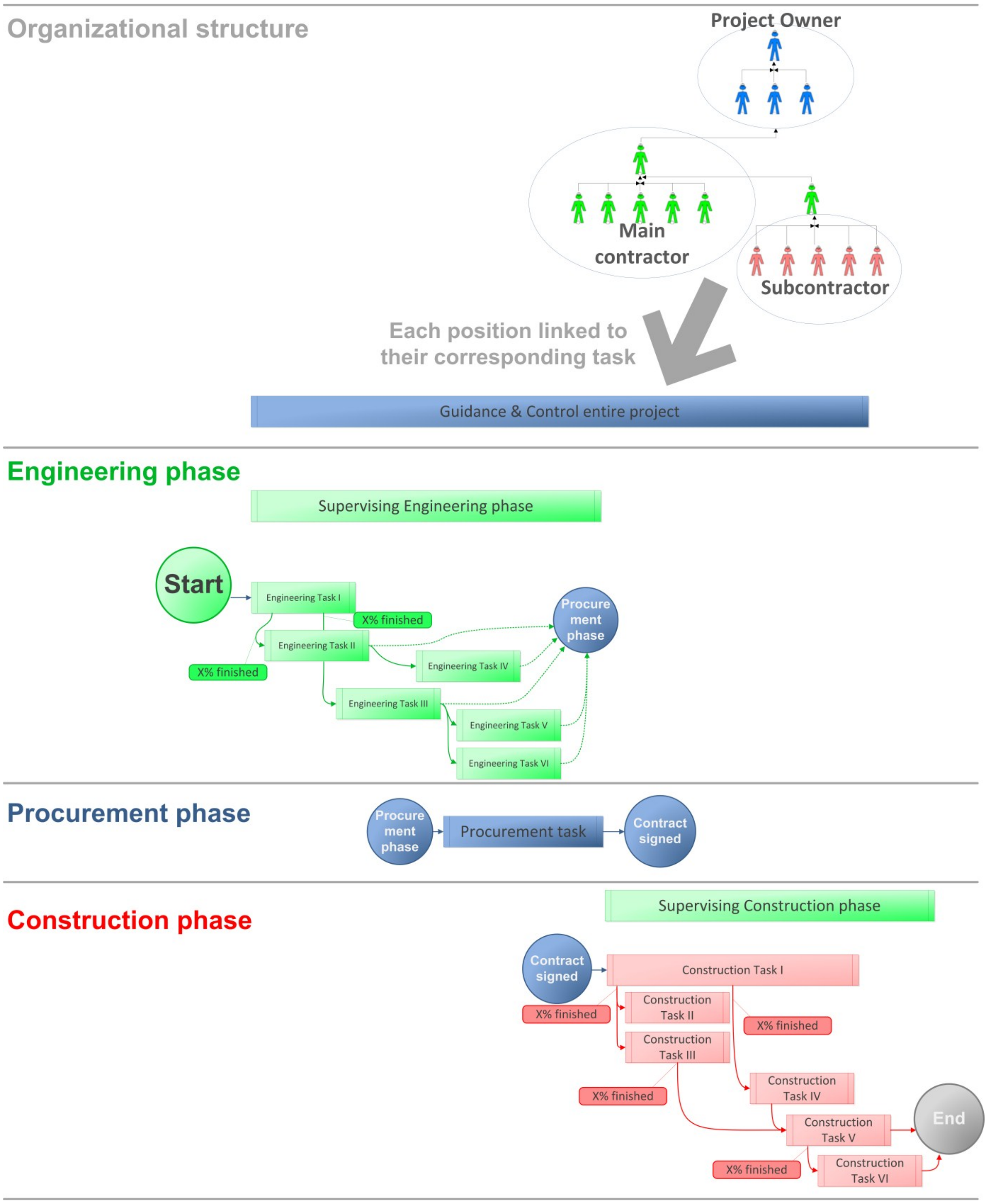


Figure 23 - Conceptual model representing high level work processes of PBOs in EPC phase

5. Applying a simulation technique

In the previous chapter a recipe for a conceptual model has been derived which can provide the means to learn more about organizational complexities embedded in work processes. In this chapter such a conceptual model is designed using a simulation technique that is suitable for the task. In the first section the proposed simulation technique is explained, after which the reasons why an appropriate tool are discussed in section 5.2. Verification techniques are used to verify the basics of SimVision in section 5.3. Finally the actual conceptual model is given in section 5.4.

5.1 What is SimVision?

This thesis uses SimVision, a project modeling and simulation technology. ePM is a consulting company that specializes in organizational simulation. SimVision is an integral part of its consulting practice and is also licensed to corporate and government clients.

While SimVision is the product of more than twenty-five years of Stanford University research and development (e.g., Jin et al, 1995a & 1995b; Kunz et al, 1998a & 1998b; Christensen et al, 1999), ePM has integrated the software into its own consulting practice. The software utilizes the concept of contingency theory, by focusing on the information exchange between individuals. Galbraith (1973) argued that the more uncertain the task is, the more information has to be processed, shaping the control structure of a project team. Furthermore Thompson (1967) argues that environmental contingencies directly shape the organizational structure. Due to the high levels of reciprocal interdependence between many project tasks, project team members are dependent on information updates from other members (Thompson 1967; Gann and Salter 2000; Jin and Levitt 1996).
With contingency theory in mind, SimVision was designed to assess organizational structures of projects, by designing a project team structure that is fit for purpose for each unique project. Thus allows clients to fix design flaws of the organizational structure and improve the reliability and performance throughout the execution phase. By laying the emphasis on the organization and adjusting the structure where necessary the client’s return on capital employed can be further improved.

SimVision is an appropriate tool for this research because of its focus on the organizational structure. Highly aggregated work processes of organizations can contain the preferred structure of project teams. Using software that can model, and therefore, test the organizational structure means the research can test (part of) the work process.

5.2 Why is SimVision appropriate?

As described in chapter 4 the conceptual model models work processes designed to structure the design, execution and control phases of projects. This research does not focus on the alignment of the tasks within these phases, but on the organizational structure of the project, bringing the scope further down to organizational aspects of the work processes. As was discussed in section 1.1, these aspects influence the likelihood of organizational complexities occurring during the various project phases. Finding relations between the aspect and complexities occurring will aid in improving project performance. To achieve this, it is required that the simulation model is able to map the organizational structure and to show the behavior of the interrelated actions (R7). As section 5.1 explained, SimVision focuses on the organization while calculating the project performance in terms of cost, time and quality. Furthermore, SimVision allows the modeler to choose for himself which level of detail, generality, formalization and quality to use to model work processes (R1). To ensure that SimVision complies with all the given requirements for a simulation technique, the requirements are dealt with one by one in Table 1.

Table 1 - Comparing SimVision with requirements of a simulation technique

Requirement	How SimVision complies
Models the four dimensions of work processes	Level of detail: can go in-depth per individual or model whole organizations as one entity Level of generality: models can be used for all sectors, independently of the type of product or process that is perceived by the project Level of formalization: through both graphical and raw data SimVision gives feedback to the modeler Quality: using validation and testing techniques the quality of the model can be determined and improved where necessary
Produces acceptable results	Both the model and the results are presented visually, thus end users can interpret the results without the modeler's aid
Provides knowledge	Provides data on how task, position and project as a whole progress. Allows for detailed analyses to determine improvements
Models different organizational structures	SimVision allows the modeler to structure organizations without constraints. Be it a singular organization with three individuals, or ten organizations with 50 people per organization
Models work processes of PBOs	By combining positions with their primary tasks, SimVision provides a swift insight into a visual check whether the work process is modeled correctly
Conceptual model usable by others	Models can be used for all sectors, independently of the type of product or process of any particular project
Output is given as project performances	SimVision produces end of simulation project performance based on simulated costs and timespan compared to the planned values, as well as how these indicators progresses throughout the simulation, allowing the modeler to understand the behavior from start to finish

SimVision is a fitting simulation technique to solve the formulated problem, as it satisfies the seven requirements stated in section 4.1. SimVision can thus be used to learn which actions within work processes could contribute to organizational complexities

Proposed simulation technique

Following the simulation modeling process of section 2.4 the simulation technique needs to be tested to determine if it is credible enough to be used as a modeling technique. Part of the credibility has already been tested by passing the requirements, as can be seen in Table 1. SimVision complies with all the requirements of a simulation technique and is thus capable of producing a conceptual model for this research. A second test is verifying the mechanisms that SimVision utilizes to simulate projects. For this purpose two verification techniques are used: inference and "predicate transformation".

5.3 Verifying the SimVision simulation technique

Before the model can be used for interpreting causal relations in work processes, the model needs to be assessed first. With each transformation data can be lost, misinterpreted or ignored. To ensure that the simulation model contains what the enclosed system shows, verification of the simulation technique is essential. In the first part the conclusions that flow from premises in the model are compared with the logic that experts in the field would recognize from such a system. Afterwards the input variables are assessed to evaluated to which output variables they are related.

5.3.1 Inference

Inference tries to derive logical conclusions from the premises that are given. Inference can be used to test if the model is built correctly, by changing the premises and expecting a change in the conclusion Birta & Arbez, 2007). If the sequence of A leads to B, which leads to C is reversed, the outcome of this change should be visible in the sequence as well. A logic result is C leads to B, which leads to A. If the result differs, the logic on which the sequence is based is either faulty or more complex than stated in the premises.

Inference was applied on SimVision by testing the logic of the sequence in which tasks were executed. In figure 24 a Gantt chart represents an example of a sequence. The example shows that the sequence starts with engineering the process. At a certain moment in time, when a percentage of the work of process engineering is finished, equipment engineering can start. Further in time, when a percentage of equipment engineering is finished, piping starts and so on.

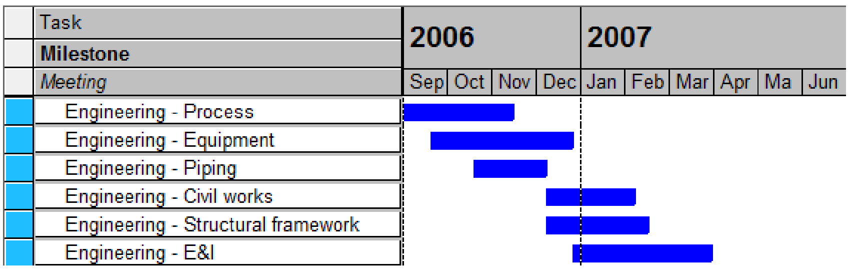


Figure 24 - Gantt chart of sequence of tasks

To test the inference of SimVision, the sequence was changed. Instead of starting with process engineering, the sequence started with equipment engineering, keeping the rest of the sequence intact. The consequence of this changed is shown in figure 25. As the rest of the sequence was left intact, the start of piping, civil works and structural framework are at the same time as the original sequence. E&I engineering starts earlier than in the original sequence, as the task of equipment engineering is completed sooner.

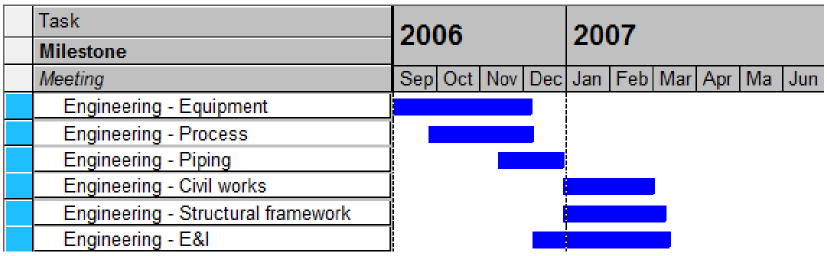


Figure 25 - Gantt chart of the modified sequence

The verification technique of inference enables a modeler to assess whether a simulation technique models predetermined premises correctly and comes to a logical conclusion that can be derived from those premises. As can be seen from the example above, a change in the sequence did correctly affect the way SimVision simulates the sequence. Based on this result, it can be concluded that SimVision simulates a modeled sequence correctly.

Besides the sequence of tasks, SimVision contains numerous constructions in which premises lead to a logic conclusion (e.g., tasks can be made interdependent on one another, positions (representing teams or individuals within the project team) are placed within a hierarchy of information flows, and tasks can be assigned to positions). In the next test, see figure 26, 'Position 1' and 'Position 2' were assigned to execute 'Task 1' and 'Task 2'. While task 1 took five days to complete, task 2 took one day. Figure 27 shows the result when position 1 was assigned to task 1, whereas figure 28 shows the result when position 1 was assigned to task 2. From these figures, it can be concluded that SimVision models the positions with assigned tasks correctly.

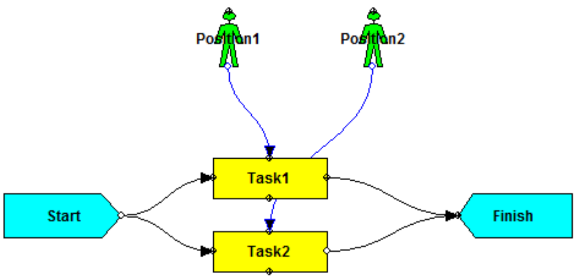


Figure 26 - Positions 1 and 2 assigned to Tasks 1 and 2

	Position Name	Total Volume (days)	Work Volume (days)
1	Position1	5.0	5.0
2	Position2	1.0	1.0

Figure 27 - Position 1 assigned to Task 1

	Position Name	Total Volume (days)	Work Volume (days)
1	Position1	1.0	1.0
2	Position2	5.0	5.0

Figure 28 - Position 1 assigned to Task 2

As SimVision is being used for commercial purposes, the conclusion that the verification technique inference reveals no errors when modifying premises is to be expected. Nonetheless, it is important that verification techniques are applied when choosing an existing simulation technique, as it both allows the modeler to understand the structure of a simulation technique and it aids in making the simulation technique more credible for the formulated problem.

5.3.2 Predicate transformation

'Predicate transformation' is a verification technique which defines the semantics of a simulation technique via mapping the transformation of output variables into all current input variables (Balci, 1994). The thought of this technique is that all input variables have to contribute to at least one output criterion. If it does not, such an input variable is only distracting and should be removed from the model.

The simulation technique SimVision focuses on the length of a project, calculating the variable costs based on the amount of work hours and peoples' salary. Taking the length of a project as the main output variable, four variables contribute to this variable: work, rework, decision wait and coordination. With these four work hour related variables, the list of input variables, see table 2, have been assessed to learn how they could relate to one the four variables.

Table 2 - Input variables of SimVision

Application experience	Matrix Strength	Project error setting	Skill level
Centralization	Noise prob.	Requirement complexity	Solution complexity
Formalization	Primary task	Secondary activity	Team experience
Functional error setting	Priority of task	Size organization	Uncertainty
Information exchange setting			

Applying the predicate transformation technique was done as follows: first the definition of each input variable was sought after which the input variable was set on a low and a high value. The difference in output was then compared to the definition to verify whether the input variable did what it was supposed to do. For example the input variable of centralization is defined as "High project centralization means decisions are made by high-level positions. With low centralization, responsible positions tend to make their own decisions and there is thus less communication required" (SimVision user guide). Given this definition, a link with the 'decision wait' variable was to be expected. However, during simulation runs the value of the input variable centralization also influenced the amount of rework that was simulated. Although stated in the definition that a high centralization influences the time in which decisions are made, the longer waiting time also puts pressure on tasks that are dependent on the task that awaits the decision. The delayed decision can result in a different execution than the high-level position has in mind, requiring rework of the dependent tasks.

The result of the verification technique is shown in figure 29. Three probability variables have been added as a sub section of the rework and coordination variables: functional error probability, project error probability and information exchange probability. The reason for these additional variables is due to multiple input variables influencing these probabilities, which have a base setting set by the likewise named input variables.

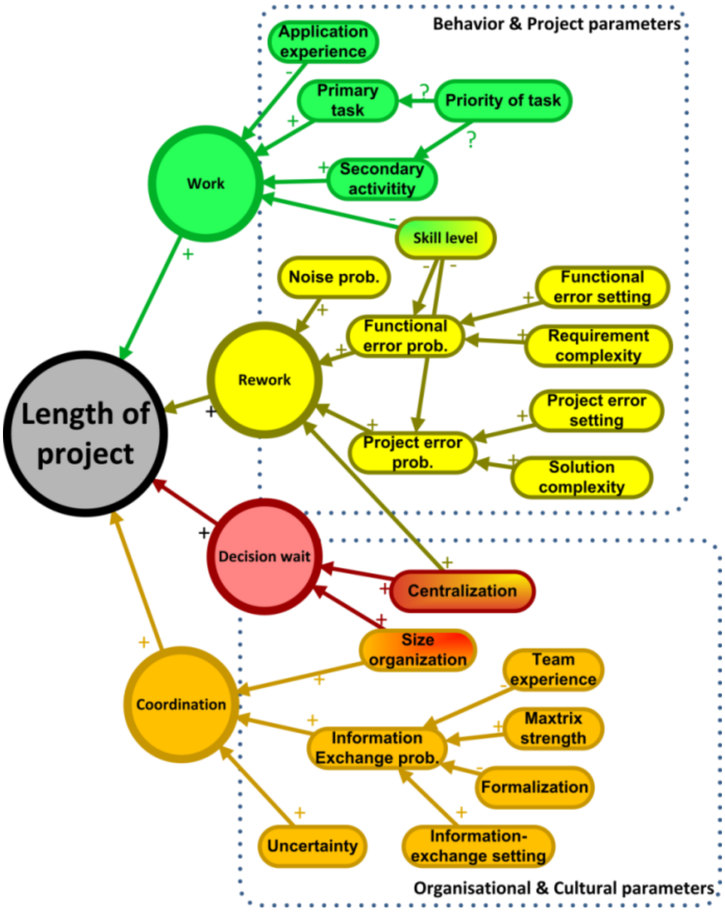


Figure 29 - Graphical representation of the predicative transformation

5.3.3 Conclusion

Using verification techniques such as inference and predicate transformation enables a modeler to test a simulation technique. Using the technique of inference enables a modeler to test the logic of SimVision by simulating sequences and assigned tasks, while the predicate transformation enables a modeler to test whether and how all input variables relate to the length of simulated project. The positive outcomes of these tests strengthen the credibility of the simulation technique and that SimVision is able to model the elements that are within the scope of this research, as was defined in sections 4.2 and 4.3. To determine whether SimVision can produce a model that accurately simulates outcomes, validation techniques are needed which will be discussed in chapter 7.

5.4 Conceptual model in SimVision

The conceptual model that is constructed with SimVision consists of two main parts. To further understand the mechanics that are at work when the simulation is running, the two parts are described separately here.

Upper half of the model

To model the organizational structure of a project, SimVision focuses on how information flows between positions. A positions can refer to individual people or a group of people. The hierarchical representation between positions in SimVision, as is shown in figure 30, is not the flow of power but represents the flow of information. Lower positions go to the position above them when problems occur in their daily work routine and nonstandard decisions need to be made.

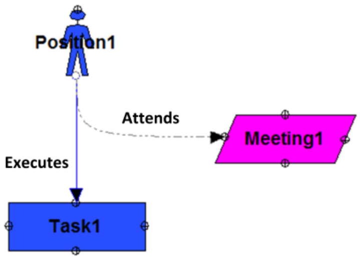


Figure 30 – Positions work on tasks while attending meetings

Information does not only have to flow vertically, but also flows horizontally. The model uses meetings – indicated with dotted links – to represent the horizontal flow of information. Furthermore, positions are linked to their tasks. Each position has at least one task to be performed. These links are what connect the upper half of the model with the lower half.

Lower half of the model

To model the project as a whole, SimVision also needs to know the tasks that have to be performed and the work required to complete it. Tasks are linked through either a successor link, a rework link or a communication link. Successor links are hierarchical links. The next task cannot start until the previous task is (partly) completed, as is shown in figure 31. Rework links work have directions, meaning an event can occur at task 3 that requires task 2 to do additional work. This extra work will require additional hours to complete task 2. The final link is the communication link. The bilateral relation between tasks indicates significant interdependences between the two tasks; e.g., Task 3 and Task 1 have an interdependence as changes to one will directly influence the other.

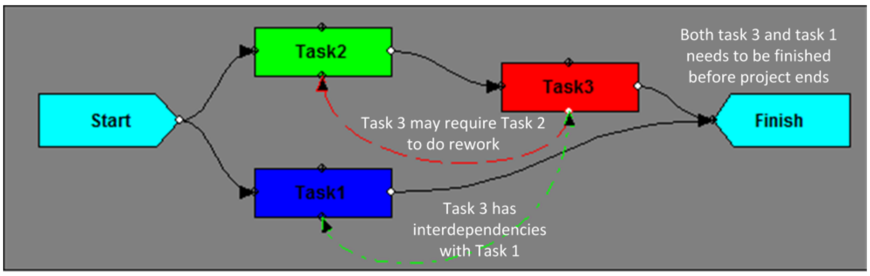


Figure 31 - Lower half with three types of links

Settings behind the scene

To create the insightful results that enables it to learn more on organizational complexities, SimVision requires a range of settings that have quite an extensive influence on the end result. A full list of these settings can be found in Appendix B.1, but the most important and less obvious ones are described here.

Functional Error Probability

Functional error probability is the probability that a task will fail and require rework. Functional errors are errors that are localized to a task and cause rework only in that task by the responsible position. Functional error probability can generate rework even if there are no rework links originating from the task.

Information Exchange Probability

The information exchange probability measures the level of communication in the project between positions that are responsible for tasks linked by communication links. The information exchange probability is set for the project as a whole. The total volume of communication in a project is a combination of the number of communication links you set up between tasks, the duration of the tasks, and the information exchange probability setting.

Noise Probability

Noise is a way to measure the effect of interruptions in the ordinary working day that take time away from doing the project tasks. In any real organization, noise can include distractions like a salesperson calling to sell insurance, a request for help from a peer, a discussion of last night's football game, or work related to another project.

Project Error Probability

Project error probability is the probability that a task will fail and generate rework for all dependent tasks connected to it by rework links. It is important to understand that, unlike functional error probability, project error probability only generates rework in the presence of rework links. The more rework links there are in a project, the more rework is generated by the exceptions that occur. Total project error work volume, therefore, depends on both the project error probability and the number of rework links in the project.

With the knowledge described thus far the conceptual model has been modeled and can be viewed on the page below. The conceptual model is used as a basis for the case study that is explained in chapter 6.

Limitations of a conceptual model

While a goal of this research is to construct a conceptual model that can be used for a wide variety of different cases, such a model has its limitations:

- The conceptual model is constructed with a specific goal in mind: it is designed to model organizational complexities embedded in work processes of project teams. Using the conceptual model for other purposes might result in a less fitting model.

- The conceptual model contains assumptions on how tasks are related to one another. These assumptions might not apply for every project team. It is wise to check up on them before applying the conceptual model.
- The proposal, initiation, finalization and close out stages of a project have been left out. Depending on the sector, these stages can or cannot be left out. In a sector in which the testing and starting up production phases contain a lot of organizational complexities it could be beneficial to add these phases to the model.
- The conceptual model is modeled with a low level of detail to increase the level of generality. A consequence of this choice is that groups are modeled instead of individuals. This simplification does harm the complexity of the project, but increases the modeling and eventually decision speed of the modeling process. This trade-off differs per case.

Modeled organizational complexities

As "project complexity is caused by, amongst others but not limited to, uncertainties and risks" (Bosch-Rekveldt, 2011, p.38), reducing the probability of occurring can improve project performance as was stated in section 1.1. With the chosen modeling technique, variables that can contribute to organizational complexities are identified based on the input variables of SimVision, as is shown in table 3.

Table 3 - Organizational complexities within SimVision

Complexities as defined by Bosch-Rekveldt (2011)	Input variables that contribute to organizational complexity
High project schedule drive	Focus on project length and costs
Resource & Skills availability	Available FTE per position Skills per position
Experience with parties involved	Skills (application experience) Team experience
Interfaces between different disciplines	Information flows between positions Meetings Reporting relationships
Size of the project team	Organizational structure through positions
Trust in project team	Centralization Information exchange probability Team experience
Trust in contractor	Centralization Information exchange probability
Organizational risks	Functional error probability Information exchange probability Noise probability Project error probability

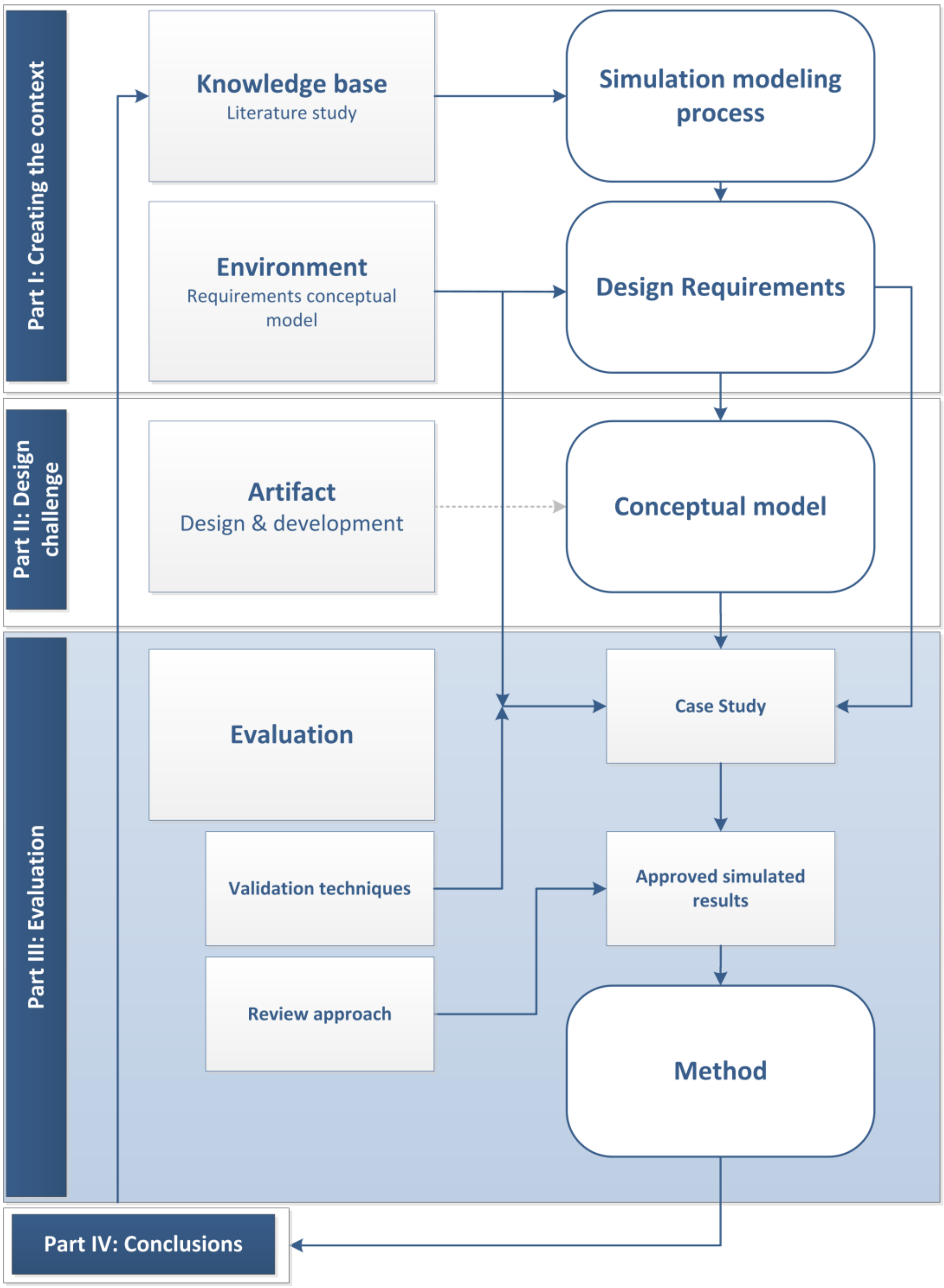
To assess whether a conceptual model has been built correctly, a number of issues need to be addressed. Firstly, a conceptual model requires a fitting simulation technique. The requirements, which were derived in chapters two and three, were used to assess whether the simulation program SimVision is a fitted simulation technique. Secondly, with a positive conclusion drawn in section 5.2, the basics of the chosen simulation technique were tested in section 5.3 using two verification techniques. The positive outcomes of those techniques gave SimVision the credibility to solve the formulated problem of this research. Thirdly, knowing the building blocks derived from section 4.3, a conceptual model within SimVision can be designed. Finally, as the research objective is to learn more on organizational complexities, contributing variables to a selection of organizational complexities have been identified which can be used to achieve the research objective.

5.5 Answering research question 1.4

With the knowledge gained in this chapter, research question 1.4 can be answered: what method is able to evaluate whether a conceptual model has been built correctly? To evaluate whether a conceptual model has been built correctly, the simulation technique is required to be tested on the following aspects:

1. verify if the simulation technique itself is constructed sound, by using different verification techniques on the logic that the technique uses.
2. Verify if the simulation technique complies with the requirements that were set up alongside the formulated problem.
3. Verify if the simulation technique is able to simulate the scope and to incorporate the buildings blocks that have been identified to be essential to find the answer on the formulated problem.

Part III



Part III: Evaluation: Testing conceptual mode with case study

Chapter 6

RQ 1.5 Which implications ensue when applying a conceptual model to real-world work processes?

Chapter 7

RQ 1.6 What method is able to evaluate whether a case-specific model is credible enough?

Chapter 8

RQ 1.7 Which approach needs to be used to get a simulation model of work processes to be accepted by its end users?

6. Specification of a conceptual model

In the first part of the research the knowledge base and the environment of PBOs are explored. These generated the requirements for building a simulation model. In this part the conceptual model is tested via a case study, entering a new stage of the simulation modeling process, see figure 32. Chapter 6 designs a case-specific model, which is validated in chapter 7. Finally, in chapter 8 a workshop is performed to evaluate the whole simulation modeling process.
In this chapter the case study is introduced in section 6.1. Section 6.2 makes the transformation from the conceptual model into the case-specific model, thus answering the sub-question of ‘Which implications ensue when applying a conceptual model to real-world work processes?’

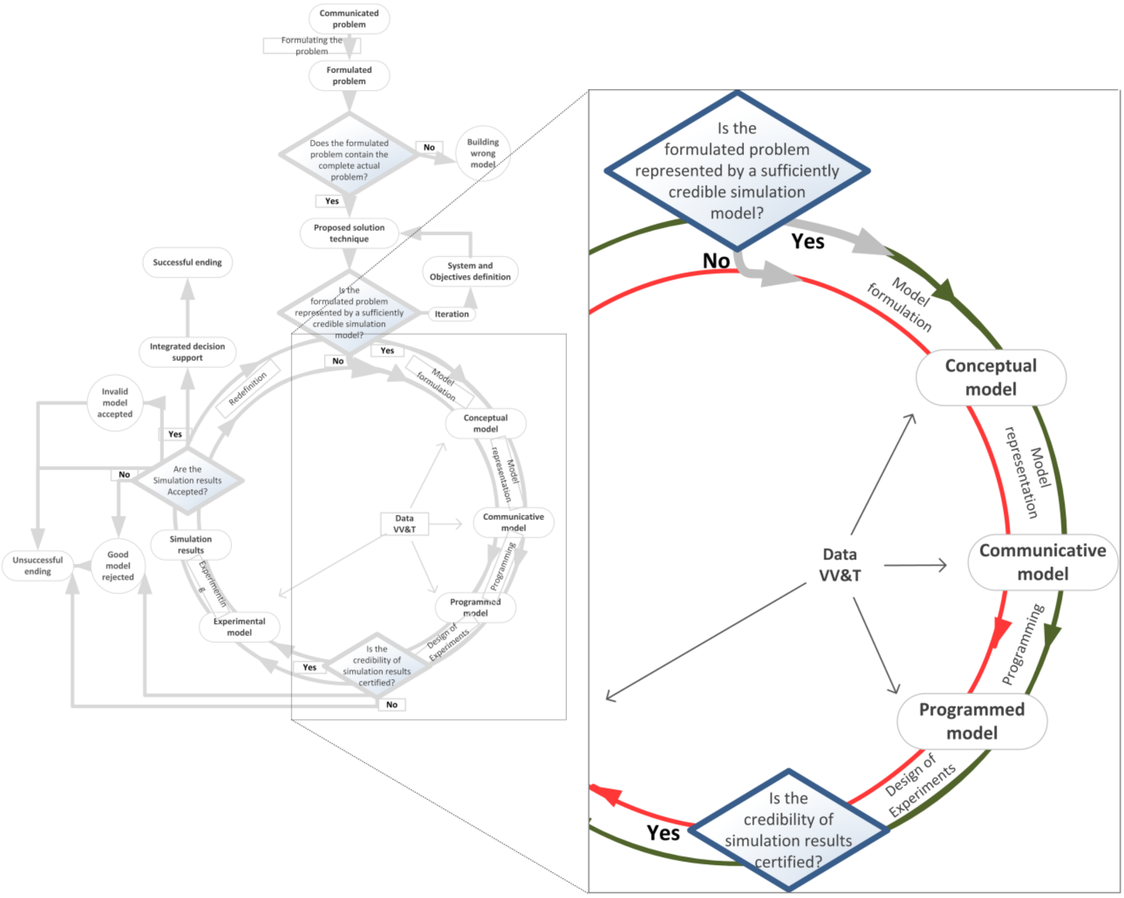


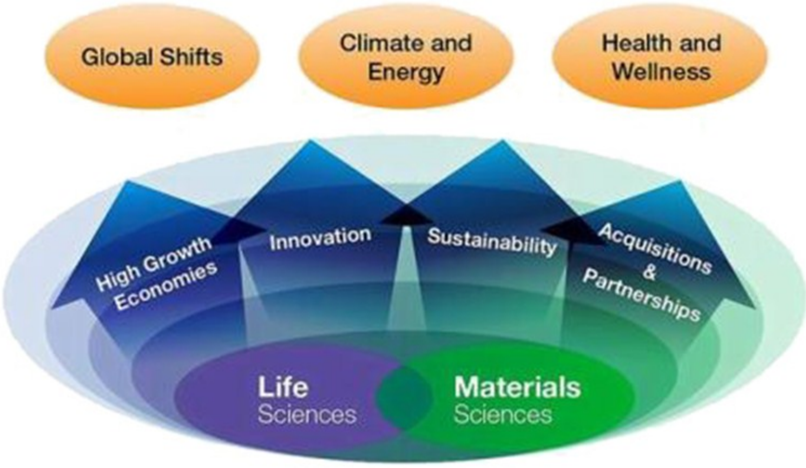
Figure 32 - Relevant section of simulation modeling process for chapters 6 and 7

6.1 Introducing the case study: DSM

To test the conceptual model from chapter 5, a case study is used. The case study enables the research to construct a specific simulation model based on the conceptual design and to relate the output to real possible outcomes. For this research the company DSM has been used as test material.

DSM - the company

DSM originates from the Netherlands, where it was formed by the Dutch government to mine for coal. Since then the company has changed over the decades into a globally operating company in the fields of, but not limited to, health, nutrition, materials and bulk chemicals. Its motto "Bright science, Brighter living" expresses its aim to combine its knowledge in the fields of life and material sciences with their commitment to creating products and solutions that make a positive difference to people's lives.



DSM's activities lie in the area of research and production of products. By bringing the two worlds of Materials science and Life science together DSM is able to come up with products that can be used in the health care, food and nutrition industry. For this research, however, this aspect of DSM is not that relevant because of the focus on project-based organizations. As the above description focuses on production, and not projects, this part of DSM is left aside.

Projects by DSM

In order to create its products, DSM requires a wide range of facilities in which chemical processes can take place. For DSM a small group of personnel is responsible for leading the projects that construct these facilities (interview Deckers, 2011). This group has little knowledge of the technical knowledge that is required to design the projects, but has extensive experience in managing projects. Together this team realizes projects across all the fields in which DSM creates products, whether it is renovating old installations or creating new ones.

When a plan is approved and is considered feasible, a team is gathered to act as the main project team that will manage the project. This so-called client team consists of project, control and procurement managers from DSM and sometimes external experts – depending on the project. As each project requires detailed engineering plans, an engineering firm is always involved as main contractor. Together with the team of DSM, the engineering firm constructs a detailed plan of the installation. With the list of requirements known, procurements can be constructed which will result in contracts with subcontractors. Graphically the structure of the project team looks as shown in figure 33:

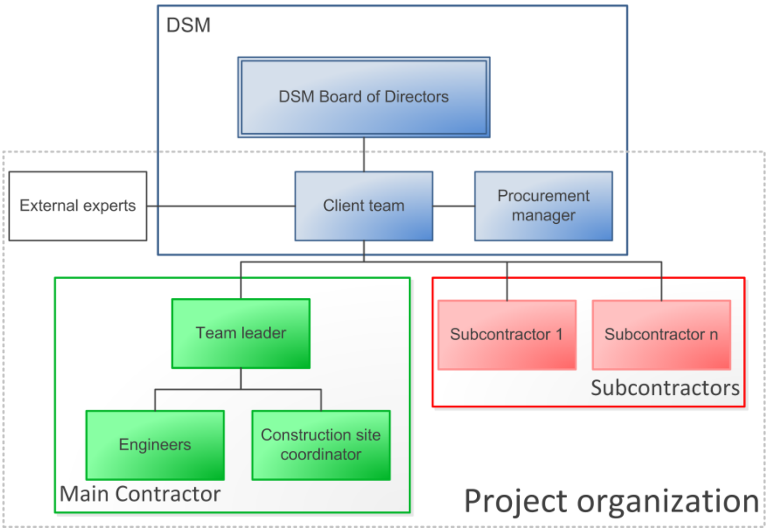


Figure 33 –Visual representation of how high level project teams are structured

Relevance as a case study

As the organogram suggests, DSM utilizes standardized procedures from the start of a project up to the project execution. These procedures are designed with different aggregation levels, ranging from abstract start-finish definitions up to a conceptual work breakdown structure that gives guidance and rules on what to do in situations that could occur. The procedures are a collection of years of experience of past projects and resembles what DSM´s views are on the way projects should be executed. These procedures combined define the work process on project execution of DSM.
The procedures described above are relevant for the research, as they both contain standardized structures on how to organize the project team and prescribe how to deal with events that can occur during the lifetime of a project. DSM's characteristics of projects such as structure of the project team, approach of project management and ways to guide and control their main contractor and subcontractors, will therefore have a lot of similarities.

While projects are unique, DSM structured the way the engineering, procurement and construction (EPC) phase of projects are managed. This structure is the main focus of the test. Structures of project teams do, however, differ depending on the size of the project. To ensure that the scope is on an achievable level, EPC projects with a budget of around 50 million Euro will be considered. This range ensures that the project contains a project team from DSM working together with a main contractor to coordinate and guide subcontractors. By limiting the range of projects it is easier for the interviewees to share their thoughts as they can relate to actual past projects of a similar size.

6.2 Specification of the case study

The scope and focus for the case study have been discussed in the previous section. In this section the different methods of data gathering are described, after which input variables are listed. The final section of this chapter shows the model and the issues that flow from converting a generic conceptual model into a case-specific model. A full list of assumptions, model choices and more about the model can be viewed in appendix A.2.

Data collection

To make a model requires detailed information: information as how a project is executed according to predetermined processes as well as raw data on the amount of man hours needed per task. It was clear from the start that DSM utilizes the concept of work processes extensively. Across all stages of a project, from project initiation to project close out and on different aggregation levels DSM has constructed work breakdown structures and utilizes other practical procedures to guide its employees. Due to confidentiality it was not possible for this research to utilize the official documents of DSM, therefore four different methods were used to gather information:

The first method was auditing. Four different DSM project managers that have multiple years of experience in their field talked in an open interview about past projects. From these audits a first conceptual structure was formed of which many elements have been discussed in chapter 4. An example of such an element that was formed by the initial interviews was that DSM forms a client team in which a mixture of own employees and external advisors are present. The project, control and procurement managers are examples of experts of DSM who are present in the client team.

The second method applied for this research is the use of estimates by modeling experts. Throughout the research ePM aided the construction of the model by giving its opinion on how projects in the chemical sector – and in general – are performed. Both ePM's knowledge of the software as well as of the industry were invaluable in modeling the basics of DSM's project structure.

The third method was using highly aggregated and anonymous data that aided in the construction of the model. DSM was able to provide the research with one project – that was made anonymous – with end project information. Overall costs per division and FTE per week during the construction were supplied. Combining these two sources of data it was possible to re-engineer how many man hours tasks had taken and how much money each task had cost.

The final method that has been applied is filling in unknown data with assumptions. Throughout the modeling process assumptions have been made by the researcher. The whole list of assumptions can be viewed in Appendix A.2.

Input data of the case study

Using the various data collection methods, a model catered to the case of DSM has been designed. In the figures below some input data is given. The amount of FTEs per position in this project, as is shown in figure 35, is determined using data supplied by DSM. The process of the recovering that data can be read in appendix B.3. The program settings, with input variables which are explained in section 5.4, are shown in figure 34. The value of these program settings were set after an interview with project control managers of DSM explaining the effects of each input variable and its range. Figure 36 shows the tasks that were modeled in SimVision, the required work value and their assigned position.

While these settings were set in conversation with the control managers of DSM, the data was also judged by ePM in order to get a better sense whether the estimates of DSM were comparable with other industries. ePM said that the values that were chosen were reasonable, but rather on the low and safe side. It was their judgment that especially the program setting are cautious and it is to be expected to generate quite low rework, coordination and decision wait, which are discussed in the validation phase of chapter 7.

Position	Name	Application Experience	FTE	Salary
1	Client Team	Medium	6	110
2	Main Contractor - Team leader	Medium	1	110
3	Engineer - Equipment	Medium	5	100
4	Engineer - Civil works	Medium	8	100
5	Engineer - Structural	Medium	7	100
6	Engineer - E&I	Medium	5	100
7	Procurement	Medium	2	90
8	Main contractor - Coordinator	Medium	5	85
9	Civil Engineer - Civil works	Medium	55	85
10	Civil Engineer - Structural framework	Medium	70	85
11	Equipment installers	Medium	1	0
12	Infra	Medium	10	85
13	Scaffolding	Medium	15	85
14	Piping	Medium	65	85
15	E&I	Medium	55	85
16	HVaC	Medium	7	85
17	Insulation	Medium	18	85
18	Prefab	Medium	20	85
19	Engineer - Piping	Medium	10	100
20	Engineer - Process	Medium	6	100

Figure 35 - Positions modeled in the case study

Program	Value
Description	
Start Date	01/sep/2006
Trials	50
Seed	0
WBS Separator	.
WBS	
Calendar	Edit...
Team Experience	Medium
Centralization	Medium
Formalization	Medium
Matrix Strength	Medium
Info Exchange Prob.	0.3
Noise Prob.	0.05
Functional Error Prob.	0.05
Project Error Prob.	0.05

Figure 34 - Program settings

Task	Name	Work Type	Work Value	Units	Assignment
1	Installing Insulation	Work Volume	350	Weeks	Insulation
2	Placing Scaffolding	Work Volume	450	Weeks	Scaffolding
3	Piping	Work Volume	1300	Weeks	Piping
4	Making Prefab pipes	Work Volume	350	Weeks	Prefab
5	Placing Equipment	Work Volume	3	Weeks	Equipment
6	Building Infrastructure	Work Volume	300	Weeks	Infra
7	Building Structural framework	Work Volume	1200	Weeks	Civil Engineer -
8	Placing Civil construction	Work Volume	1200	Weeks	Civil Engineer -
9	Procurement	Work Volume	45	Weeks	Procurement
10	Engineering - Structural framework	Work Volume	65	Weeks	Engineer -
11	Engineering - Civil works	Work Volume	65	Weeks	Engineer -
12	Engineering - E&I	Work Volume	65	Weeks	Engineer -
13	Engineering - Piping	Work Volume	65	Weeks	Engineer -
14	Engineering - Equipment	Work Volume	65	Weeks	Engineer -
15	Engineering - Process	Work Volume	60	Weeks	Engineer -
16	Installing HVaC	Work Volume	150	Weeks	HVaC
17	Installing E&I	Work Volume	1200	Weeks	E&I
18	Supervising construction site	Supervisory	2	FTEs	Main contractor -
19	Supervising Main contractor activities	Supervisory	0.6	FTEs	Main Contractor -
20	Guidance & Control	Supervisory	4	FTEs	Client Team

Figure 36 - Tasks modeled in the case study

The model

Using the collected data and characteristics of individual DSM projects, the conceptual model can be made case-specific. In this iterative process, a number of validation techniques are applied which will be discussed in the next chapter. To generalize further, when building a case-specific model based upon a conceptual model three issues need to be addressed, as was found in section 5.4.

1. A conceptual model can be designed as a generic model, but also a conceptual model is built with a specific focus and thus with its limitations. For example, for this research the phases of project initiation and project closing have been left out, while the task of procurement has been

reduced heavily. These choices affect the case-specific model directly. Surely the case-specific model can extend in areas in which the conceptual model did not venture, but this will risk creating a type III modeling error, see section 2.4. This could lead to leaving the formulated problem and adding more features than necessary resulting in a decrease of decision speed.

2. Venturing forth on the above, the conceptual model is based upon a formulated problem. It is built with a specific idea in mind. This means that the case-specific model inherits the formulated problem from the conceptual model. When building conceptual models, it is thus vital to be clear on what the problem is that this conceptual model can answer. Only then you can pick a case for the correct conceptual model.
3. From the conversation with people at DSM (interview: van Gisbergen, 2011), it can be concluded that they erroneously view work and work processes as organization-independent. Further, engineering companies think in terms of work-hours and performance (or productivity) factors. An example is: placing concrete takes seven hours a cubic meter in Holland, but fifteen in Bahrain. The truth is that each measure of productivity is actually a measure of how well the organization fits the work (interview: Triesch, 2011).

Given that the issues are correctly dealt with, the case-specific model has been designed with the input variables from figure 34, figure 35 and figure 36. As the focus lies on finding relationships between organizational complexity that occur in projects, the structure of the case-specific model represents this focus. In the constructed model the emphasis lies on the simulated interaction between the different positions that are present in the design, execution and control phases of DSM's project execution. The case-specific model can be viewed in figure 37 on page 59.

When looking at the input variables of SimVision and their relationship to the organizational complexities as listed in table 3 of section 5.4, two conclusions can be drawn. Firstly, the input variables that can contribute to the identified organizational complexities influence additional work in the form of rework, coordination or decision wait, and do not influence the original estimated work volume. This distinction is only possible when the work volume is separated in original planned volume and additional volume as is done in SimVision. Project planners thus have to be aware that even though the organizational complexities of projects create additional work, they do not necessarily slow down estimated work progress (e.g., the additional work of a task can be caused by an increase in required coordination due to a large organization or a high information exchange).
A second conclusion is that organizational complexities can complement each other as characteristics were identified to be related to multiple organizational complexities. This can influence project execution both negatively and positively, e.g., a project team that exist of organizations with prior experience combined with a high formalization standard will both reduce the required information exchange. This leads to less coordination volume, meaning that less resources and time is spent in additional coordination efforts improving project performance.

6.3 Answering research question 1.5

By applying SimVision onto the conceptual model, it is possible to answer research question 1.5: which implications ensue when applying a conceptual model to real-world work processes? When the step from a conceptual towards a case-specific model is being made, two issues need to be dealt with:

1. The choices and the limitations of a conceptual model are conveyed onto the case-specific model. This means that a modeler should be aware that a formulated problem and an objective definition influences the conceptual model and thus also the programmed model.
2. DSM sees work processes as organization-independent, which causes them to miss or ignore important organizational characteristics within work processes. The conceptual model thereby falsely inherits characteristics from these work processes.

Case-specific model in SimVision

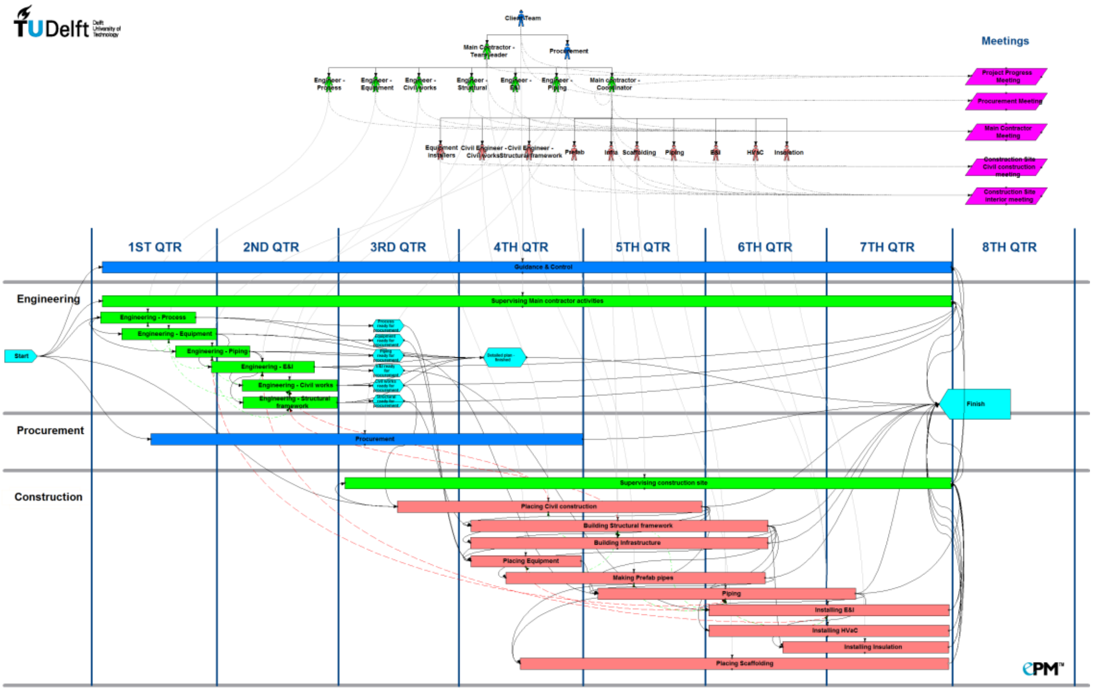


Figure 37 - DSM case-specific model modeled with SimVision

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7. Validating specified model

In the previous chapter the case study for this research has been discussed. To ensure that the model produces correct outcomes for this case, a series of validation techniques are performed. After all techniques have been passed satisfactorily, it can be concluded that the model can sufficiently accomplish its intended goals.

Complete validation of a model is an objective that is often beyond the realm of attainability; the best that can be achieved is ‘failure to invalidate’ (Neelankavil, 1987). For this research several different validation techniques are used. Each technique focuses on a different piece of the model, ranging from the model performing what the problem asks for, up to controlling internal mechanisms and relationships. The goal of passing six validation steps is twofold. Firstly, it makes it possible for the model to be checked on different levels. It ensures that the model is capable of performing what it was intended to do and thereby avoiding type III modeling errors (Banks, 1998). The second reason is that each validation technique shows DSM that the model is projecting the system’s behavior accurately. Applying these validation steps, therefore, increases the chance of acceptance of the conclusions that derive from the model by the end user.

As discussed in chapter 2, Banks (1998) describes four decision moments in which critical evaluations need to be performed to avoid type I, II and III errors. In short, these errors mean that either the model is not accepted even though it is a valid model (type I); the model is accepted even though it should not be (type II); or the model solves the wrong problem (type III).
To ensure that the right decisions are made, each moment is supported by a validation step, see Figure 38. In section 7.1 a type III error is avoided by returning to the formulated problem and checking whether the model is constructed to solve the problem. This is followed by assertion checking, face validation and black-box testing in section 7.2 which give weight to the credibility of the simulation model in solving the problem. Section 7.3 focuses on validating the results by going in-depth into the mechanics of the simulation model with a structural analysis and a sensitivity analysis. The last decision moment, whether the results are accepted or not, will be discussed in chapter 8.

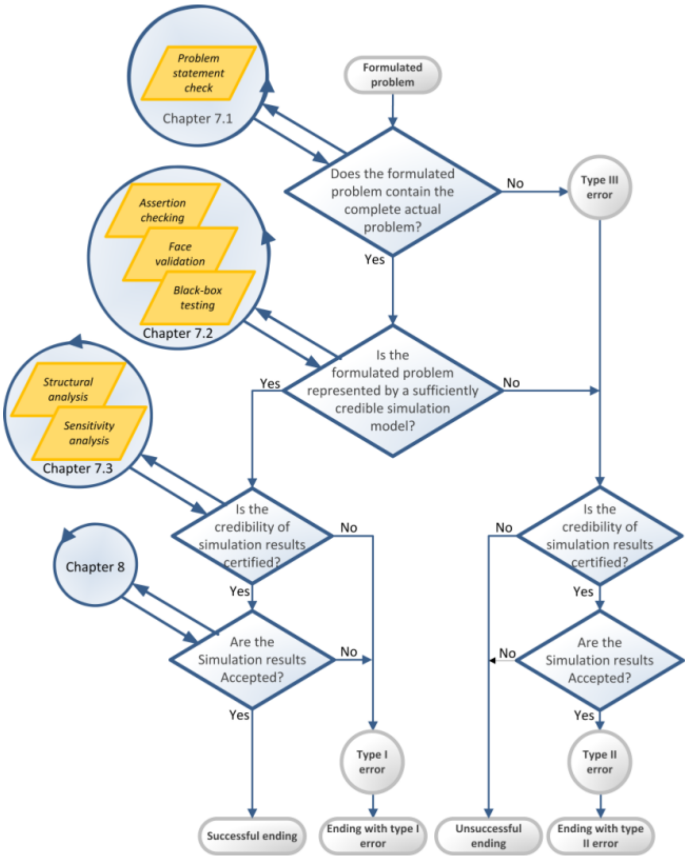


Figure 38 - Process of simulation study as derived from Banks (1998)

7.1 Validating the problem statement

In section 2.4 the simulation modeling process expressed the importance of focusing on the right problem when applying modeling. A model can represent anything from the system, depending on the focus that is used to build the model. It is thus essential to model the right problem. In this section the problem that the model can solve is checked with the original problem statement.

The goal of this research is to use simulation modeling to learn more about organizational complexities influenced by actions within work process of project-based organizations. The case study is used to test this goal by using projects of DSM. The focus in this test is to model the actions and provide insight how they contribute to these complexities.

As was shown in section 5.4, the simulation model is able to model the organizational hierarchy in affiliation with tasks that need to be performed to complete the design and execution of the new facility. The model enables the testing of relationships between actions within the project. As the scope of the model aims at the design and execution phase of project execution, as was discussed in section 4.2, modeling the positions and tasks within these phases is required with the building blocks from section 4.3. The listed requirements that a simulation technique needs to comply with of section 4.1, strengthen the aim to create insight into how strong relations are by modifying characteristics of individual actions of work processes and by showing the result on the model performances. As the simulation model is able to model variables that were identified in section 5.4 which contribute to seven organizational complexities, and the relationship between the variables can be tested, the problem statement can be solved using this simulation model.

7.2 Validating the credibility of the simulation

The next validation step is to ensure that the simulation model is credible enough to represent the formulated problem statement. This is done by applying three techniques: assertion checking, face validation and black-box testing.

To successfully use the case study, the simulation model not only needs to be built correctly, as was checked in chapter 5, but also needs to be the right build, meaning that the formulated problem needs to be reflected by the model and the model thus is made case-specific. To guarantee this fit, multiple audits have been performed with people from DSM. Several specifics of the presented model were the focus of these audits: were the assumptions that the modeler made correct (assertion checking); does the model show a flow of costs, length and work volume that is similar to the system (face validation); and are the sub-components and final outcomes within the expected range (black-box testing)?

7.2.1 Assertion validation

Assertion validation requires experts to judge the assumptions and input variables. The aim of this validation technique is to create realistic values and assumptions. As a model consists of a lot of assumptions, to compensate for lacking information, having validated assumptions increases the quality of the case-specific model.

One of the assumptions that were named and adjusted was the way the design phase was modeled. The assumption was that it follows a similar path to the construction phase, starting with civil works, followed by placing the equipment and placing the pipes and installing the electrics and instruments. The assumption was found to be incorrect and the reason was explained: in order to know how strong the civil works need to be, information about the equipment and the amount of pipes needs to be supplied first. And in order to know what type of equipment is required, the process of the facility is created first.

The use of audits has played an important role in designing the model. Knowledge of the company's work process is invaluable in building a simulation model that represents that same work process. Without the audits assumptions would have been still in place that would lead to a lack of credibility of the model and its outcomes. Thus from a modeling point of view the source of knowledge was essential.

7.2.2 Face validation

A different type of validation is that of checking the flow of the model. The simulation applies the right structure if the steps that the model simulates make sense for the people who work within the modeled system. If they can identify their experience with the way the project progresses in the simulation, then the model applies the correct sequence of events from start to finish. While this type of validation is a very subjective and a naïve approach (Birta & Arbez, 2007), it can provide additional insight into whether the simulation contains the right structure.

To reduce the subjectivity and increase the quality of the face validation, three people at DSM were asked to give feedback on a regular basis throughout the research: two control managers and one project manager. Between the stages of building a conceptual model, programmed model and experimental model each of them have given feedback at least ones per stage. Each iteration step produces less commentary leaving the conclusion that the model approaches system values.

An example was the feedback on the way the costs increase as the project progresses, as is shown in figure 39 below. While the representation of the cost increase was not wrong, it raised questions on how the simulation technique handles costs. If those questions cannot be answered truthfully, the acceptance of the model is hurt. After consulting with ePM it became clear that the reason for the jump in the costs graphic is due to the costs attached to some of the tasks. In contracting it is normal to provide a small fee up front while the rest of the payment is done after the job is completed (interview Linssen, 2011). SimVision shows the progress of the value assets, i.e. when the costs occur and are made and invested in the project. Thus when the installation of the equipment begins, nine million Euros are added to the project cost, explaining the sudden jump. In consultation with ePM, the large costs are typically spread out over time to represent a cost curve that is more in line with the experience and expectation of DSM.

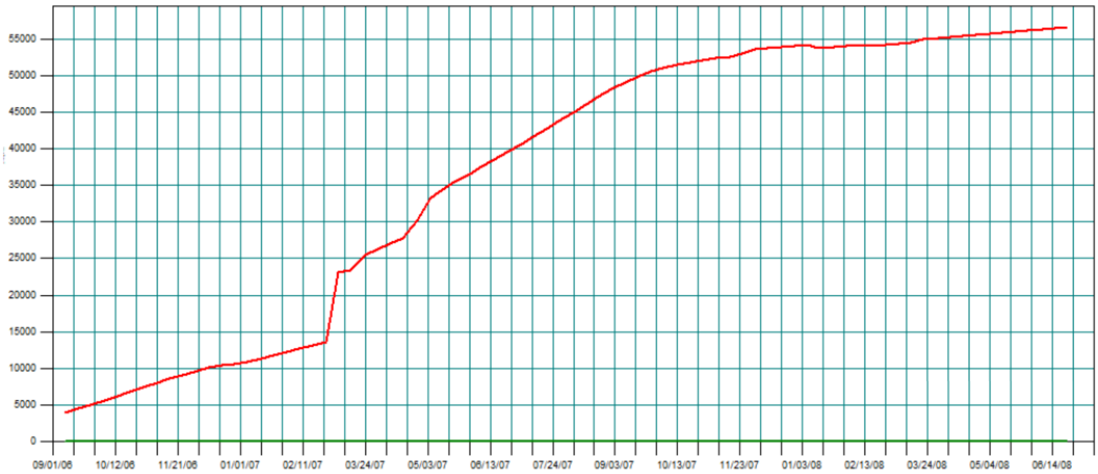


Figure 39 - Cost graph (in k€) from base case with sudden jump in March 2007

7.2.3 Black-Box testing

Black-box testing builds confidence that the model can cope with different sets of input variables and still produce accurate outcomes. As the simulation model represents a work process, being able to apply the model to a range of input variables and thus different projects, a positive conclusion of the black-box test will boost the acceptability of the result.

In this research data on input variables were scarce, and therefore through an audit with one of the control managers a range of input variables was constructed with some margin to enable testing of expected outcomes. These estimates are listed as historic output in table 4. Based on the control managers' years of experience the historic data shown can be used for black-box testing, even though the data does not derive from actual measurements. This is not required, as 1) the model applies on a high aggregation level; and 2) the goal is to match behavior of the data, not simulating an actual specific project.

Table 4 - Difference in model and system output variables

Input variable	Range historic output data	Simulated output data	Dimension
Coordination volume	5.0 – 10	7.57	% of total
Labor costs	20 – 35	24.68	Euros in millions
Non-labor costs	20 – 25	18.76	Euros in millions
Total Costs	40 – 55	47.53	Euros in millions
Total volume	20 – 22	20	Months
Rework volume	1.0 – 3	5.13	% of total
Rework costs	1.0 – 3	3.09	% of total
Wait volume	0.1 – 1	1.46	% of total

As the results in table 4 indicates, the simulation model produces outcomes that are in range or higher than was anticipated by DSM. However, ePM's industrial experience judges the historic output as low. Reasons for this difference is found in the inexperience of the control managers to judge from past projects which pieces of work are rework or are designated as wait volumes. This differentiation is uncommon for them, as they are not used to seek identification of the additional work and costs of a task but estimate the total work of tasks regardless of original and additional levels. This would explain why the ‘rework volume’ and the ‘wait volume’ are high compared to the historic output.

As the control managers of DSM are more accustomed to judge total values of the output, the total costs and total volumes had to be within the expected margin to come to a successful end of this validation technique. The non-labor costs are low compared to historic data, as little data was supplied on the actual costs of equipment, pipes and other materials. It is possible that some of the material costs are placed within the variable costs of labor costs, but this was not checked.

7.3 Validating the simulation results

The final validation step that needs to be performed before presenting the results to DSM is the validation of the way in which the simulation comes to the results. With the above validation techniques the general flow and outcomes of the model have been validated using audits. The final step focuses on the mechanics, by applying a structural sensitivity analysis.

7.3.1 Structural analysis

The simulation model consists of interrelated actions that follow a predetermined sequence. As became clear in section 7.2.1, the sequence in the designing phase underwent changes when false assumptions were identified. Controlling the model’s sequence of actions is thus required. While the simulation model of the case study has been based upon a verified conceptual model, the flows could be different for DSM from what is perceived in general. Therefore, flow diagrams were constructed based on DSM’s procedures to provide guidelines when building the model. Two examples are shown below in figure 41 and figure 40.

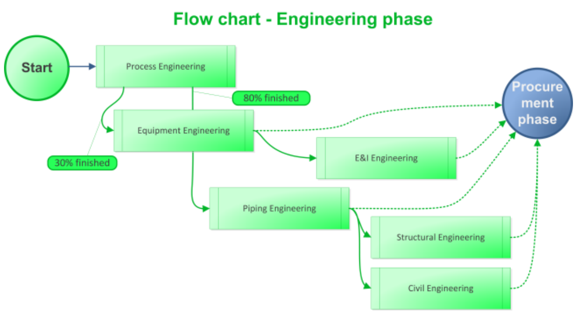


Figure 41 - Start-finish sequence of the engineering

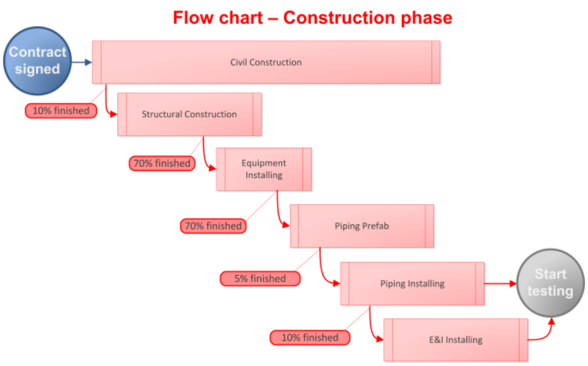


Figure 40 - Start-finish sequence of the construction phase

Using the flow diagrams, a structural analysis was performed on the model by showing the flow diagrams to the aforementioned experts of DSM and receive their feedback and their expectations whether the flow correctly shows the general progress of their project’s design and execution phase. The analysis showed that both the structure of the organization and the actions were placed in the right order and that each position was linked to the correct task. The result of the structural analysis, along with the face validation and black-box testing, gave a robust result. Each successful result strengthens the outcome of each technique individually.

7.3.2 Sensitivity analysis

Before running the sensitivity analysis, it is important to state that due to the use of probability functions each run will produce results within a certain margin. In order to identify this margin, the base scenario as developed in chapter 6 is run ten times with 50 trials each. The variation of the length of the project and the total costs are shown in table 5. The range on costs shows that for the base scenario the costs are on average 47.3 million Euros with a standard deviation of 80,000. Applying the three-sigma rule it means that 95% of the base scenarios are simulated within a range of [47.13 - 47.47] million Euros of total costs, which is a difference of 0.27%.

Table 5 - spread of ten identical simulation runs

Output	Mean	Deviation	Square error
Length of project (in weeks)	78.5	0.0678	0.030171
Total costs of project (in millions of Euros)	47.3	0.0871	0.039655

In this research sensitivity analysis combines behavior validation with white-box testing. Behavior validation tests cause and effect relations (Birta & Ozmizrak, 1996). This means that when the work force is doubled (*cause)*, the time required to finish the same work volume should be roughly halved (*effect*). If the time span does not change accordingly, this is reason to doubt the relationship between work force and work volume. White-box testing is closely related to sensitivity analysis, as it employs data flow and control flow diagrams to assess the accuracy of internal model structure. Both validation procedures aim to examining model elements such as internal logic, internal data representations, sub-model interfaces, and model execution paths.

As this type of validation is closely related to the goal of the research, i.e. modeling organizational complexities which are embedded in the work processes, the list of cause-effect relationships is extensive. To prove that the behavior in the model works as expected, as is shown in the table 6 below.

The data in table 6, and the visual representation of this data in figure 42, shows the cause-effects of the input variables which were identified in the predicate transformation in section 5.3.2. For each input variable the setting was set to a low and a high value individually to see its effect on the total simulation length and project costs in relation to the base case in which settings were set to normal.

The result is that changing one variable will not heavily influence the end result. The two input variables that do stand out: “application experience”, and “skill level”; do so because the skill level and application experience of all employees were adjusted per run. With application experience set to ‘high’, this means that everyone on the project team has performed these exact same actions before, as if the exact project has been done earlier by exactly the same crew. Reducing rework and coordination volume drastically.

Table 6 - Sample of cause-effects and the results of behavior validation

Sensitivity analysis

Input variables	Amount (days)	Variance to base case	Costs (Euros)	Variance to base case
Base case	443		€ 43,660,000	
Application Experience - all High	378	85.3%	€ 29,323,904	67.2%
Application Experience - all Low	535	120.7%	€ 62,446,684	143.0%
Centralization – High	445	100.6%	€ 44,074,089	100.9%
Centralization – Low	439	99.1%	€ 43,035,833	98.6%
Formalization – High	439	99.0%	€ 42,756,121	97.9%
Formalization – Low	451	101.9%	€ 46,043,267	105.5%
Functional Error Prob – High	452	101.9%	€ 45,869,638	105.1%
Functional Error Prob – Low	438	98.8%	€ 42,418,876	97.2%
Information exchange prob - High	446	100.6%	€ 44,360,022	101.6%
Information exchange prob - low	443	99.9%	€ 43,501,301	99.6%
Matrix Strength – High	444	100.1%	€ 43,885,425	100.5%
Matrix Strength – Low	442	99.8%	€ 43,725,339	100.1%
Noise Prob – High	444	100.3%	€ 43,861,937	100.5%
Noise Prob – Low	443	100.0%	€ 43,603,308	99.9%
Project Error Prob – High	451	101.9%	€ 45,225,250	103.6%
Project Error Prob – Low	437	98.7%	€ 42,571,811	97.5%
Requirement complexity – all High	448	101.2%	€ 44,899,363	102.8%
Requirement complexity – all Low	442	99.8%	€ 43,179,057	98.9%
Skill level – all High	378	85.3%	€ 29,552,108	67.7%
Skill level – all Low	534	120.6%	€ 62,149,613	142.3%
Solution complexity – all High	448	101.0%	€ 44,713,345	102.4%
Solution complexity – all Low	441	99.6%	€ 43,581,100	99.8%
Team Experience – High	443	100.0%	€ 43,580,591	99.8%
Team Experience – Low	445	100.4%	€ 44,187,141	101.2%
Uncertainty – all High	445	100.3%	€ 44,025,367	100.8%
Uncertainty – all Low	444	100.2%	€ 43,638,167	99.9%

Figure 42 - Spread of sensitivity analysis on total length and costs of project

The sensitivity analysis shows that no singular input variable exert a large impact on the total costs and length of the simulated project. The two input variables “skill level” and “application experience” do impact the outcomes extensively, but that is to be expected as the settings were applied on all positions simultaneously. In essence, this means that if a project is done a second time, the project length could be reduce with 15% and costs with more than 30%. This is just in theory, as an exact copy of a project is unrealistic due to the technical and environmental variables that affect a project (interview: Deckers, 2011).

The case-specific simulation model has been validated on different levels: its scope via validating the formulated problem, the flow and behavior of the model via face validation, structural analysis and sensitivity analysis, and the sub-components and outcomes via black box testing. The combined set of validation techniques create a confident view that the case-specific model is able to correctly simulated the design and execution phases of DSM’s projects with a budget in the range of 50 million Euros.

7.4 Answering research question 1.6

In this chapter the conceptual model has been made case-specific using the simulation modeling process. With the successful transformation of the model into a case-specific model, research question 1.5 is answered: which methods are able to evaluate whether a case-specific model is credible enough?

It can be concluded that the simulation modeling process is a good process to evaluate a case-specific simulation model based upon a general conceptual model. Using the simulation modeling process, it becomes apparent that the decision moments provide structure to the modeling process. This structure aids the modeler and the end user as such, due to the quality checks with diverse validation techniques in various places of the simulation model.

This research applies six validation techniques which are all able to evaluated a model on its credibility. The shared characteristic of these techniques is that not only do they test a model on a specific aspect, the validation techniques involve the end user of the model. Assertion checking, face validation, structural analysis and black box testing require feedback from experts or the problem owner. The results of the sensitivity analysis were used to seek dominant variables and served as input for the workshop of chapter 8. The interaction of the end user with these validation techniques not only increased the quality of the model, as tacit knowledge was used in using the validation techniques, but it also increased the acceptance of the model by the end user.

8. Acceptance of the results

In the previous part of the research the case-specific model has been validated. The end user has been involved through the use of validation techniques and has approved the model, meaning that the end user agreed that the model represents an industrial EPC project of 50 million Euros.

In this chapter an approach is discussed and applied to get the results of the model accepted. It is important that the model is validated and accepted, but if the results are not accepted, then the model itself produces unusable outcomes. In the first section the goal of the approach is elaborated, followed by a description of the chosen approach in section 8.2. The outcomes of the approach are discussed in section 8.3. In section 8.4 the results of the workshop performed in this research are elaborated.

8.1 The goal

As stated above, besides an accepted model, the results that the model produces also need to be accepted by the end user. Looking at the simulation modeling process, represented in figure 43, the final decision moment occurs after making the experimental model: are the simulated results accepted? To guide this step, a specified goal aids in choosing a correct approach, similar to choosing a simulation technique for a formulated problem.

The research question in section 1.3 was the basis for making the conceptual model, which in itself was the basis for the case-specific model. The simulation model of the DSM's case is thus constructed to enable the learning on organizational complexities.

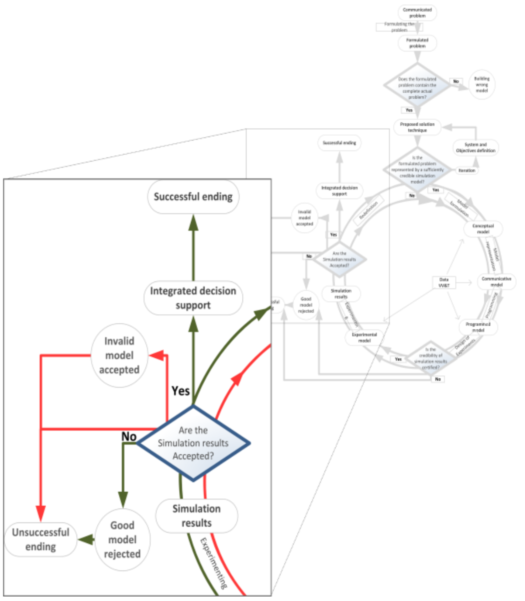


Figure 43 - Last part of Simulation modeling process

> The results are accepted for this research when the end user acknowledges the identified variables within the simulation model are influencing organizational complexities.
>
> **Successful acceptance of results**

To come to a successful result of the modeling process, an approach that provides structure is required. For this research the preferred approach was the use of a workshop. The reason for choosing the use of workshops is threefold:

1) Workshops promote active discussion, involving the participants.
2) Workshops lead to cooperation and consensus.
3) Workshops have a flexible structure, giving room for modifications where needed.

8.2 Structure of the workshop

The workshop in this research was structured around the availability of the participants and the content it had to include. Therefore, these two characteristics are briefly described.

Participants: The participants for the workshops were the same DSM people that were interviewed in the first round of data collection of this research. This means that these people knew of the research and its goals, but were not involved in validating the model, which was done with a different group of people. The participants all had experience as project manager or are still active in that function. They saw the model for the first time and their answers are therefore their own view on organizational complexities in the design and execution phase of DSM projects.

Content: Due to the time constraints that the DSM participants were under, the workshop was reduced to a one-hour session. This led to a shorter version of what was initially planned. The original concept included some design questions within the model, but these were scrapped, as the essence of the workshop was to get the modeled results accepted. What remained was a workshop that contained three scenarios based on the validated simulation model. Each scenario focused on different variables that influence organizational complexities, which were identified in section 5.4, that occur during project execution - see Appendix C.1 for more information on the scenarios. Per scenario the setting was introduced by a story and followed up with three questions:

- What is the expected behavior of the scenario?
- What would be the root of the problem?
- How can the project best be adjusted to counter the problem?

The three questions served as openers of the workshop. The participants were free to share their thoughts on how the scenarios influenced the project team and performance. While some clarifying questions were raised during the workshop, the participants were mostly talking.
After all the scenarios had been dealt with, a discussion on the comparison between the answers given and the modeled reasons started. As the constructed scenarios focused on variables that contribute to organizational complexities, and the goal of the workshop is to get these variables acknowledged and to make DSM aware that work processes are not organization independent. To get the simulated results accepted, it is the researcher's belief that participants need to be able to relate their personal thoughts and experience with the simulated scenarios.

8.3 Workshop results

With the structure and characteristics of the workshop known and constructed, the workshops were executed with three participants from DSM. From the DSM workshops the following observations can be drawn:

- Participants were able to relate to the scenarios with their own experience. While not all of the scenarios had not occurred to each of the participants personally, they were able to identify the behavior that was modeled in each scenario and foresee its effect on project performance.
- The participants could identify causes when these related to productivity and work hours, but had trouble identifying whether the given organization structure fitted the analyzed project. This confirms what is experienced by ePM: a strong focus on man-hours and performance factors, often at the expense of finding the causes behind the performances such as organizational and cultural parameters (interview Triesch, 2011).
- Participants see work processes as organization independent. Focusing on work-hours and performance factors, one could argue that a detailed work process can be optimized to fit a range of projects. However, as became clear in section 6.2, each project contains characteristics that always require modifications to generalized work processes to keep productivity on par.
- Following the previous conclusions, project team characteristics had not been subject of discussion by DSM before when evaluating the project's work process. These characteristics were seen as given if identified at all.
- From the conversation with project managers of DSM, it became apparent that their work process mainly entails information on how actions need to be performed, who is responsible and what the normal work volume of that action is. The work process does not entail a lot of details on the structure of a project team or how the team should be managed, given experienced project managers the freedom to fit the project team for purpose.

8.4 Conclusions of evaluation part

With the workshops completed, the end has come to the evaluation part of this thesis. In this part the conceptual model of project teams, which was designed in chapter 5, has been made case-specific by applying the characteristics of project teams of DSM. In this process a few issues were identified in chapter 6 which affect the transition from a conceptual model towards a case-specific model: choices and limitations are conveyed from one to another, DSM views work processes as organization-independent which causes them to miss or ignore important organizational characteristics.

With the data gathered through audits, the case-specific model was constructed and was validated via various validation techniques in chapter 7. While a complete validated model is beyond the realm of attainability, the failure to invalidate after all techniques were applied gave credibility to the model. As the goal of using simulation modeling was to build a correct model, but also get the model accepted, the validation techniques used had to involve the end user as well.

The final step in this part was the use of workshops to get the results of the simulation model accepted. The workshop had as goal to facilitate learning and the creation of insight on how project team characteristics are organization dependent and can exert influence on project performance, stressing the importance of front end development when the project teams are formulated.

DSM was able to learn a number of things from the results of this research:

1) Simulation modeling can be used to evaluate project team performance, before the project has started. In the initial rounds of audits with people of DSM, quite some skepticism was present how simulation modeling, a deterministic tool, could be utilized as a learning tool. This research shows that such a modeling tool can be used for learning purposes.
2) The simulation results show that project team characteristics influence project performance. This focus, from a modeling point of view, on the impacts of a project team on project performance, and not a focus on tasks, was new to DSM (interview Van Gisbergen, 2011).
3) Project team characteristics complement each other, as can be read in the scenarios in appendix C.1. Aligning these characteristics results lead to improvements of project team performance.

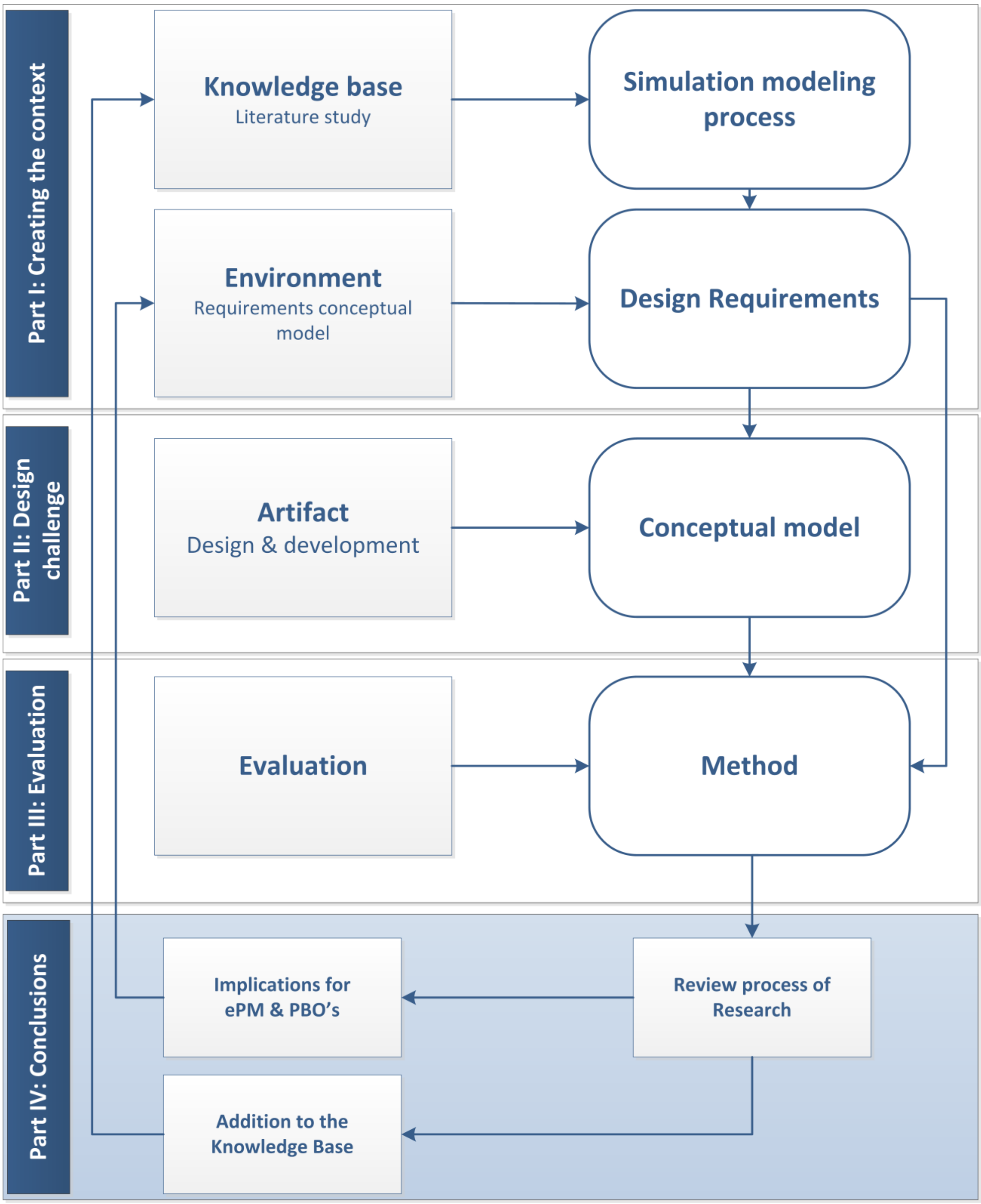
8.5 Answering research question 1.7

The simulation modeling process has been successfully ended by applying a workshop with participants from DSM. From this experience, research question 1.7 is answered: which approach needs to be used to get a simulation model of work processes to be accepted by its end users?
The importance of getting the simulated results accepted is stressed in this chapter. To get the simulated results accepted, an approach can be used to structure the final phase of the simulation modeling process. The approach chosen is able to achieve a predetermined successful acceptance of results, and promotes action afterwards. The following issues need to be considered when choosing an approach:

- Goal – To support a design decision or to learn about a specific element?
- Knowledge – How does the end user see project teams and productivity?
- Time constraint – How much time does the end user have?
- Level of interaction – How much interaction is needed for achieving acceptance?

Based on the above issues, an appropriate approach can be chosen. For this research, a workshop was constructed. The goal was to create additional insights into the variables that influence organizational complexities, which created a high level of interaction in a short time period. Using different scenarios, the participants were able to learn how the identified variables can be chosen to positively influence complexities, by reducing the likelihood of occurring.

PART IV



Part IV: Conclusion: Contribution to knowledge base and environment

Chapter 9

RQ 1.8 What are the contributions of this thesis, and what are the implications for the environment?

9. Implications of the results

The previous part of the research tested the conceptual simulation model on a specific case. With the test an evaluation of the conceptual model has been made from which conclusions can be drawn. In this part of the research the lessons that are learned are summarized and divided up into lessons for the knowledge base and for the environment. In section 9.1 the addition of this research to the knowledge base is summarized, while the implications for ePM and PBOs in general are given in section 9.2. Sections 9.1 and 9.2 together are the answer to the research question 1.8: what are the contributions of this thesis, and what are the implications for the environment?

9.1 Addition to the knowledge base

Project-based organizations (PBOs) structure the projects they execute based upon past experiences. The procedures within which these are structured are named work processes. The relevant definition is: "A work process is a collection of interrelated actions in response to an event that achieves a specific result" (Sharp & McDermott, 2001). Within these work processes PBOs' organizational structures are stated. Each organization has its own way of giving the project team structure in which choices on organizational characteristics are made. The choices on characteristics affect the likelihood of uncertainties and risks (e.g., using inexperienced people will lead to higher risk of mistakes; hiring the same firm a second time increases team strength as the organization is known reducing the chance for miscommunication). As "project complexity is caused by, amongst others but not limited to, uncertainties and risks" (Bosch-Rekveldt, 2011, p. 38), the characteristics of a project team influence the likelihood of complexities occurring. This research has identified eight organizational complexities, see table 7, that are influenced by characteristics of project teams which were within the scope of this research on modeling the work processes of PBOs.

Table 7 - Identified organizational complexities embedded in work processes

From TOE framework, Bosch-Rekveldt 2011
High project schedule drive
Resource & Skills availability
Experience with parties involved
Interfaces between different disciplines
Size of the project team
Trust in project team
Trust in contractor
Organizational risks

In section 6.2 the observation was made that the PBO of the case study, DSM, sees work processes as organization-independent, while literature and this research show that the organizational structure of a project team is dependent on characteristics of the organization. As organizational complexities are related to the work process through project team characteristics, making it clear that work processes are organization-dependent is a first step towards dealing with these organizational complexities.

Simulation modeling in evaluation cycle

Making the organizational characteristics that influence the likelihood of complexities occurring within work processes explicit, creates awareness of these complexities. This awareness supports decision making when work processes are evaluated and when suggested modifications are addressed. Understanding the relationship between these characteristics, operationalizes the assessment of the related complexities. A technique of making causal relations explicit is simulation modeling. By modeling the actions of work processes, simulation modeling can quantify the effect of the modeled characteristics on project performance. Thereby, simulation modeling supports decision making during evaluation cycles of work processes as suggested modifications to actions can be modeled and tested, see figure 44. The simulation model requires two inputs to be useful for the evaluation cycle: 1) a simulation technique that can create a conceptual model that can model the specific work process with 2) the knowledge on the work process-specific actions. In order to be useful for the organization, however, more than just a valid simulation model is required. The simulation model needs to:

- have a formulated problem which it tries to solve
- be placed within the evaluation cycle with predefined scope.

If these aspects are not present, the simulation model might be able to represent the work process but cannot deviate from the base model and help in the evaluation of the work process. Therefore is it important that organizations provide a proper role, function, and place to the simulation model in the evaluation process of work processes to be of use.

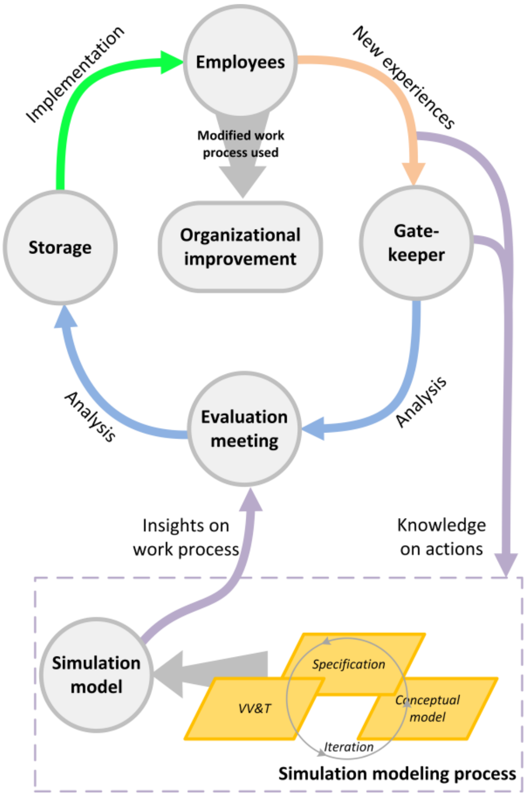


Figure 44 - Simulation modeling process in evaluation cycle

Simulation modeling process

A simulation modeling process is designed by combining the work of Balci (1994) and Banks (1998), see figure 45. The simulation modeling process focuses on using iterative steps between the different stages of modeling to come to a high-quality model, while applying four decision moments to allow periodical assessment of the process. As the process progresses, the focus shifts from modeling the correct formulated problem towards modeling with correct and validated data, and finally towards producing results that are accepted by the end user. In each stage of the process numerous verification, validation and testing techniques (VV&T) need to be applied to ensure outcomes to be satisfactory.

If a decision moment results in a negative conclusion, an unsuccessful ending of the process will be the result. The two inner circles reflect the path on which the modeling process continues depending on whether the model is considered credible enough for the formulated problem. Iteration serves two goals: a negative outcome can be corrected by going back a step, and enables fine tuning to increase the integrated support in the evaluation meetings.

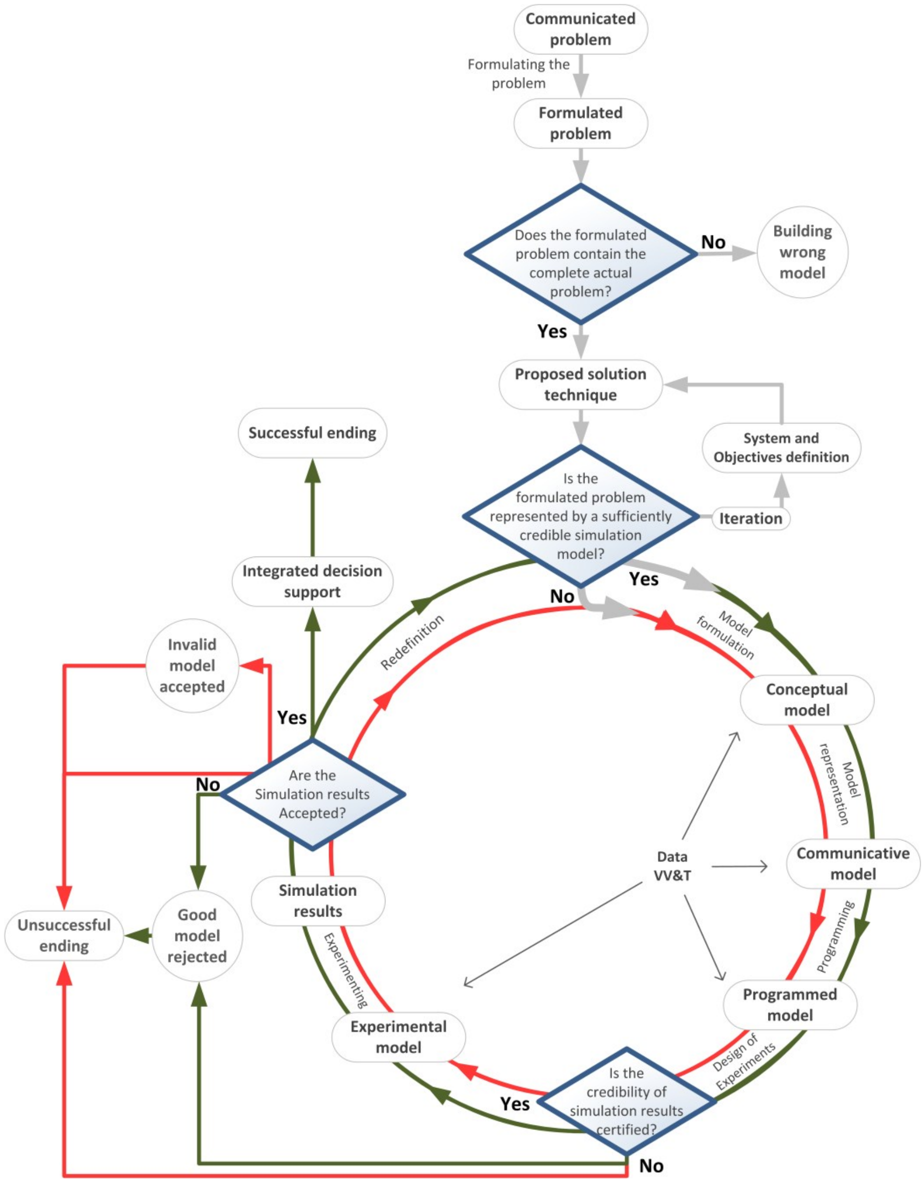


Figure 45 – Simulation modeling process

With this framework an organization is capable of cross-referencing its own work flows. A few rules of thumb in the process of simulation modeling are:

- having the correct scope is essential. Without the correct scope a type III modeling error is likely to occur (i.e. modeling the wrong problem). Recovering from this error is very difficult and time-consuming, so it is essential to use additional time and resources at the beginning.
- All choices and assumptions made between the different modeling steps have to be recorded in order to answer any question on assumptions and improve the acceptance.
- Simulation modeling of work processes requires iteration steps. It is unlikely that work processes are correctly modeled the first time around due to the hidden nature of interrelated actions. Communicate with the end users who utilize the work processes helps in recovering these hidden elements. If they feel something is incorrectly modeled, they are probably right.
- Following the above: communicate with the end users. They will be utilizing the results of the model in the end, by using the results to support a decision, and therefore they have to agree

with how the model works. A perfect model without the end user acceptance has no added value as it will not be used.

Requirements for simulation technique

When simulation modeling is used to model work processes, a fit for purpose simulation technique needs to be used. To use a fit for purpose simulation technique, requirements have been derived from the knowledge base. To achieve an additional contribution to the environment the business needs are also summarized in requirements to check whether the simulation technique can produce useable outputs. The combined list of requirements is summarized in table 8.

Table 8 - Seven requirements for using conceptual models

The simulation technique needs to be able to model the four dimensions of work processes
The simulation technique needs to be understandable by the end user for it to produce results that can be accepted
The simulation results can provide knowledge on the modeled work process
The simulation technique can model the different organizational structures
The simulation technique can model PBOs' work processes
The simulation technique can create conceptual models applicable to different projects
The simulation technique produces project performances as output

Combining the above contributions, it is the belief of this research that work processes of PBOs can be successfully and satisfactorily modeled with a fit for purpose simulation technique using the simulation modeling process. With the end result, via either a conceptual or a case-specific model, the end user is able to formulate a problem, choosing a correct simulation technique, apply it and come to credible and accepted results.

9.2 Implications for Environment

This research utilized a design science approach that combined a knowledge base with the related environment. In this section we explore how the findings of this research impact the environment. First the implications for ePM are listed, and in the second part the implications for PBOs in general are summarized.

Business need of ePM

ePM believes that simulation modeling provides an additional depth, an immersive layer, when going through the learning cycle. ePM seeks ways to improve its business approach by answering practical questions such as: when simulation modeling is applied, how can ePM determine what should be modeled and when is the designed model performing correctly for that particularly case? When can the model be viewed as a good model, who determines what a good model is and when is a model finished? In other words, the business need of ePM can be summarized by the following question: how do you know that the model that is designed, is a good model and fit for purpose?

This question is centralized in the simulation modeling process. The question of what should be modeled is answered via the formulated problem and the decision moment that checks the formulation. The direction, goal and scope of the problem are defined in this stage, giving the modeler enough substance to know what should be modeled.

The question of what a good model looks like is a subjective question, and therefore, the answer will as ambiguous as well. It is up to the end user to determine whether the model looks good, not up to the modeler. In order to know when the model is fit for purpose, frequent checks with the end user is necessary. Only by going into conversation with the end user, will reveal what the end user finds satisfactory.

Validation is a key aspect in this respect, as a validated model represents the real system acceptable as defined by the end user. To ensure this, the validation techniques that are used should always require the involvement of the end user. Techniques such as, but not limited to, face validation, black-box testing and structural analysis, aid the modeler in getting a sense of what the end user's perception is, while at the same time receiving valuable tacit knowledge of the end user when he gives his feedback.

The implications of this research for ePM can be summarized in three statements:

1. The simulation modeling process allows ePM to model the correct problem and produce a model that is accepted by its customer, as the process changes the focus of the modeling process as the model progresses. The focus shifts from modeling the correct formulated problem towards modeling with correct and validated data, and finally towards producing results that are accepted by the end user.
2. To achieve an acceptable model, communication with, and interaction of, the customer during the process is essential. Not only because communicating with the customer reveals the problem and expectations of the customer and thus the definition of a good model for this specific case, but also the involvement of the customer increases the acceptance as the product is partly constructed by the customer himself.

3. The designed conceptual simulation model and conceptual simulation models in general can be used for different cases, if the cases have the following characteristics in common: The formulated problem is alike, the level of detail is similar and the assumptions of a conceptual model hold for the specific case.

Based on the experience of applying the simulation modeling process on the case study of DSM, the following two examples can be of help for ePM as a reference:

1. The use of the 6 validation techniques worked out quite well in this research, as each of the techniques focused on different elements of the model. Depending on the available time with the customer, this research would advise to use at least two techniques per decision moment, see figure 38, as the results of those techniques can be compared and together strengthen the overlapping statements while differences can be material for questions to the customer.
2. When deciding on the approach used to convey the results with the end user, the following aspects need to be addressed: what is the goal of approach, how does the end user look at the problem, what is the time availability of the end user, how much interaction is required to achieve the acceptance of the results? Per case the appropriate approach would differ, as the aspects are answered differently. An end user with a lot of time but with no knowledge of the problem, will require a more educational approach as information needs to be explained. Whereas a returning end user already has experienced with simulation modeling and an intensive workshop is preferable to make the most out of a limited window of opportunity.

PBO business needs

Project-based organizations (PBOs) have two business needs in relation to work processes. Firstly, the need for *decision speed*. The faster the pace, the more iteration steps can be made and thus the higher the quality of the work processes can become. Simulation modeling is able to quickly calculate a modification and quantify its effects, once a base model exists. Building models is time-consuming, but having a conceptual model ready to be used for a variety of different cases reduces the time required. The benefits of using conceptual models are: the basis of the model is sound; it saves time compared to working from scratch; and the customer can already recognize his organization with the rough setup and can give feedback based on the mold for further specifications. Simulation modeling can thus contribute to this business need, by identifying bottlenecks of a proposed structure. For this research the organizational structure of project teams has been modeled, through which characteristics of the structure of project teams have been related to organizational complexities. This research shows that PBOs can influence these complexities by being aware of the characteristic of project teams that affect those complexities.

The second business need of PBOs that was taken into account was the need for *predictability of outcomes* of work processes. Through simulating the work process in a model, weak spots can be identified and overall robustness is increased. Furthermore, by applying simulation modeling the organization can learn via the simulated environment and safely test different setups and see the projected outcome. While the goal of this research was more on identifying characteristics of project teams in work processes, the use of what-if scenarios during the making of the experimental model did provide insights into how specific problems can be averted with small adjustments, as can be reviewed in appendix C.

It can be concluded that for PBOs the implications of this research are as follow:

1. Work processes are organization-dependent, as work processes are defined as "a collection of interrelated actions in response to an event that achieves a specific result" (Sharp & McDermott, 2001). Each PBO has their own 'specific result' and therefore create a different work process. The research focused on work processes with a high level of aggregation, as the research was interested in aspects of organizational structure of project teams. The relevance of this focus is stressed in literature, stating that the people involved in the project make or break the project (Bakker, 2008; Bosch-Rekveldt, 2011). Therefore, being able to understand how characteristics of the structure of project teams influence project performance, leads to performance improvement as the structure can be made fit for purpose.
2. Project complexity, consisting of uncertainties and risks, can negatively influence project performance. It is the believe of this research that the aforementioned characteristics influence organizational complexities through reducing the likelihood of appearing (e.g., the occurrence of the identified organizational complexity of "interfaces between different disciplines" can be reduced by increasing the information exchange between the disciplines).
3. Simulation modeling is an additional tool to support the design of work processes, as it increases decision speed and provides predictability of outcomes. To successfully use a simulation technique, the technique needs to comply with requirements that come forth from the problem. In this research seven requirements have been established and are listed in section 4.1. The simulation technique can, for example, be added to the evaluation cycle of work processes, to assess recommended modifications to an existing work process or to assess the effectiveness of new work processes.
4. Simulation modeling can provide insight into how the structure of project teams influences project performance, by making causal relationships visible. Furthermore simulation modeling can, by quantifying the outcomes, create a fit for purpose structure of the project team for a specific project.

The final implication of this research for PBOs in general is that characteristics of project team structures can complement each other. The impact of this can be shown by the following example: A project team with individuals that have worked with each other before has a high team experience. If that team is indicated as having an high formalization, meaning communication is formal and information is exchanged effectively, the two characteristics (team experience and formalization) both reduces the required amount of information exchange within the project team. People know from each other what to expect (team experience) and when communication is required, it is done formal and clear (formalization). The reduction of information exchange, means that less time is spend on communication resulting in more efficient project execution. When either of these characteristics are reversed the required information exchange increases and thus project execution is weakened.

Knowing the structure of the project team, and being able to quantify the outcomes of suggested project teams, allows a PBO to assess the viability of suggested structures. While the TOE framework of Bosch-Rekveldt (2011) allows a PBO to assess which complexities could occur, this research shows that simulation modeling can (partly) operationalize those complexities that are linked with characteristics which can be modeled with the chosen simulation technique. It is not a forecast of what will happen to the project, but what could happen to the project and how the structure of the project team affect that outcome. In this view simulation modeling is beneficial for PBOs during the front end phase of projects, when the structure of a project team is still shaping.

10. Conclusions

In the past nine chapters the research has answered the elements that lead to the main research question. The final conclusions of the research are discussed in this chapter. In the first three sections the summary of the approach is given and the sub and main research questions are answered. In section 10.4 the limitations of the research are given and a reflection on the research approach can be found in section 10.5. This chapter is finalized with a section on future research.

10.1 Summary of results

In section 1.1 the importance of managing complexities in projects by project-based organizations was linked with the work processes that these organizations use to execute the project. There is a feeling that complexities are embedded in work processes, but no real insights are currently present in literature. The objective of the research was defined as: *to learn about the relationship between organizational complexities, which influence project performance through the structure of the project team of project-based organizations.* Therefore the main research question was posed as:

> How can simulation modeling of the work process of project-based organizations support the understanding of organizational complexities?
>
> **Research Question**

To answer this question a design science approach was adopted. This approach focuses on combining existing knowledge with business needs to develop a new artifact, which after thorough evaluation contributes new knowledge to the knowledge base while providing the environment with validated concepts. The first step of this research was to identify the applicable knowledge from the knowledge base on work processes and simulation modeling. With the applicable knowledge a simulation modeling process was designed that was used and evaluated in this research. Furthermore, requirements on using simulation techniques to simulate work processes of PBOs were derived from both the knowledge base and the environment of ePM and PBOs.

The next step was to combine the requirements and use the new simulation modeling process to construct a conceptual simulation model. The scope, building blocks and outputs of the conceptual model were set out next. These findings can be used by both ePM and PBOs that want to use simulation modeling on work processes. Using the simulation technique of ePM a conceptual model was designed to give an impression of, and serve as a foundation for, the case study.

The case study utilized the conceptual model and turned it into a case-specific model by applying the other stages of the simulation modeling process. The case study revealed possibilities and limitations of the use of conceptual models, and also revealed variables within the structuring of project teams, which can (partly) influence organizational complexities.

Finally the findings of both the design phase and the evaluation were used to contribute to the knowledge base with additional knowledge and to supply ePM and PBOs with implications of the research results.

10.2 Answer to sub-questions

First the answers to the separate sub-questions are discussed, leading to the answer of the overall research question.

Part I: Theoretical foundation: Creating the context

Chapter 2

RQ 1.1 Which requirements for designing a conceptual simulation model based on work processes can be derived from literature?

Projects and the work processes of PBOs were viewed from different fields of study. Work processes are defined as “a collection of interrelated actions in response to an event that achieves a specific result“ (Sharp & McDermott, 2001). From a modeling perspective work processes can be modeled if the four dimensions of work processes are taken into account: level of detail, generality, formalization and quality (Theiβen et al, 2010). From a project management perspective organizations have specialized teams have that fulfill the role of project owner, main contractor or subcontractor. Furthermore, projects are about managing the complexities, making a distinction in Technical, Organizational and External complexities (Bosch-Rekveldt, 2011). As work processes state how and by whom actions need to be executed, work processes contain information on how the project team is structured and thus contain characteristics of team structures that (partly) influence some organizational complexities.

To successfully design a simulation model of work processes, the above features of work processes and project teams need to be taken into account. Further requirements are derived from a simulation modeling perspective: the predefined goal of providing knowledge on the modeled work process needs to be answered by the model, and the end user of the model should accept the results. The combined requirements from the knowledge base that the design of a conceptual model needs to meet are:

R1. The simulation technique needs to be able to model the four dimensions of work processes
R2. The simulation technique needs to be understandable to the end user for it to produce results that can be accepted
R3. The simulation results can provide knowledge on the modeled work process

Chapter 3

RQ 1.2 Which are the needs derived from practice that simulation modeling and modeling work processes of project-based organizations can satisfy?

The environment of this research is the company ePM and its customer base of project-based organizations. ePM expressed the need to have a framework that supports the questions that it has to answer with its customers in each case: how can be determined what should be modeled and when is the designed model performing correctly for that particularly case? When can the model be viewed as a good model, who determines what a good model is and when is a model finished? These questions have been defined as: (1) the need to identify what lies within the scope of the problem, to determine which model is fit for purpose; and (2) a way to measure when the model will be accepted by the customer. In section 2.4 the simulation modeling process has been designed, see figure 46, which deals with both needs. By using decision moments the formulated problem can be checked to answer the question of 'what lies within the scope of the problem?'. Later the decision moments are utilized to measure whether the model contains enough elements to get the model accepted by the customer.

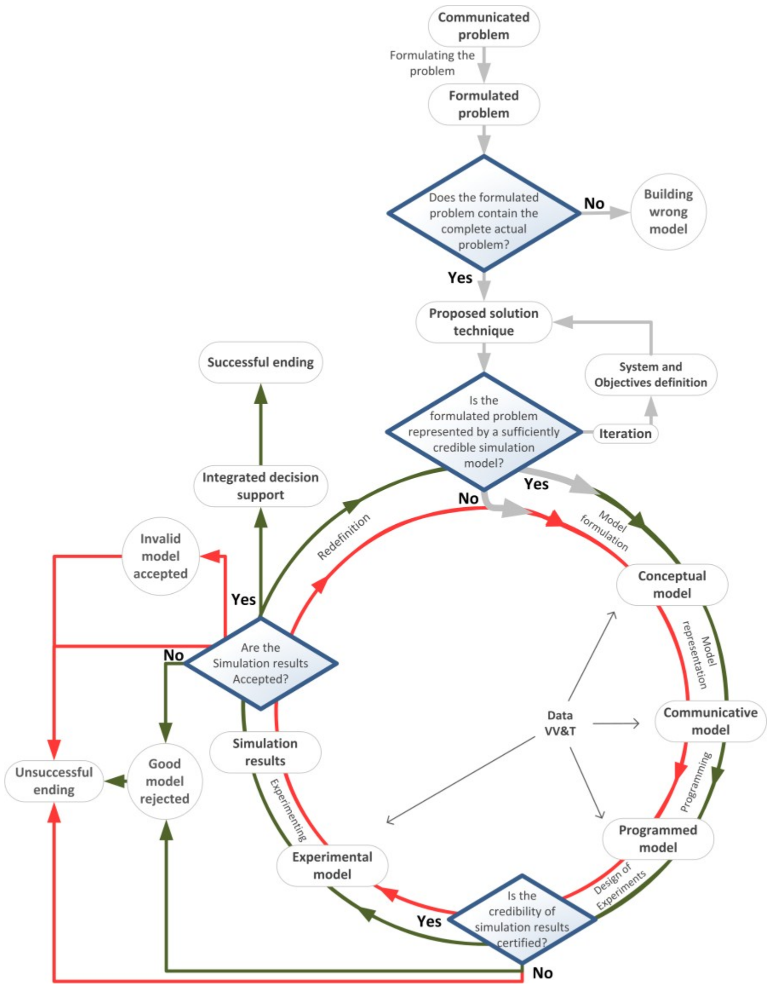


Figure 46 - Simulation modeling process

PBOs' business needs with respect to simulating work process are twofold: decision speed and predictability of outcomes. Simulation modeling can increase the decision speed through its calculating powers by giving the results of what-if scenarios. This way the iteration steps can be made more quickly, making it possible to improve the quality of the work process.

Simulation modeling supports the need for predictability of outcomes by modeling the causal relations between the interrelated actions that are described within the work process. By understanding the effects of changing parts of the work process, knowledge of the work process is increased. As characteristics of team structures are part of the defined actions, these characteristics are made explicit when the causal relations are modeled and identified. The combined requirements from the environment that the design of a conceptual model needs to meet are:

R4. The simulation technique can model the different organizational structures
R5. The simulation technique can model PBOs’ work processes
R6. The simulation technique can create conceptual models that can be applied to different projects
R7. The simulation technique produces project performances as output

With the list of requirements on the simulation technique the second sub-question is answered. With the requirements from both the knowledge base and the environment, it is possible to conceptualize projects in the next chapter.

Part II: Design challenge: Designing conceptual simulation model

Chapter 4

RQ 1.3 What does a conceptual model that models organizational complexities in project teams of project-based organizations look like?

Using the simulation modeling process the construction of a conceptual model requires three aspects to be clear: defining the system and objective of the model, the basic building blocks and a simulation technique that meets with the requirements.

For this research the system definition is provided by the environment: PBO work processes. The scope is narrowed due to the focus on organizational complexities within work processes, resulting in the focus on the design and execution phases of project execution, see figure 47.

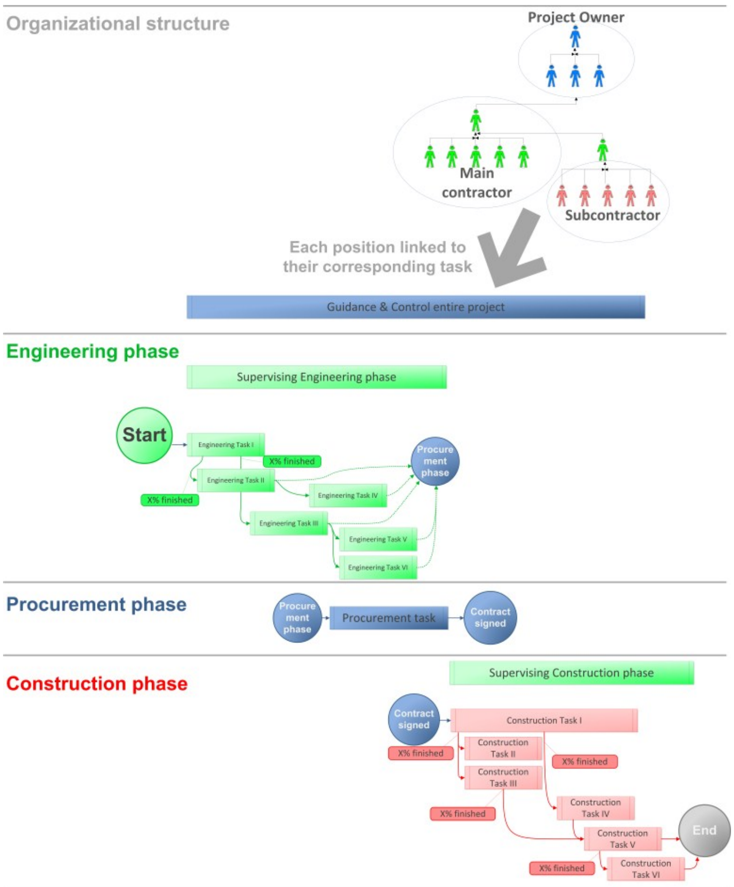


Figure 47 - Conceptual model representing high level of PBO work processes in EPC phase

The objective of the conceptual model is to understand how organizational complexities influence project team performance. That is why the project organization and its primary tasks are centered in the model. To achieve this, the conceptual model requires the creation of a hierarchy of positions in terms of information flows, since the exchange of information is key to managing the project interfaces. As positions are linked to tasks within the design and execution phases of the project, a simulation can both identify the tasks that are the bottleneck of the project and explain how this reflects back on the organizational structure. This way the model tests the fitness of the organizational structure on the work process.

Chapter 5

RQ 1.4 Which methods are able to evaluate whether a conceptual model has been built correctly?

The conceptual model has been built correctly if the simulation technique meets the requirements, and when the simulation technique is determined to be a credible technique to deal with the formulated problem. One step in this process is checking for verification errors in the conceptual model.

Checking for verification errors is achieved by going through the simulation technique itself. Questions that can be asked are: does the simulation technique handle changes to task sequences logically and are all input variables in some way linked to the model outputs? For this research the verification techniques' inference and predicate transformation were used to evaluate the correctness of the program SimVision. To evaluate whether a conceptual model has been built correctly, the applied simulation technique is required to be tested on the following aspects:

1. verify if the simulation technique itself is constructed sound, by using different verification techniques on the logic that the technique uses.
2. Verify if the simulation technique complies with the requirements that were set up alongside the formulated problem.
3. Verify if the simulation technique is able to simulate the scope and to incorporate the buildings blocks that have been identified to be essential to find the answer on the formulated problem.

Part III: Evaluation: Testing conceptual model with case study

Chapter 6

RQ 1.5 Which implications ensue when applying a conceptual model to real-world work processes?

The conceptual model was tested in part III of this research by means of a case study on work processes of projects by DSM. To model the work process of DSM correctly, the conceptual model needed to be made case-specific. This specification step raised two issues:

1. The choices and the limitations of a conceptual model are conveyed onto the case-specific model. This means that a modeler should be aware that a formulated problem and an objective definition influences the conceptual model and thus also the programmed model.
2. DSM sees work processes as organization-independent, which causes them to miss or ignore important organizational characteristics within work processes. The conceptual model thereby falsely inherits characteristics from these work processes.

Chapter 7

RQ 1.6 Which methods are able to evaluate whether a case-specific model is credible enough?

It can be concluded that the simulation modeling process is a good process to evaluate a case-specific simulation model based upon a general conceptual model. Using the simulation modeling process, it becomes apparent that the decision moments provide structure to the modeling process. This structure aids the modeler and the end user as such, due to the quality checks with diverse validation techniques in various places of the simulation model.

This research applies six validation techniques which are all able to evaluated a model on its credibility. The shared characteristic of these techniques is that not only do they test a model on a specific aspect, the validation techniques involve the end user of the model. Assertion checking, face validation, structural analysis and black box testing require feedback from experts or the problem owner. The results of the sensitivity analysis were used to seek dominant variables and served as input for the workshop of chapter 8. The interaction of the end user with these validation techniques not only increased the quality of the model, as tacit knowledge was used in using the validation techniques, but it also increased the acceptance of the model by the end user.

Chapter 8

RQ 1.7 Which approach needs to be used to get a simulation model of work processes to be accepted by its end users?

To get the simulated results accepted, an approach can be used to structure the final phase of the simulation modeling process. The approach chosen is able to achieve a predetermined successful acceptance of results, and promotes action afterwards. The following issues need to be considered when choosing an approach:

- Goal – To support a design decision or to learn about a specific element?
- Knowledge – How does the end user see project teams and productivity?
- Time constraint – How much time does the end user have?
- Level of interaction – How much interaction is needed for achieving acceptance?

Based on the above issues, an appropriate approach can be chosen. For this research, a workshop was constructed. The goal was to create additional insights into the variables that influence organizational complexities, which created a high level of interaction in a short time period. Using different scenarios, the participants were able to learn how the identified variables can be chosen to positively influence complexities, by reducing the likelihood of occurring.

Part IV: Conclusion: Contribution to knowledge base and environment

Chapter 9

RQ 1.8 What are the contributions of this thesis, and what are the implications for the environment?

The research contributes to the knowledge base with the designed simulation modeling process, as this research combines the rigorous design process of Balci (1994) with constructive decision moments of Banks (1998). The simulation modeling process aids a modeler to shift his focus from modeling the correct formulated problem towards modeling with correct and validated data, and finally towards producing results that are accepted by the end user.

Furthermore this research contributes through the requirements and checks for designing a conceptual model of work processes. The seven requirements derived from chapter 2 and 3 can be used to test the applicability of a simulation technique when a work process needs to be modeled.

The research contributes with a practical goal by satisfying the business needs as discussed in chapter 3. The complete list of contributions can be found in section 9.2, in this section only the main elements are described.

The need of ePM is satisfied with the simulation modeling process, basing key steps of a simulation process on literature and stating decision moments in which the progress of the simulation process can be measured together with the customer.

The identified needs of PBOs: decision speed and predictability of outcomes, are aided with the use of simulation modeling. Through the modeling of the structure of project teams, causal relationships of characteristics within those structures are identified and quantified. By making these characteristics visible, a PBO is able to test its project team structure in the front end phase of project execution. By enabling testing project team structure, PBOs can utilize simulation modeling to increase predictability of project outcomes.

With the applied simulation technique SimVision, characteristics related to seven organizational complexities were identified in section 5.4. In line with the TOE framework of Bosch-Rekveldt (2011), these characteristics are a step in making complexities more insightful, by operationalizing (parts of) these complexities. During the workshops within the case study of DSM, the related characteristics were applied in scenarios and DSM confirmed that these characteristics can influence project performance heavily if ignored or wrongly designed.

10.3 Thesis conclusions

Based on the answers to the sub-questions and the lessons that were learned during the execution of the research approach, the answer to the main research question can be formulated.

> How can simulation modeling of the work process of project-based organizations support the understanding of organizational complexities?
>
> **Research Question**

The answer to this question is:

Simulation modeling can support the process of understanding organizational complexities by making characteristics that contribute to these complexities testable. A number of identified characteristics of a project-based organization are decided in work processes and those characteristics influence (partially) the likelihood of organizational complexities occurring. By understanding the causal relations of the interrelated actions, knowledge is created on how work processes can be positively influenced by designing fit for purpose project teams and thus improving project execution.

10.4 Research limitations

The conclusion and contribution of the research to the knowledge base helps both ePM and PBOs with their business needs. However, some limitations of the research have been identified.

The research states that the acceptance and utilization of a simulation model depends on a number of issues: (1) the simulation model is placed within the evaluation process of an organization; (2) there has been open communication with the employees who apply the work process; (3) to ensure that the model represents the formulated problem, verification, validation, and testing techniques, need to be applied. While on paper all these issues should lead to an accepted model, there is no guarantee that an appropriate level of acceptance is created in reality. Process management (de Bruijn et al, 2002) and institutionalization (Selznick, 1957) should be further investigated to lay out a process of change in attitude towards the use of simulation modeling.

The research uses the program SimVision as its simulation technique. While this program is able to pursue the research objective, it limits the amount of organizational complexities that can be investigated. ePM has stated that they seek ways to implement more parameters in their program to increase the simulated complexities, but for this research it meant that seven organizational complexities were related to variables active within the simulation technique. The focus on these variables could result in a disproportional amount of attention, while other complexities are just as important to be dealt with.

The simulation modeling process and conceptual model are tested on only one case, which has characteristics that might not be shared by other project-based organizations and may thus produce different outcomes. The following characteristics might not be shared by other PBOs and could influence the outcome of a similar process:

- As the core business of DSM is manufacturing, DSM has a small group that is focused on projects. As a consequence this team of employees knows each other very well and each employee has years of experience in the field of managing projects, reducing the need for procedures and guidelines.
- For the engineering phase DSM attracts a main contractor. This influences the structure of the work processes. The level of detail of the work process is low and the level of generality is higher than is to be expected for other project-based organizations. The result is that a high-level work process was quite suitable for identifying organizational complexities via simulation modeling.
- The case was studied from outside the project-based organization. The commitment was purely voluntarily and no consequences were attached to the results. In this free environment comments and opinions were exchanged simultaneously. When results of the simulation modeling process are used as input for an evaluation cycle, employees could act strategically (e.g., by making their positions more prominent or stating that their task is understaffed).

10.5 Reflection research method

Firstly the research approach and process is reflected upon, including how this could have been enhanced and a reflection on the theories used. Secondly, the research results are reflected upon: the degree to which the research met its practical and scientific aim, including a reflection on the validity of the results.

Reflection on research approach

When reflecting on the scope of the research it may be the case that the subject of work processes has been around for at least two decades, but that a clear definition has never been agreed upon in the academic literature. By using a broad, but complete, definition of work processes the research was able to be flexible in formulating a fitting and doable work process from the case. The choice to approach work processes from a knowledge management perspective proved to generate learning cycles. While valuable insights have been found between work processes and a learning cycle, it opened up an additional dimension, making the research more complex than was necessary. With hindsight the scope could have been be more rigid allowing the research to refine the results a bit more. It could have been decided to purely focus on identifying organizational complexities in work processes and to deliver a causal diagram describing which complexities exert influence on which actions. The scope of this research might have been broad, but it did make it possible to combine a variety of disciplines, which was a motivating factor for the researcher.

When reflecting on the choice of methods and techniques, the following remarks can be made. Focusing on the methods to gather information from the employees of DSM while working with them on the model did achieve the perceived goal – usable knowledge and validating remarks. Audit proved to be a very effective method and combined with desk research and semi-structured meetings a broad scale of information was produced. However, the recap of the results of these methods and iteration steps could have been more elaborate. With hindsight it can be said that one or two more rounds with people from DSM would have resulted in a more refined base model and more extensive scenarios. This does not mean that it would have resulted in different conclusions and results, but the visual aspects of the research would have been of higher value. The use of SimVision can be said to have worked very well, especially as personnel of ePM were helpful to explain the core aspects of SimVision creating a steep learning curve for the researcher. The use of any other simulation model might not have resulted in the same quality.

When reflecting on the choice of scientific theories, the research uses a mixture of different frameworks to enable the design science approach. While the framework of Hevner (et al, 2004) aided in structuring the four phases, the thoroughness of the practical approach could not have been achieved without Banks (1998) and Balci (1994). With hindsight more research should have been spent on how to structure the research, as modifications of the approach shifted multiple times during the execution of this study. With hindsight it can be said that putting in more effort into defining the scope and goals at the start would have resulted in a more rigid process with structured steps, whereas in this study the steps were sometimes dynamic and organic. A similarity has to be made with project management. More time on the front-end development could have resulted in a higher quality and shorter graduation length, but then again the experience can be judged as full with high quality lessons learned.

Reflection on the research results

In section 10.3 the answer to the main research question was given: a viewpoint on how and what kind of insights simulation modeling can create on organizational work processes of project-based organizations. The process towards developing this viewpoint was rigorous: with the use of a combined framework by Hevner and the use of the designed simulation modeling process, an in-depth literature review formed the basis of this research.

For the practical aim of this research a diversity of methods was used to assess the current situation: It was determined which elements of the work process were suitable for the research; and a modeling framework was designed to guide simulation modeling organizations to a successful modeling process. The quality of the designed model and framework was enhanced by applying the many iteration and VV&T techniques. From that perspective the research itself went through the different modeling processes and the modeling framework is a description of that process. ePM has expressed that the road towards the results was often fruitful and that the results have given them food for thought. While DSM was purely involved to test the conceptual model and simulation modeling process, they judged the results of workshop to be interesting and the focus on organizational parameters within work processes promising. With this, the practical aim defined for this research has been satisfactory.

10.6 Future research

With the results of this research as shown in this chapter a lot of work has not been touched upon or has only been explored slightly. Recommendations for future research are:

Academic future work

The research is only done on one case. While the case itself contained multiple projects, the structure of the project team is the same in each of those projects. It would be prudent to add other project-based organizations and to learn how suitable their project teams are for the conceptual model and how well the simulation modeling process can guide those cases. Comparisons between organizations could then as well – if a correlation is found – contribute to quantifying the effects of organizational complexities on project performances.

Given the TOE framework of Bosch-Rekveldt (2011), the technical and external complexities were outside the scope of this research. It will be interesting to see if simulation modeling is able to create insights into the interrelated actions that affect parameters defined in technical and external complexity. It will require a different scope and thus a different type of simulation model than was the case in this research. If successful, the different simulation models might be able to create knowledge on characteristics that influence these complexities and therefore create tools to deal with these complexities. In that light this research can be seen as an exploratory research, a small step in a long chain to come.

At the end of the thesis, the work of Trompenaars (2004) "Culture for Business series" was introduced by ePM in one of the meetings the researcher had with ePM. From a simulation modeling point of view, the work of Trompenaars could prove a nice addition to current simulation modeling on organizational structures. His research shows that cultural, behavioral and organizational parameters influences project performance, quality research on those parameters should be investigated further.

Future work for ePM

Given the TOE framework of Bosch-Rekveldt (2011), only a selection of the variables within SimVision were connected to a small group of organizational complexities. Future work could focus on adding more organizational parameters to simulation modeling to achieve greater insight into organizational structures and project performances (e.g. behavior that flows from the different types of contracts could be added to SimVision: i.e. commercial arrangements, lump sum, cost plus).

Besides the behavior that is evoked from contracts, more extensive parameters on how the meetings are done could be valuable work to be added to the simulation program. As the scenarios in this research showed that meetings can exert a good amount of influence on project performances as information exchange is blocked, more settings on the quality of the meetings would do justice to the meetings' influence.

Literature

A

Abdelhamid, T. S. (2003), 'Evaluation of teacher-student learning style disparity in construction management education', *Journal of Construction Education,* 8 (3), 124-45.

Ackoff, R.L. (1989), 'From data to wisdom', *Journal of applied systems analysis,* 16, 3-9.

Agency, Virginia Information Technologies (2011), 'What is a lesson learned?', www.vita.virginia.gov/itTrain/pmDev/bpll/BPLL.CFM?Q=LL, accessed 10-03.

Ajmal, M., Helo, P., and Kekale, T. (2010), 'Critical factors for knowledge management in project business', *Journal of Knowledge Management,* 1 (1), 156-68.

Antoni, M., Nilsson-Witell, L., and Dahlgaard, J. (2005), 'Inter-project improvement in product development', *International Journal of Quality & Reliability Management,* 22 (9), 876-93.

Argote, L. and Ingram, P. (2000), 'Knowledge transfer: a basis for competitive advantage in firms', *Organizational Behavior and Human Decision Processes,* 82 (1), 150-69.

B

Baccarini, D. (1996), 'The concept of project complexity - a review', *International Journal of Project Management,* 14 (4), 201-04.

Bakker, H.L.M. (2008), *Management of Project: a People Process (inaugural adress)* (Delft: Delft University of Technology).

Balci, O. (1994), 'Validation, Verification, and testing techniques throughout the life cycle of a simulation study', *Annals of Operations Research,* 53 (1), 121-73.

Balci, O. (2001), 'A methodology for certification of modeling and simulation applications', *ACM Transactions on Modeling and Computer Simulation,* 11, 352–77.

Banks, J. (1998), *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice* (New York: John Wiley).

Barney, C. (2011), 'Cross-project learning in project-based organizaitons', (Technical university of Delft).

Benware, C.A. and Deci, E.L (1984), 'Quality of learning with an active versus passive motivational set', *American Educational Research Journal,* 21, 755-65.

Birta, L.G. and Ozmizrak, N.F. (1996), 'A knowledge-based approach for the validation of simulation models: The foundation', *ACM Transactions on Modeling and Computer Simulation,* 6, 67-98.

Birta, L.G. and Arbez, G. (2007), *Modelling and Simulation* (London: Springer London Ltd).

Blumentritt, R. and Johnston, R. (1999), 'Towards a strategy for knowledge management', *Technology Analysis and Strategic Management,* 11 (3), 287-300.

Boehm, B.W. (1979), 'Software Engineering; R&D Trends and Defense Needs', in ed. Research Wegner (ed.), *Directions in Software Technology* (Cambridge: MA:MIT Press).

Bosch-rekveldt (2011), 'Managing Project Complexity: A study into adapting early project phases to improve project performances in large engineering projects', (Technical University of Delft).

Brink, P. van den (2003), *Social, organizational, and technological conditions that enable knowledge sharing* (Dissertation).

Brown, J.S. and Duguid, P. (1991), 'Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation', *Organization Science,* 2 (1), 40-57.

Brown, J.S. and Duguid, P. (2001), 'Knowledge and Organization: A Social-Practice Perspective', *Organization Science,* 12 (2), 198-213.

Bruijn, H. de , Heuvelhof, E. ten, and Veld, R. in 't (2002), *Process management* (Dordrecht: Kluwer academic publishers).

Bruijn, J.A. de and Herder, P.M. (2009), 'Systems and actor perspectives on sociotechnical systems', *IEEE Transactions on Systems, Man and Cybernatics - Part A: Systems and Humans,* 39 (5), 981-92.

Burkhard, R. A. (2005), 'Towards a framework and a model for knowledge visualization: Synergies between information and knowledge visualization', (3426 LNCS), 238-55.

C

Carvalho, R.B. and Fereira, M.A. (2001), 'Using information technology to support knowledge conversion processes', *Information Research,* 7 (1), 21-32.

Chou, S.W. (2005), 'Knowledge creation: Absorptive capacity, organizational mechanisms, and knowledge storage/retrieval capabilities', *Journal of Information Science,* 31 (6), 453-65.

Christensen, L. Chr, et al. (1999), 'Modeling and Simulating Coordination in Projects', *Journal of Organizational Computing and Electronic Commerce,* 9 (1), 33-56.

Clarke, R. and Soltan, H. (1995), 'Towards quality control for knowledge-based systems development', *Knowledge-Based Systems,* 8 (5), 269-77.

Cleland, D.I. and King, W.R. (1983), *Projcet Management Handbook* (New York: Van Nostrand Reinhold Company Inc.).

Construction Industry Institute, C.I.I. (2007), 'Effective management practices and technologies for Lessons Learned Programs', (Austin: University of Texas).

Construction Industry Institute, C.I.I. (2007b), 'Implementation of Lessons Learned Programs', (Austin: University of Texas).

Construction Industry Institute, C.I.I. (2007c), 'An analysis of Lessons Learned Programs in the construction industry', (Austin: University of Texas).

Construction Industry Institute, C.I.I. 'Construction Industry Institute Best Practices', http://www.construction-institute.org/scriptcontent/bp.cfm?section=aboutcii.

Construction Industry Institute, C.I.I. (2011), 'Message from the Conference Chair', https://www.construction-institute.org/ac/2011/acchair-mes.cfm, accessed 10-05.

Cooke-Davies, T. (2002), 'The 'real' success factors on projects', *Journal of Project Management,* 20, 185-90.

Cooper, K.G., Lyneis, J.M., and Bryant, B.J. (2002), 'Learning to learn, from past to future', *International Journal of Project Management,* 20 (3), 213-19.

Covey, S.R. (1989), *The 7 habits of highly-effective people* (New York: Simon & Schuster).

D

D.M., Gann. and Salter, A.J. (2000), 'Innovation in project-based service-enhanced firms: the construction of complex products and systems', *Research Policy,* 29, 955-72.

Davenport, T.H. (1993), *Process innovation* (Boston: Harvard Business School).

Davis, R. (2001), *Business process modeling with ARIS: A practical guide* (Berlin: Springer).

De Bruijn, J.A., et al. (1996), *Grote projecten: Besluitvorming & management* (Alphen aan de Rijn: Samson HD Tjeenk Willink).

Deckers, W. (2011), 'Workshop discussion on simulating work processes', (Workshop).

Derryberry, A. (2011), 'Serious games: online games for learning', http://www.adobe.com/resources/elearning/pdfs/serious_games_wp.pd>, accessed 10-05.

DMO (2006), *Acquisition Categorisation Framework - Policy for the Categorisatio of projects (Defence Material Organisation)* (Commonwealth of Australia: Department of Defence).

Donaldson, L. (1996), 'Organization design and the life-cycles of products', *Journal of Management studies,* 22 (1), 25-37.

Donoghue, L.P., Harris, J.G., and Weitzman, B.A. (1999), 'Knowledge management strategies that create value', (1: Accenture Institue for Strategic Change), 48-53.

DSM (2011), 'Bright science, Brighter living', <**Error! Hyperlink reference not valid.**, accessed 01-10.

DSM, Employees (2011b), 'Discussion on work process within DSM', (Interview & Audits with various people).

Dym, C. L. and Levitt, R. E. (1991), 'Toward the integration of knowledge for engineering modeling and computation', *Engineering with Computers,* 7 (4), 209-24.

E

East, E.W. and Fu, M.C. (1996), 'Abstracting lessons learned from design reviews', *Journal of Computing in Civil Engineering,* 10 (4), 267-75.

Engwall, M. (2003), 'No project is an island: Linking projects to history and context', *Research Policy,* 32 (5), 789-808.

ePM (2011), 'Organization Engineering', http://epm.cc/services-organization-engineering.php, accessed 05-05.

ERCIM, European Research Consortium for Informatics and Mathematics (2011), 'Glossary of Education - related terms (A-C)', <palette.ercim.eu/FormaHeticeTest/bayfac/download.php/Glossaryofeducation-relatedterms(A-C).doc>, accessed 10-05.

ESA, European Space Agency (2011), 'Alert and lessons learned: an effective way to prevent failures and problems', http://conferences.esa.int/99/c06/index.html, accessed 03-10.

F

Felder, R.M. and Silverman, L.K. (1988), 'Learning and teaching styles in engineering education', *Engr. Education,* 78 (7), 674-81.

Fitzek, D. (2002), 'Knowledge management in inter-project learning – a systematic attempt of integration', (Linköping University Sweden).

G

Galbraith, J. (1973), 'Designing Complext Organizatinos. Boston, MA: Addison-Wesley.

Goffin, K. and Koners, U. (2008), 'Capturing tacit knowledge in new product development: A study of post-project reviews', *International Journal of Technology Intelligence and Planning,* 4 (3), 234-56.

Goffin, K. and Koners, U. (2011), 'Tacit knowledge, lessons learnt, and new product development', *Journal of Product Innovation Management,* 28 (2), 300-18.

H

Herder, P. and Stikkelman, R.M. (2004), 'Methanol-based industrial cluster design. A study of design options and the design process', *Journal of Industrial & Engineering Chemistry Research,* 43, 3879-85.

Hevner, A. R., et al. (2004), 'Design science in information systems research', *MIS Quarterly: Management Information Systems,* 28 (1), 75-105.

Hillson, D. and Simon, P. (2007), *Practical Project Risk Management - the ATOM Methodology* (Vienna, VA: Management Concepts).

Huber, G.P. (1999), 'Facilitating project team learning and contributions to organizational knowledge', *Creativity and Innovation Management,* 8 (2), 70-76.

Hutchinson, R. and Wabeke, H. (2006), *Opportunity and Project Management Guide (OPMG)* (The Hague: Shell International Exploration and Production B.V.).

J

Jashapara, A. (2004), *Knowledge management.- an integrated approach* (Harlow, Essex UK: Pearson Education Limited).

Jasimuddin, S.M. and Zhang, Z.J. (2011), 'Transferring stored knowledge and storing transferred knowledge', *Information Systems Management,* 28 (1), 84-94.

Jennex, M.E. and Olfman, L. (2004), 'Assessing knowledge management success/effectiveness models', in R. H. Sprague Jr (ed.), (Proceedings of the Hawaii International Conference on System Sciences, 37; Big Island, HI.), 3687-96.

Jin, Y. and Levitt, R. E. (1996), 'The Virtual Design Team: A Computational Model of Project Organizations', *Journal of Computational and Mathematical Organizational Theory,* 2 (3), 171-95.

Jin, Yan, et al. (1995a), 'Virtual Design Team: A computer simulation framework for studying organizational aspects of concurrent design', *Simulation,* 64 (3), 160-74.

Jin, Yan, et al. (1995b), 'Virtual design team: modeling organizational behavior of concurrent design teams', *Artificial Intelligence for Engineering Design, Analysis and Manufacturing: AIEDAM,* 9 (2), 145-58.

K

Karns, G. L. (2006), 'Learning style differences in the perceived effectiveness of learning activities', *Journal of Marketing Education,* 28 (1), 56-63.

Kim, W. and Park, S.S. (2003), 'Knowledge Management: A Careful Look', *Object Technology,* 2 (1), 29-38.

Koch, C. (2004), 'The Tyranny of Projects: Teamworking, Knowledge Production and Management in Consulting Engineering', *Economic and Industrial Democracy,* 25 (2), 277-300.

Koners, U. and Goffin, K. (2007), 'Managers' perceptions of learning in new product development', *International Journal of Operations and Production Management,* 27 (1), 49-68.

Kotnour, T. and Vergopia, C. (2005), 'Learning-based project reviews: Observations and lessons learned from the Kennedy Space Center', *EMJ - Engineering Management Journal,* 17 (4), 30-38.

Kunz, J. C., et al. (1998), 'The virtual design team', *Communications of the ACM,* 41 (11), 84-XI.

L

Lam, A. and Lambermont-Ford, J.P. (2008), 'Knowledge sharing in organizational contexts: a motivation-based perspective', *Journal of Knowledge Management,* 14 (1), 51-66.

Leybourne, S.A. (2007), 'The changing bias of project management research: a consideration of the literatures and an application of extent theory', *Project Management Journal,* 38 (1), 61-73.

Linssen, H. (2011), 'Validating the base model: Sharing data on work volumes, salaries and general work process behavior', (Interview in person & on telephone).

M

Mason, R.M. (2003), 'Culture-free or culture-bound? A boundary spanning perspective on learning in knowledge management systems', *Journal of Global Information Management,* 11 (4), 20-36.

McDermott, P. (1998), 'Learning across teams: the role of communities of practice in team organizations', *Knowledge Management review*.

Miller, R. and Lessard, D.R. (2000a), *The strategic management of large engineering projects* (MIT Press).

Miller, R. and Lessard, D.R. (2000b), *The strategic management of large engineering projects: shaping institutions, risks, and governance* (Massachusetts: Massachusetts Institute of Technology).

Milton, N. (2010), *The lessons learned handbook- practical approaches to learning from experiences* (Oxford: Chandos Publishing).

Mintzberg, H. (2007), *Organisatie structuren* (2nd Edition edn.; Amsterdam: Pearson Education Benelux).

Mitsuru, Kodama 'Project-Based Organizations in the Knowledge-Based Society'.

Morris, P.W.G. and Hough, G.H. (1987), *The Anatomy of Major Projects: a Study of the Reality of Project Management*

(Chichester: John Wiley).

Murray, A. (2009), *Managing Successful Projects iwith PRINCE2* ed. (Office of government Commerce) ((5th ed.); Norwich: The Stationery Office).

N

Neelankavil, F. (1987), *Computer Simulation and Modeling* (Chichester, UK: John Wiley and Sons).

Newell, S. (2004), 'Enhancing cross-project learning', *EMJ - Engineering Management Journal,* 16 (1), 12-20.

Newell, S. and Edelman, L.F. (2008), 'Developing a dynamic project learning and cross-project learning capability: Synthesizing two perspectives', *Information Systems Journal,* 18 (6), 567-91.

Newell, S., et al. (2006), 'Sharing knowledge across projects: Limits to ICT-led project review practices', *Management Learning,* 37 (2), 167-85.

Nonaka, I. and Takeuchi, H. (1995), *The knowledge creating company* (Oxford UK: Oxford university press).

O

O'Connor, B. (2008), 'Lessons learned about lessons learned: (How best to remember the "unforgettable")', (657 SP edn.).

P

Patton, M.Q. (1990), *Qualitative evaluation and research methods* (2 edn.; London: Sage Publication).

Phalp, K.T. (1998), 'The CAP framework for business process modeling', *Information and Software Technology,* 40 (13), 731-44.

Phalp, K.T. and Shepperd, M. (2000), 'Quatitative analysis of static models of processes', *Journal of Systems and Software,* 52 (2-3), 105-12.

Pich, M.T., Loch, C.H., and de Meyer, A. (2002), 'On uncertainty, ambiguity, and complexity in project management', *Management Science,* 48 (8), 1008-23.

Project Management Institute, P.M.I. (2010), *A Guide to the Project Management Body of Knowledge*.

R

Ras, E., et al. (2005), 'Using weblogs for knowledge sharing and learning in information spaces', *Journal of Universal Computer Science,* 11 (3), 394-409.

Rummler, G.A and Brache, A.P. (1995), *Improving performance: How to manage the white space on the organizational charts* (San Fransisco: Jossey-Bass).

S

Sartorius, B. (2011), 'Validating the base model: Sharing data on work volumes, salarise and general work process behavior', (Interview in person).

Sausar, B.J., Reilly, R.R., and Shenhar, A.J. (2009), 'Why project fail? How contingency theory can provide new insights - A comparative analysis of NASA's Mars Climate Orbiter loss', *International Journal of Project Management,* 27 (7), 665-79.

Scarbrough, H., et al. (2004), 'The process of project-based learning: an exploratory study', *Management Learning,* 35 (4), 491-506.

Selznick, P. (1957), *Leadership in Administration* (New York: Harper & Row).

Seningen, S. (2011), 'Learn the value of lessons-learned', http://www.projectperfect.com.au/downloads/Info/info_lessons_learned.pdf, accessed 03-10.

Sharp, A. and McDermott, P. (2001), *Workflow modeling: Tools for process improvement and application* (Norwood, MA: Artech House).

Shell (2010), 'Right first time', *Shell Global Solutions,* 2, 7.

Shenhar, A.J. and Divir, D. (1996), 'Toward a typological theory of project management.', *Research Policy,* 25 (4), 607-32.

Smyth, H.J. and Morris, P.W.G. (2007), 'An epistemological evaluation of fresearch into projects and their management: Methodological issues', *International Journal of Project Management,* 25 (4), 423-36.

Söderlund, J. (2008), 'Competence dynamics and learning processes in project-based firms: Shifting, adapting and leveraging', *International Journal of Innovation Management,* 12 (1), 41-67.

Sommer, S.C. and Loch, C.H. (2004), 'Selectionism and learning in projects with complexity and unforeseeable uncertainty.', *Management Science,* 50 (10), 1334-47.

Soo, C., et al. (2002), 'Knowledge management: Philosophy, processes, and pitfalls', *The regents of the University of California,* 44 (4), 129-50.

Stary, C. (2009), 'Didactic models as design representations', (5613 LNCS), 226-35.

Stoker, L. (2011), 'An Airborne Education', http://www.airforce-technology.com/features/feature106863/, accessed 10-05.

Studer, R., Benjamins, V.R., and Fensel, D. (1998), 'Knowledge Engineering: Principles and methods', *Data and Knowledge Engineering,* 25 (1-2), 161-97.

T

Theiben, M., Hai, R., and Marquardt, W. (2010), 'A framework for work process modeling in the chemical industries', *Computers and Chemical Engineering,* 35, 679-91.

Thompson, J.D. (1967), *Organization in Action* (New York: McGraw-Hill).

Triesch, M. (2011), 'Discussions on current practice ePM and PBO's', (Meetings & interview with Mark Triesch).

Trompenaars, F. (2004), *Culture for Business series: Business across cultures* (West Sussex: Capstone Publishing Ltd).

Turner, J.R. (2008), *The Handbook of Project-Based Management* (3rd edition e.d.; London: McGraw-Hill).

Turner, J.R. and Cochrane, R.A. (1993), 'Goals-and-methods matrix: coping with projects with ill defined goals and/or methods of achieving them', *International Journal of Project Management,* 11 (2), 93-102.

V

van Gisbergen, C. (2011), 'Interview on Work processes of DSM project department', (Audit).

Vaughan, D. (1996), 'The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA', (Chicago: University of Chicago Press.).

W

Wardall, I. (2011), 'Product and Process lessons learned: Similarities and differences between them', (Interview on the phone).

Whitty, S.J. and Maylor, H. (2009), 'And then came Complex Project Management (revised)', *International Journal of Project Management,* 27 (3), 304-10.

Williams, T.M. (1999), 'The need for new paradigms for complex projects', *International Journal of Project Management,* 17 (5), 269-73.

Williams, T.M. (2002), *Modelling complext Projects* (London: John Wiley & Sons).

Williams, T.M. (2005), 'Assessing and moving on from the dominant project management discourse in the light of project overruns', *IEEE transactions on Engineering Management,* 52 (4), 497-508.

Wong, K.Y. (2005), 'Critical success factors for implementing knowledge management in small and medium enterprises', *Industrial Management and Data Systems,* 105 (3), 261-79.

Workflow Management Coalition, W.F.M.C (2011), http://www.wfmc.org/, accessed 15-10.

Appendices

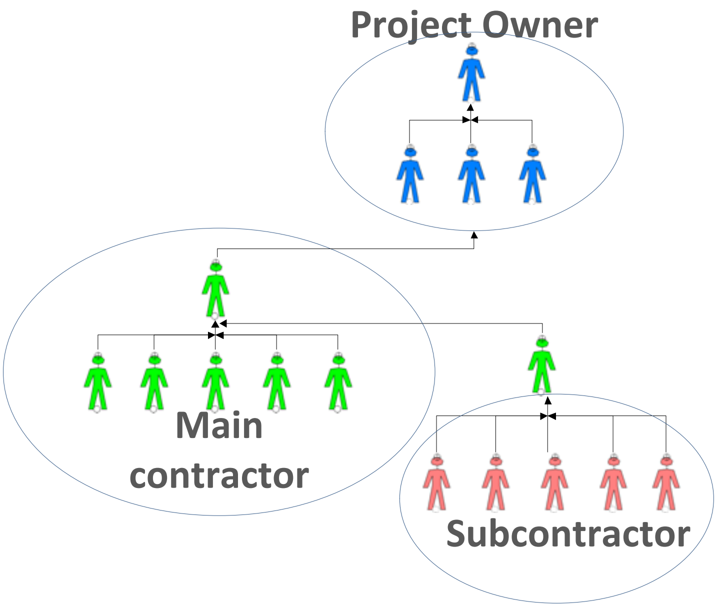
Appendix A Building the model

Appendix A goes in-depth in the construction of the model. While chapter 4 has provided the reader a small insight in all the choices, all choices are listed in A.2. Appendix A.1 shows the conceptual diagrams that were constructed using the assumptions and acted as basis for the construction in SimVision®.

Appendix A.1 Conceptual diagrams

Applying the list of assumptions in the audits with DSM allowed the research to come to conceptual models that served as base. As the focus of this research lays on the EPC phase and the procurement phase is reduced for the sake of simplicity, the conceptual diagrams of the tasks can be viewed in figure 48, figure 49 and figure 50. For the conceptual model of the organizational structure Appendix C.2 goes in-depth into the transformation.

The main part of the conceptual model is the organizational structure. As project team consists of three main roles the conceptual model reflects this. The hierarchical order does not represent the chain of command or the way contracts are arranged, but it represents the flow of information. The assumption is that horizontally information is exchanged on the 'floor' while vertical information is only exchanged in official meetings. The more layers, the more information has to be exchanged in these meetings.



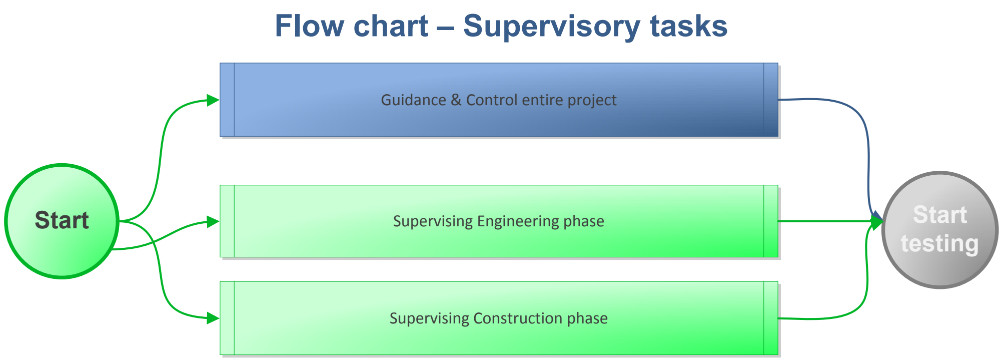


Figure 48`- Supervisory tasks

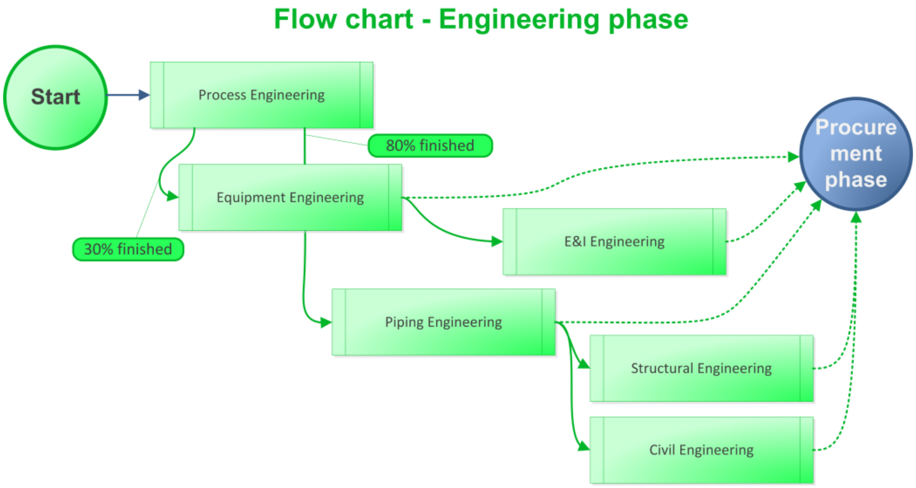


Figure 49 - Conceptual model of the tasks in the engineering phase

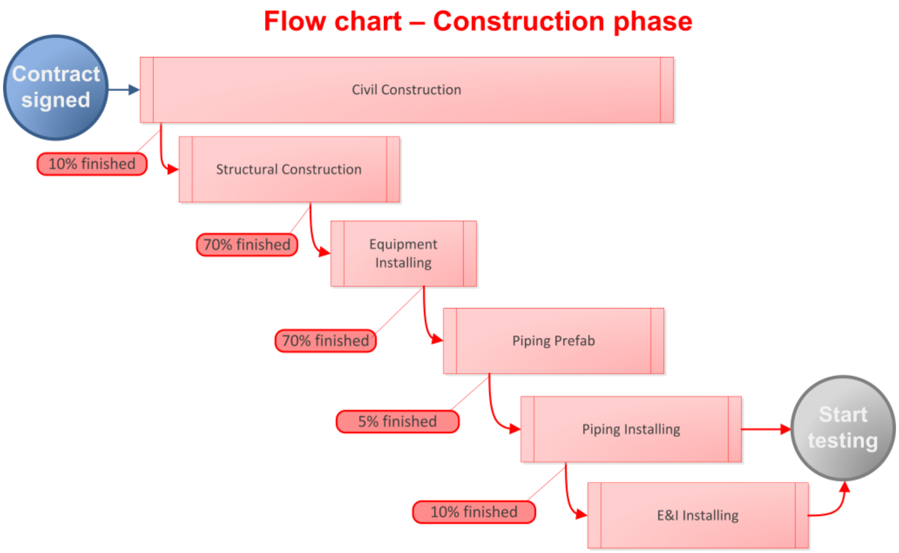


Figure 50 - Conceptual model of the tasks in the engineering phase

Figure 49 starts when the decision has been made by DSM that the proposed installation is deemed feasible for construction. The start is given to the main contractor to start developing the detailed plan on the installation. Each time more detailed plan is finished, other departments can start designing. An argument is given by DSM through reasoning: To know how strong the foundation needs to be of the installation, the engineers need to know what type of equipment will be placed but also the amount of pipes that are connected to these equipment. All these variables add up to the total amount of weight. It all starts thus in designing the process followed by the restrictions on the equipment to achieve the required pressure, temperature etcetera.

When enough information is known the procurement phase can start. When a subcontractor is contracted, Figure 50 starts. Similar to the waterfall structure of the engineering phase, the construction tasks flow from each other. In the audits of DSM became clear that as soon as parts of the piping and the E&I are finished the testing phase can start. As described in appendix B.1, however, this phase is out of the scope of this research.

Appendix A.2 Assumptions & Choices

The simulation model contains a lot of assumptions made by the modeler when information was lacking or when the system was too complex to model completely in the simulation. Table 9 contains all the assumptions that have been made and the choices for these assumptions are listed.

Table 9 - List of assumptions present in the model

Assumptions	Values	Why?
Project phases	Only EPC	DSM has an organic and dynamic structure prior to the Go/No go decision for EPC phase.
Organizations	3 different orgs	In the EPC phases 3 different types of organizations can be identified: People from DSM, the main contractor and the diversity of subcontractors. As names of companies and people involved will differ per project, these functions have been made anonymous.
Organizational structure	Based on information flow, not hierarchy	SimVision® ignores the hierarchy in organizations. What matters are the flows of information between positions. The hierarchy in the simulation model represents therefore the way information flows between positions. It goes vertical to deal with decisions and unexpected errors. Horizontally information does not flow automatically, that requires meetings
Use of colors	Color is related to the involved organizations	To allow swift identification of both the positions and the related tasks, each organization has been designated an own color. DSM has been given a blue color, the main contractor green and the subcontractors are identified with red.
Meetings	Only system meetings which involved horizontal placed positions are modeled	In the system subcontractors do individually with the coordinators in frequent meetings. However, in the model the vertical hierarchy results in frequent contact between the two type of positions. Modeling these meetings would result in double sessions. Therefore only meetings that involved horizontal placed positions are utilized.
Width of tasks	Esthetic similar to expected length	The width of the tasks in the model are purely esthetic. However, the width plays a role in the identification of the experts. Therefore a timeline has been used to show what the expected length of tasks are. That way the tasks show a similarity with the calculated Gant charts.
Milestones	Ready for	According to the audits with DSM, the engineering

	procurement	phase is done in rapid pace of about 4-5 months before procurement can send out their competitions. However, the task of engineering is far from complete at the moment. Therefore milestones are placed at the 75% mark of each engineering task.
Milestones	Procurement to construction delay	The procurement for civil works is the first one that needs to be completed, but is one of the last that can be send to possible subcontractors. To ensure that the model simulates the delay of setting up the procurement and coming to a contract with the subcontractor a delay of 12 weeks has been utilized.
Procurement	Reduces to 1 task	This research recognizes that the procurement phase is vital for the project performances. However, similar to the phases prior to EPC phase, the procurement is dynamic and will require to add a lot of positions and procedures. This would make the model substantially larger and more complex, making the identification of causal relations harder and thus influence the goal of the research negatively.
Successor links	% finish – start	Many of the engineering and construction tasks can start as soon as a portion of a previous task is finished. Through several iteration steps between the modeler and personnel of DSM the percentages of the tasks have been determined. See Appendix B.2 for a graphical overview.
Successor links	Start – start Finish – finish	Supervisory tasks have no assigned work volume, as the duration of these tasks is dependent on the duration of the normal tasks they supervise. To avoid unnecessary links in the model, only a the earliest and latest tasks that a supervisor controls are linked to the supervisory task.
Communication links	Placement & amount	Communication links are used to give additional attention to interdependences between tasks. The guidelines for applying communication links is that the two tasks should be 'significant' related to one another. This is a very subjective criteria, therefore the communication links have been discussed with control managers of DSM to assess the interdependences and make a selection with them.
Rework links	Placement & amount	Rework links are used to provide a feedback loop to previous tasks when work needs to be redone. The guidelines for applying rework links is that the leading task should have a 'significant' affect to the reworked

		task. This is a very subjective criteria, therefore the rework links have been discussed with control managers of DSM to assess the influence and amount of the links and make a selection with them.
Construction tasks	Adding non critical tasks	The purpose of modeling the EPC phase is to find the relations between project structures and the performance on the engineering and construction phase. For this purpose the tasks such as 'installing HVaC' and 'scaffolding' are not essential. They have been added to the model for two reasons. Firstly, they are key for DSM to identify them with the model in terms of work volume, amount of people and total costs. The second reason for adding them is that there are interdependences and relations with the critical elements; making prefab pipes influences the task piping.
Testing phase	Excluded	Similar to the procurement phase, the phase of testing is an important part in the whole process of project execution. Testing the individual systems and finally the installation as a whole are required before the installation can start production. The argument to exclude procurement from the model holds for the testing as well: adding it would result in an even more complex model that forgoes its purpose.
Program settings	Average	The model is specialized in organizational simulation. Therefore parameters about the structure and culture can be determined per case. For the base level, however, an averaged level has been chosen. This is done to give a general representation regardless of specific examples that were given during the audits with DSM.
Fixed costs	Spread out over duration task	Tasks are accompanied by fixed costs due to equipment, vendor costs or the simplified 'support costs'. To avoid that the charts give a sudden jump of costs when a task starts, and the fixed costs are declared, the fixed costs have been spread out over the duration of the tasks. Based on the expected duration of the task the fixed costs are divided over the number of weeks.
Variable costs	Salary of positions	The salaries have been deducted by reverse engineering the total costs of history projects. More about the different salaries can be found in Appendix B.3 Work volumes and costs of DSM's projects

Positions	FTE	As explained in appendix C.3 the work volume per task and the amount of FTE per week were deducted from a history graph provided by DSM. Based on those data FTE's per position were averaged and rounded to reflect more a general project than the specific case provided with the graph.
Positions	Skills & Experience	It is assumed that for the base scenario each position has averaged skills and experience. This allows the scenarios to differentiate and show the influences the skills and experiences have on tasks and on the project performance.
Work Volume	Tasks	Combining all the FTE's per week spend on specific tasks as described in Appendix C.3 the total work volume (including decision wait, rework and coordination work) was extracted. After rounding it up, to represent projects in general the work volume was constructed.
Work Volume	Supervisory tasks	As described, supervisory tasks do not have specifics on work volume. Do they require to note how man FTE's the task occupy. If a position contains 1 person, and the connected supervisory task is occupied by 1 FTE it means that the one person is full time working as supervisor. Especially team leaders do more than merely supervising, therefore the supervisory by rule of thumb are giving the related positions time to other tasks besides supervising, such as attend meetings and make decisions for others.
Work week	40 hours	The simulation model assumes a working days of 8 hours with 5 days in a week.
Revenues	Ignored	For the simplicity of the research the revenues that tasks might include when finished early or finished at all are negated and ignored.

Appendix B Data

This appendix is focused on the data that is gathered, processed and utilized for the simulation model. Appendix B.1 elaborates all the input variables that SimVision ® uses to model the project. Understanding the influences the input variables have on the output is the key to understanding the causal relations of the system the simulation model is representing. Appendices B.2 and B.3 lay the focus on the transformation from raw data into used data for the organization structure, the costs and the work volume of DSM projects.

Appendix B.1 Input variables

SimVision utilizes about twenty input variables to produce its simulations. The variables can be divided in Behavior, Project, Cultural and Organizational parameters. Together the input variables influences tasks by modifying the quantity needed to perform work, rework, waiting for a decision and time needed to coordinate information. In the table 10 below the input variables and their effect are summarized.

Table 10 - Complete list of input variables and their effect

Input variable	Description of variable & its effect on project
Team experience	lowers the need for information exchange and thus lowers coordination time
Centralization	Increases decision wait as managers need to make more decisions, and will request more rework
Formalization	Results to formal interaction between positions. High setting halves the info exchange prob., while low setting doubles the info exchange
Matrix Strength	Results in high information exchange and lower attendance of meetings. Medium is equal (70%) and low is opposite. Matrix Strength complements with reversed formalization
Information exchange prob.	Relates to high interdependent tasks by less skilled/busy workers
Information exchange sett.	Sets the base level for the information exchange probability
Noise prob.	Increases the rework, as people are not focused while doing their job
Functional error prob.	Increases the amount of rework, even without rework links
Functional error sett.	Sets the base level for the functional error probability
Project Error prob.	Increases the amount of rework if rework links are present
Project Error sett.	Sets the base level for the project error probability
Application experience	Reduces the work time. It affects work processing speed, not the amount of rework. Tells about experience, not skill of position!

Skill level	Reduces the work time. Skills need to match the skill that is attached to a task to be effective
Requirement complexity	Increases the functional exception levels, thus longer duration and more errors
Solution complexity	Increases the project exception levels, thus longer duration and more errors
Uncertainty	Increases coordination volume
Primary task	The main task assigned to a person or position
Secondary activity	Other tasks that need to be performed by a person or position
Priority of task	Adjusting the level of priority
Size organization	Is an indicator of the amount of positions or people involved with the project. The larger the organization, the more information needs to be shared between people, more managers need to make decisions increasing the decision wait time

Appendix B.2 Organizational structure of DSM's projects

Phase 2 of the project focuses on the work processes of DSM's project department. To model the Engineering, Procurement and Construction management (EPC) phases of a project, data on their organizational structures are gathered. Through multiple audits with their project and control managers (interviews with C. van Gisbergen, H van D, W. Dekkers, H. Linssen, B. Sartorius, 2011) a high level organizational structure was constructed. Using the high level structure as a first conceptual model representing the system the translation to the experimental model structure was possible.

With the process of translation a shift in hierarchy was made. The original organogram as seen at the top of Figure 51, focuses on which position is legally connected to one another. In the simulation the hierarchy is based on how information flows between positions. The biggest adjust is that the subcontractors are dealing with the coordinators of the main contractors on a daily basis and not with the client team. The main reason for this change is because the main contractor knows the ins and out of the design while the client team has expertise on manager projects on a higher aggregation level.

Table 11 - Positions and their attributes

Position	FTE	Salary	Primary task	Attends meeting
Client team	6	110	Guidance & Control	-Project progress meeting -Procurement meeting
Procurement Manager	1	90	Procurement	-Procurement meeting
MC – Team leader	1	110	Supervising MC activities	-Project progress meeting -Main contractor meeting
Engineer –	6	100	Engineering – Process	-Main contractor meeting

Process				
Engineer – Equipment	5	100	Engineering – Equipment	-Main contractor meeting
Engineer – Civil works	8	100	Engineering – Civil works	-Main contractor meeting
Engineer – Structural	7	100	Engineering – Structural framework	-Main contractor meeting
Engineer – E&I	5	100	Engineering – E&I	-Main contractor meeting
Engineer – Piping	10	100	Engineering – Piping	-Main contractor meeting
MC - Coordinator	5	100	Supervising construction site	-Project progress meeting -Main contractor meeting -Civil construction meeting -Interior meeting
Equipment Installers	1	85	Placing equipment	-Civil construction meeting -Interior meeting
Civil Works	55	85	Placing civil construction	-Civil construction meeting
Structural Framework	70	85	Building Structural framework	-Civil construction meeting -Interior meeting
Prefab piping	20	85	Making prefab pipes	-Interior meeting
Infrastructure	10	85	Building infrastructure	-Interior meeting
Scaffolding	15	85	Placing scaffolding	-Interior meeting
Piping	65	85	Piping	-Interior meeting
E&I	55	85	Installing E&I	-Interior meeting
HVaC	7	85	Installing HVaC	-Interior meeting
Insulation	18	85	Installing insulation	-Interior meeting

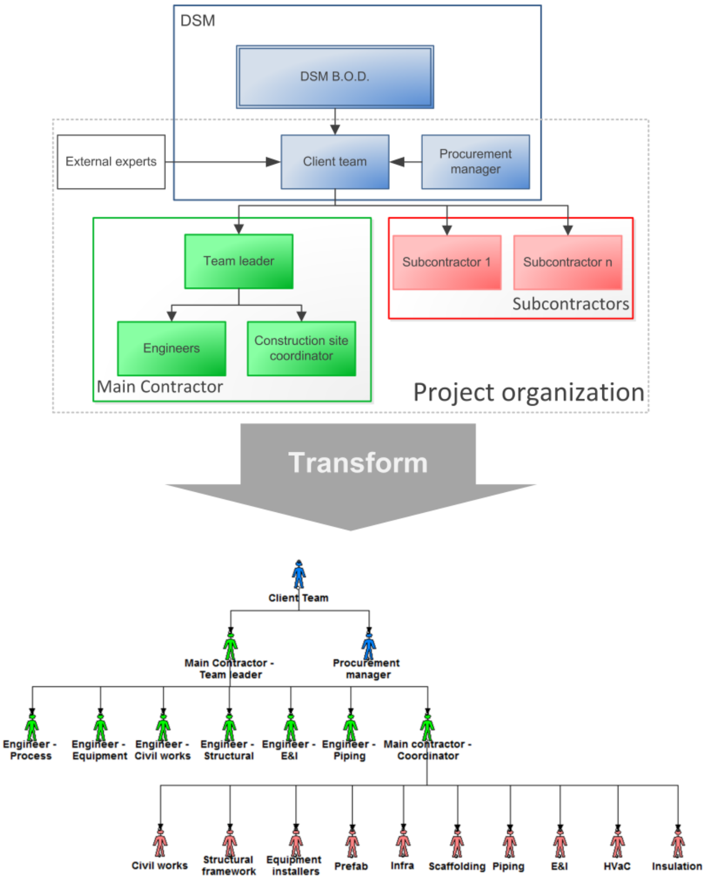


Figure 51 - Translating conceptual organogram of projects into the simulation model

Appendix B.3 Work volumes and costs of DSM's projects

The only source of information for the work volumes was a graph showing the declared FTE per week per subcontractor over the entire construction phase (Figure 52) and a high level overview of the costs at the end of the project (Table 12).

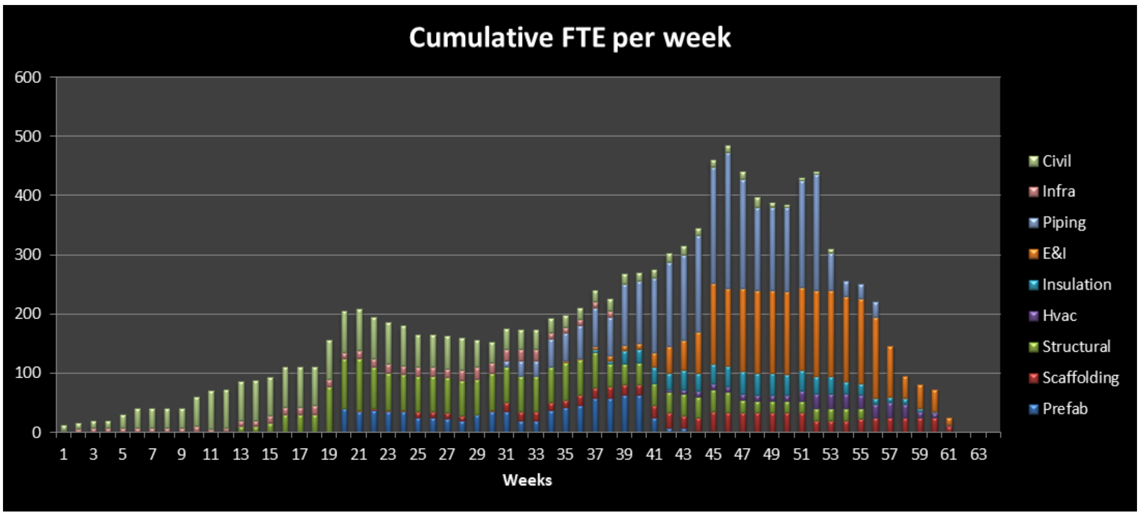


Figure 52 - Graphical overview of FTE's per week per subcontractor as provided by DSM

Table 12 - Rough cost overview as provided by DSM

	Budget per company	
Company	**type**	**Euro´s**
Civil works	labor	3.750.000
Structural	labor	3.750.000
Equipment	fixed	9.000.000
Prefab	labor	1.190.000
Piping	labor	4.420.000
	fixed	1.500.000
E&I	labor	4.080.000
	fixed	1.500.000
Scaffolding	labor	3.500.000
Infrastructure	labor	1.020.000
HVaC	labor	510.000
Insulation	labor	1.190.000
Main Contractor	labor	10.000.000
Client Team	labor	7.000.000
	extern	3.000.000
	Total	55.410.000

Combining the above two raw data allows to create more information on how many people are working per subcontractor and what their salary is. The result are given in Table 13 below. What immediately is noticeable is the high amount for Piping and E&I. After consulting with DSM it turned out that this specific case had encountered trouble with numerous delays and had to catch up to get back on schedule. When the costs for these data are placed on a cumulative scale, see, the total costs for purely the construction phase is already 40 million, while the budget on average for the entire project is 50-55 million which includes of about 20 million labor costs by the main contractor and the client team.

Despite the high accumulative costs, the S-curve it represents can serve a as measurement for the simulation model as it should project a similar curve. As can be concluded from Figure 53 and Figure 54 is that the simulated labor costs represent the flow of the historic growth fairly well.

Table 13 - Amount FTE per company as derived from Figure 52

		FTE during project			
Company	**Min (FTE/wk)**	**Max (FTE/wk)**	**AVG (FTE/wk)**	**Total (FTE)**	**Weeks worked**
Civil works	5	70	35	1868	53
Structural	2,5	88	42	1863	44
Equipment					
Prefab	2,5	63	32	825	26
Piping	10	230	103	2668	26
E&I	2,5	145	79	2125	27

Scaffolding	2,5	33	19	743	40
Infrastructure	2,5	20	12	443	38
HVaC	2,5	25	14	288	20
Insulation	2,5	38	23	560	24
Main Contractor			50		
Client Team			12		

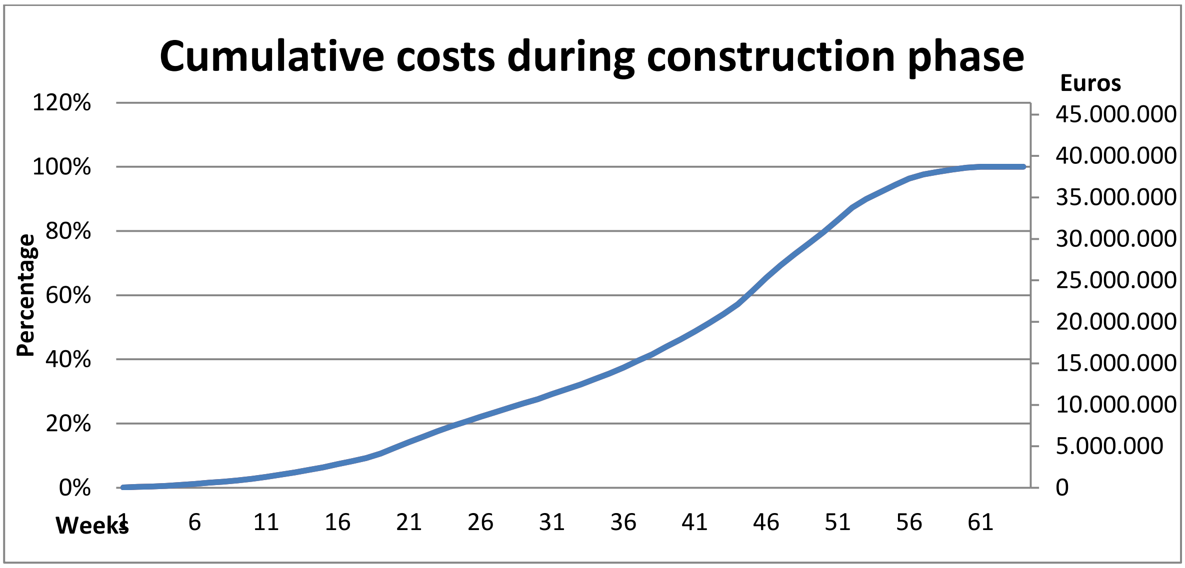


Figure 53 - Cumulative costs derived by multiplying Figure 52 with salaries

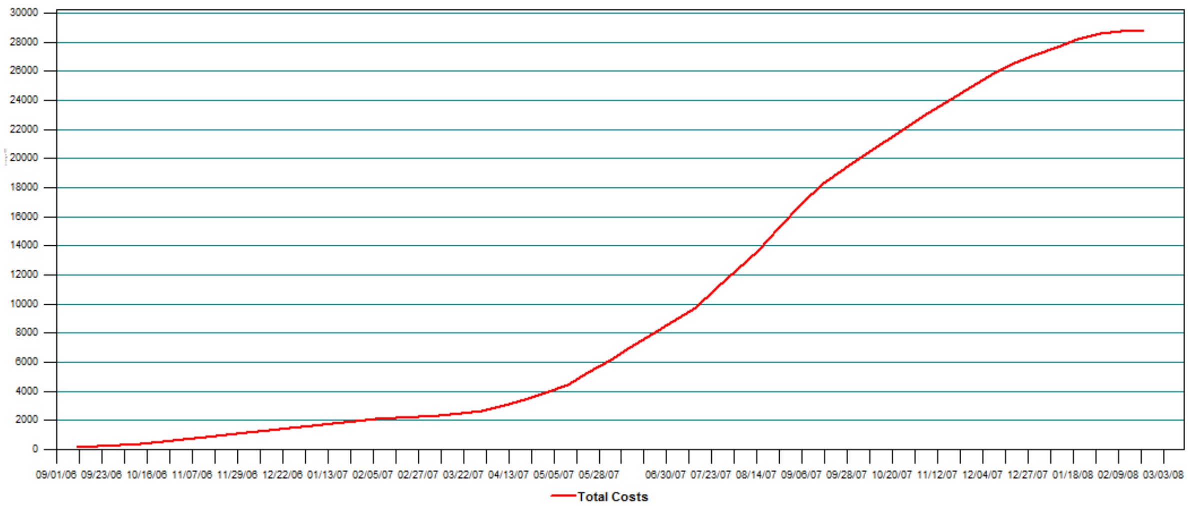


Figure 54 - Simulated cumulative costs during construction phase

Data from case specific model

The additional input data is given below, while the main input was given in section 6.2. Figures 55-58 are complementary to the data shown in section 6.2 from the report.

Rework	Strength	Units	Connected From	Connected To
1	1	Days	Piping	Making Prefab pipes
2	1	Days	Piping	Installing E&I
3	1	Days	Placing Equipment	Piping
4	0.5	Days	Piping	Engineering - Piping
5	0.5	Days	Installing E&I	Engineering - E&I
6	0.5	Days	Placing Civil construction	Engineering - Civil works
7	0.5	Days	Building Structural framework	Engineering - Structural framework

Figure 55 - Rework links in the model

Communication	Connected From	Connected To
1	Building Structural framework	Placing Equipment
2	Placing Civil construction	Building Structural framework
3	Making Prefab pipes	Piping
4	Piping	Installing E&I
5	Engineering - Piping	Engineering - E&I
6	Engineering - Structural framework	Engineering - Civil works
7	Engineering - Equipment	Engineering - Piping
8	Engineering - Process	Engineering - Equipment
9	Engineering - Piping	Engineering - Structural framework
10	Engineering - Equipment	Engineering - Civil works
11	Piping	Building Infrastructure

Figure 56 - Communication links in the model

Successor	Type	Lag	Units	Connected From	Connected To
1	Start-Start	75	% Complete	Placing Civil construction	Placing Scaffolding
2	Start-Start	75	% Complete	Building Structural framework	Installing HVaC
3	Start-Start	75	% Complete	Building Structural framework	Installing Insulation
4	Start-Start	75	% Complete	Engineering - Process	Process ready for procurement
5	Start-Start	75	% Complete	Engineering - Equipment	Equipment ready for procurement
6	Start-Start	75	% Complete	Engineering - Piping	Piping ready for procurement
7	Start-Start	75	% Complete	Engineering - E&I	E&I ready for procurement
8	Start-Start	75	% Complete	Engineering - Civil works	Civil works ready for procurement
9	Start-Start	75	% Complete	Engineering - Structural framework	Structural ready for procurement
10	Start-Start	70	% Complete	Engineering - Process	Engineering - Piping
11	Start-Start	50	% Complete	Making Prefab pipes	Piping
12	Start-Start	50	% Complete	Piping	Installing Insulation
13	Start-Start	40	% Complete	Building Structural framework	Piping
14	Start-Start	30	% Complete	Placing Civil construction	Building Structural framework
15	Start-Start	30	% Complete	Placing Civil construction	Placing Equipment
16	Start-Start	30	% Complete	Building Structural framework	Placing Equipment
17	Start-Start	25	% Complete	Piping	Installing E&I
18	Start-Start	25	% Complete	Building Structural framework	Placing Scaffolding
19	Start-Start	25	% Complete	Engineering - Process	Engineering - Equipment
20	Start-Start	10	% Complete	Placing Civil construction	Building Infrastructure
21	Start-Start	5	% Complete	Building Structural framework	Making Prefab pipes

Figure 57 - Sequence of tasks in the model

Meeting Participant	Allocation	Connected From	Connected To
1	100	Client Team	Project Progress Meeting
2	100	Main Contractor - Team leader	Project Progress Meeting
3	100	Main contractor - Coordinator	Project Progress Meeting
4	100	Procurement	Procurement Meeting
5	100	Client Team	Procurement Meeting
6	100	Main Contractor - Team leader	Main Contractor Meeting
7	100	Engineer - E&I	Main Contractor Meeting
8	100	Engineer - Structural	Main Contractor Meeting
9	100	Engineer - Civil works	Main Contractor Meeting
10	100	Engineer - Equipment	Main Contractor Meeting
11	100	Engineer - Process	Main Contractor Meeting
12	100	Engineer - Piping	Main Contractor Meeting
13	100	Main contractor - Coordinator	Main Contractor Meeting
14	100	Main contractor - Coordinator	Construction Site interior meeting
15	100	HVaC	Construction Site interior meeting
16	100	E&I	Construction Site interior meeting
17	100	Piping	Construction Site interior meeting
18	100	Scaffolding	Construction Site interior meeting
19	100	Infra	Construction Site interior meeting
20	100	Prefab	Construction Site interior meeting
21	100	Insulation	Construction Site interior meeting
22	100	Civil Engineer - Structural framework	Construction Site interior meeting
23	100	Main contractor - Coordinator	Construction Site Civil construction meeting
24	100	Civil Engineer - Civil works	Construction Site Civil construction meeting
25	100	Civil Engineer - Structural framework	Construction Site Civil construction meeting
26	100	Equipment installers	Construction Site Civil construction meeting

Figure 58 - Positions that attend meetings

Appendix C Complexities in the work process

In this appendix the complexities that were found in the work processes of DSM are discussed. First the complexities are listed, followed by the what if scenarios that were constructed based upon these complexities. This appendix ends with the construction and results of the workshop which was performed with people of DSM.

Appendix C.1 Complexities

Following the TOE framework of Bosch-Rekveldt (2011) 17 major organizational complexities are identified. It is the believe of this research that these complexities are determined by the organizational and cultural characteristics of the PBO's within the project team. Using SimVision the organizational complexities have been linked to the following input variables, see table 14.

Table 14 - Organizational complexities within case specific model

Complexity as defined by Bosch-Rekveldt (2011)	Complexity as present in model
High project schedule drive	Focus on costs, project length and quality
Resource & Skills availability	Available FTE per position Skills per position
Experience with parties involved	Team experience
Interfaces between different disciplines	Information flows between positions Formalization
Size of the project team	Organizational structure through positions layout
Trust in project team	Centralization Information exchange probability
Trust in contractor	Centralization Information exchange probability
Organizational risks	Noise probability Information exchange probability Project error probability Functional error probability

Based on Table 14 the research designed 3 scenarios that reflect a group of complexities. As the objective of the research is to create insight in the influence of the complexities the choice was made to divide the complexities into the additional work groups: Rework, coordination and decision wait. With these groups what if scenarios were constructed.

Appendix C.2 What if scenarios

The identified complexities that were found after validation the model are grouped and placed into a what-if scenario

Simple example – Increased rework

In this scenario the subcontractor that does the piping has employed a group of less skilled workers. The group consists of people that lack the years of experience and that results in less efficient work. Not only will they take longer to do the same amount of work, the percentage of error is higher and thus more rework is required to get to the same level of quality.

To make the scenario is bit more heavier, the coordinators hired by the main contractor have not done this type of project before. While they have years of experience and are qualified for the job, it still is the first time that do similar tasks as is required for this project. Table 15 and Figure 59 show the influence of the scenario on project performance.

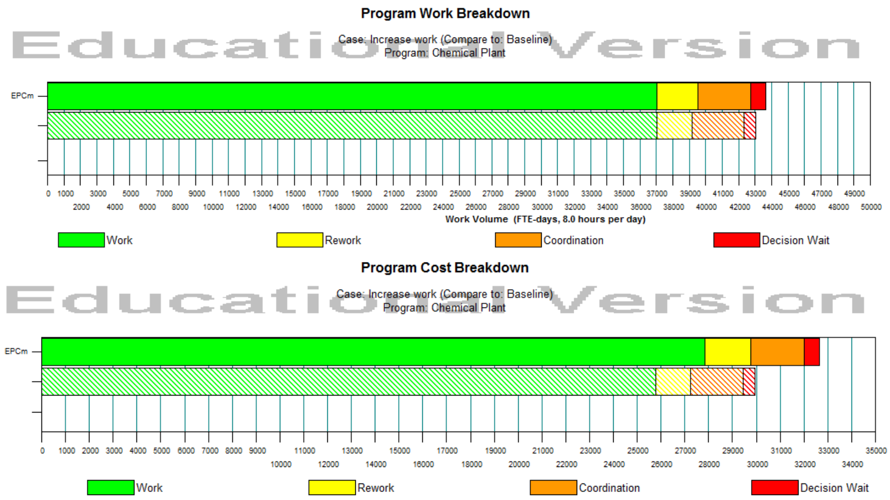


Figure 59 - Performance scenario compared to base case

Table 15 - project performance scenario 1

Length of project i.r.t base	**102,2%**
Total costs of project i.r.t. base	106.2%

The scenario shows that the amount of work stays the same, while the amount of rework slightly increases. At first glance nothing to worry about, especially since the date that the project is finished is delayed with only two weeks. The reason why this scenario is important is due to the increased costs. As is shown in Figure 59 the costs to perform the same amount of work, as indicated with the green block, is increased with an additional 2 million euro's. This is an increase of about 8% compared to the base scenario due to the low skilled employees required more time.

When faced with this scenario, there are a couple of considerations to make. The first one is that when it becomes apparent that the skills of workers and the experience of coordinators are less than optimal, it is too late to change the contracts. Therefore the project leader has to accept the pace of the current workers of the subcontractor.

Accepting the pace is something different than ignoring the problem. By following the chain of command the project manager can steer the main contractor to deal with the subcontractor. The subcontractor is most likely put more workers on the task, in order to get the progress of the work to the level of the base case, completing the project within the same time. At the same time the main contractor needs to put additional people, or replace the old ones, to the supervisory task to ensure that all additional issues that arise with the increased pace are dealt with.
By using more men hours for the same work volume, the project will lead to more expenses for that task. By speeding up the slacking task, however, other actions within the model do not have to wait nor do supervisors have to work the additional 2 weeks. The effect of the additional men hours is that the costs are about the same as when the problem is identified, but is done within the same time as the base scenario. In reality this is doubtful, as the interdependent tasks such as E&I and scaffolding incurred their delay already and initially will not follow the increase of pace by the piping crew without additional efforts. The summarized solution of this scenario and its impact on project performance in comparison with the given scenario are stated in figure 60 and table 16.

Table 16 - Solution scenario 1

Solution for scenario 'increased work'	
Main contractor coordinators	Extra men hours or add extra employee
Subcontractor	Extra men hours or add extra employees

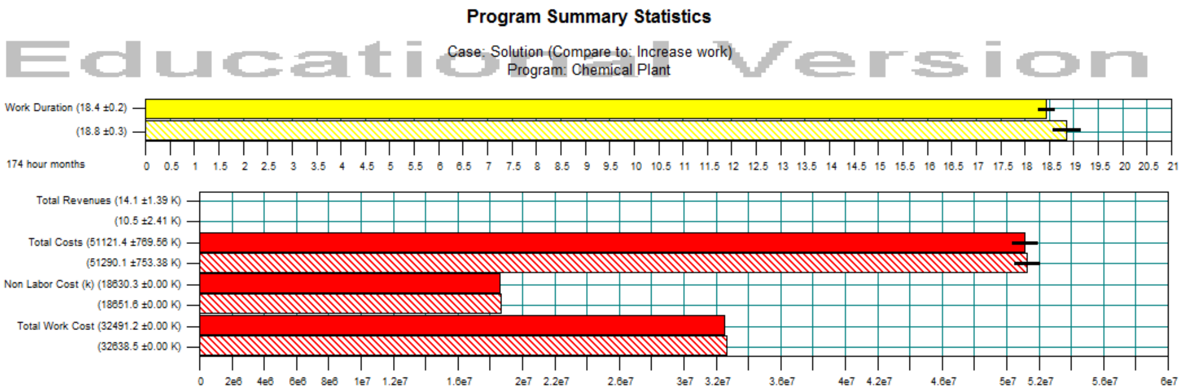


Figure 60 - Summary of project statistics of the solution vs. the problem

Medium example – Increased decision wait

The second scenario places the emphases on the time lost waiting for decisions to be made. In this scenario the culture of the people involved in the project is defined as highly centralized. This means that any decision that is not predetermined will go through the superior as identified in the organizational structure. Furthermore, the workers that are behind schedule will not automatically join a meeting, as they value the opportunity to catch up on some work equally to attending the meeting. Compared with the base scenario, where the centralization is considered 'normal' and the meetings are indicated as vital, the results are shown in table 17, figure 61 and figure 62.

Table 17 - Project performance of scenario 2

Length of project i.r.t base	102,7%
Total costs of project i.r.t. base	107.5%

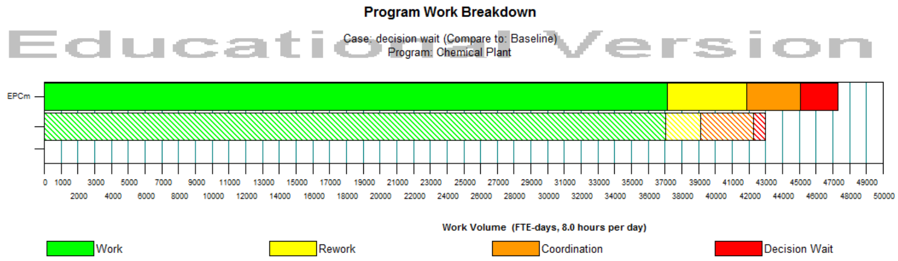


Figure 61 - Effects on work volumes when using a highly centralized organization

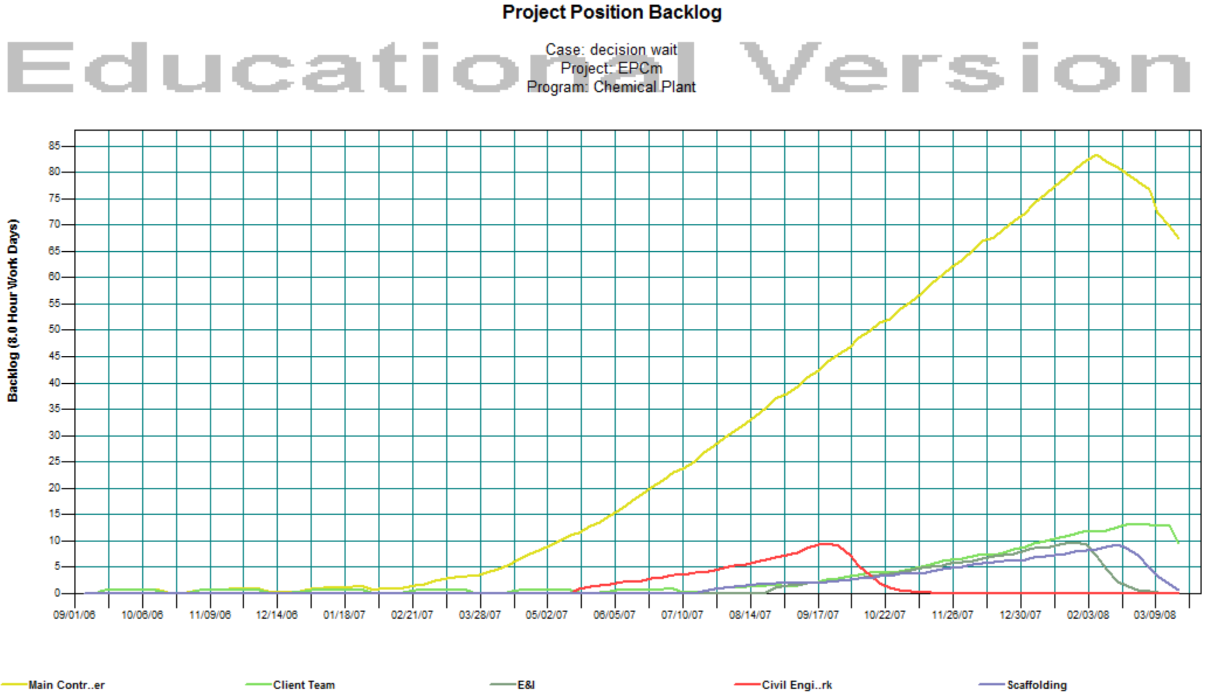


Figure 62 – Top 5 positions with backlog

The effect of the scenario is that a lot of decisions need to be made by the project leader of the main contractor. With all these requests this position cannot cope with the work load resulting in an increasing backlog. As a consequence decisions will lay on his desk to an extent that workers will make a decision for themselves. When the superior does get to the issue he can judge that the solution is ill-chosen and demands to rework the issue.

The solution for this scenario is fairly simply on paper, but will require quite some people skills to achieve. As the culture is identified as 'formal', information is not frequently shared outside of meetings. To utilize this characteristic, it is vital that everyone attends the meetings. As the meetings in which the issues can be raised and discussed are weekly, it should be doable to structure everyone's agenda to increase their attendance.
The prioritizing of the meetings is part of the solution, as the amount of questions towards supervisors remain. To decrease the backlog, and thus the stress on the team leader of the main contractor, another person should be added to this position. This does not have to be a full time position. This way the main team leader can deal with the more difficult issues while the auxiliary team leader takes some of the more routine tasks. The solution variables are summarized in table 18, while its effects are shown in figure 63.

Table 18 - Solution variables for scenario 2

Solution for scenario 'increased decision wait'	
Position team leader main contractor	Add auxiliary team leader
Meetings	Prioritize attendance

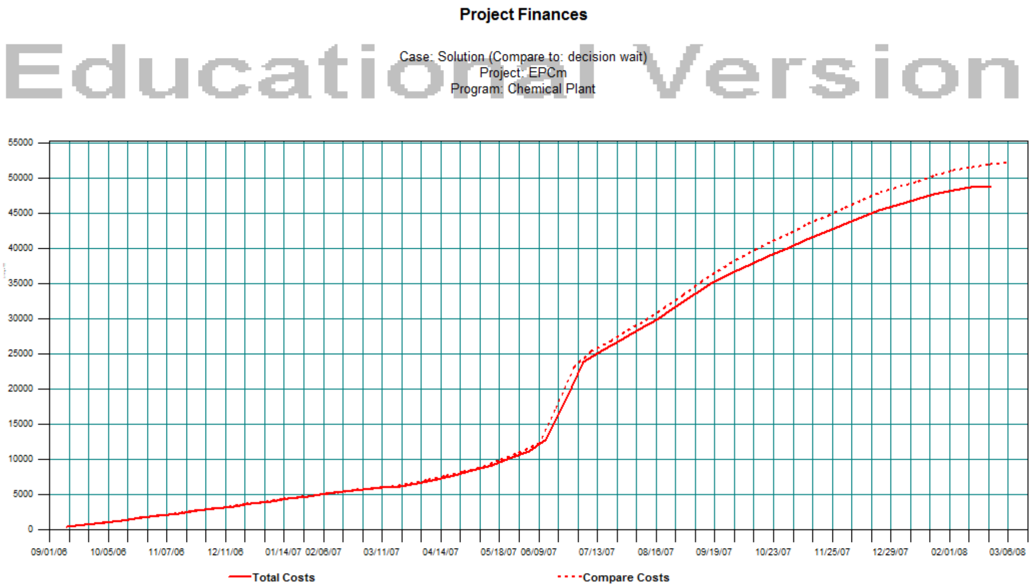


Figure 63 - Cost progression throughout the project. A comparison between solution and problem

Difficult example – Increased coordination

The last scenario that will be discussed here combines organizational and cultural parameters that shape the structure of the project team. The goal of this scenario is to show the importance of information flowing within the organization. While the first scenario focused on the work volume and the second on the team leaders, this scenario focuses on the coordination between positions to achieve their tasks. Therefore the information exchange probability has been doubled, meaning that twice as many information is flowing between positions than in the base case. The team experience is reduced to increase the amount of information that needs to flow in order to achieve the same quality. Furthermore the matrix strength is lowered which means that people are situated as if they are geographically working distant with each other and thus cannot quickly ask a question, but need to put effort in to ask questions. To make matters worse, the culture is defined as decentralized and less formal to give less meaning to the meetings. The effects of this scenario can be viewed in Table 19, Figure 64 and Figure 65.

Table 19 - Project performance scenario 3

Length of project i.r.t base	**101,1%**
Total costs of project i.r.t. base	107.8%

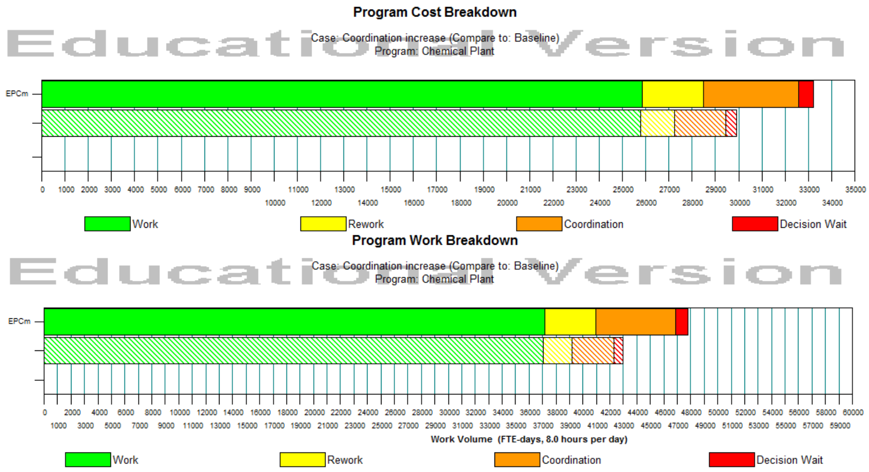


Figure 64 - Program breakdown for scenario 3

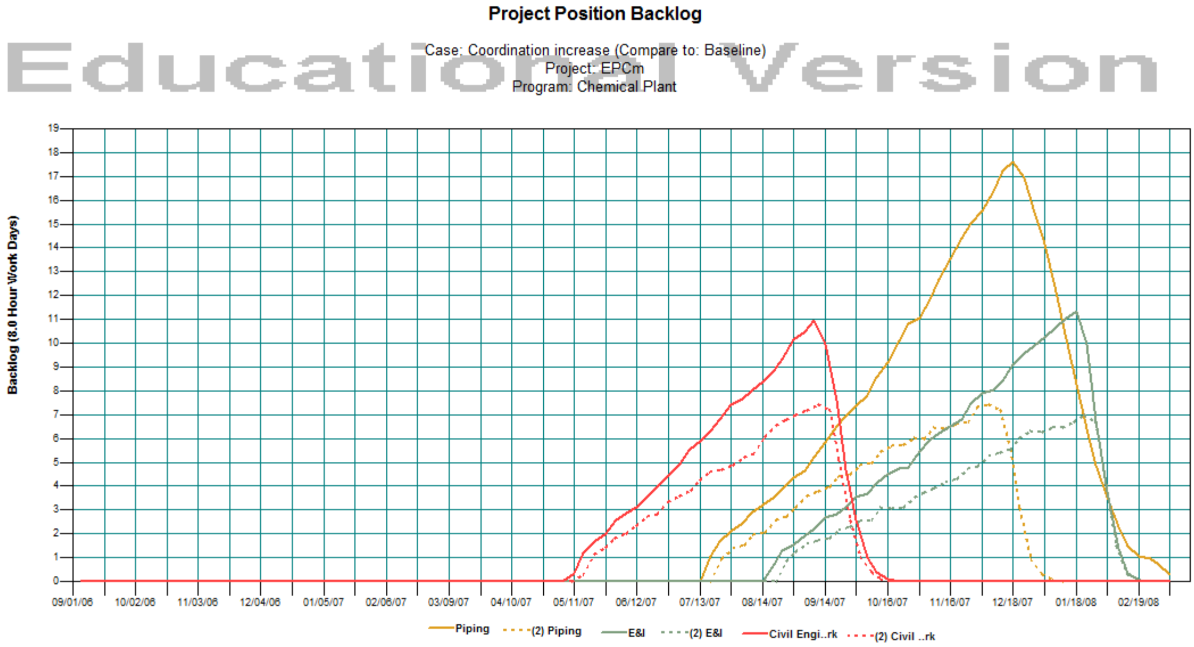


Figure 65 - Backlog due to increased coordination

Similar to scenario 2, the solution is found in using the culture that is provided, see table 20. As the organization is decentralized, information will not flow on itself very easily. By increasing the level of formalization from low to medium, the required communication will be done through formal communication channels. To achieve this, procedures need to be sharpened which will require a cultural change of the parties involved, which will not be an easy task but required to utilize the culture. The effect of increasing the formalization is drastic. The amount of work defined as rework, coordination and decision wait is halved. This shows the importance of having procedures matching the cultural and structure of the project.

Table 20 - Solution for scenario 3

Solution for scenario 'increased coordination'	
Formalization of project team	Increase via procedures

Appendix C.2 Workshop

Using the three what if scenarios a story for each scenario was constructed, see below. Ones read, the participants were asked to answer the other fields of the template, see Table 21.

Table 21 - Enquiry template

Response sheet scenarios	
Scenario	<name>
Description ***<given>***	<story> project goes good/bad, here and there problems -characteristic 1 -characteristic 2 -characteristic 3
Expected behavior ***<by expert>***	<room for text>
Source of behavior ***<by expert>***	<room for text>
Solution ***<by expert>***	<room for text>
Compare with the results from model & Discuss	
Reaction ***<by expert>***	<response on hearing model cause + solution>

Scenario 1:

The build of a new installation goes according to schedule. The detailed plan was developed in time and thus far the experience with the main contractor was positive. This can, however, not be said about some of the subcontractors. Especially the 'piping team' is of concern to you. Their rate of errors is higher than what you anticipated and they require more attention of the coordinators, whom are struggling to get everything aligned within the structured meetings. It is clear that, while they have the skills on coordinating interfaces, it is their first job in industrial construction

Scenario 2:

The project estimates on work volumes are dead on, both designing and construction engineers are skilled workers and do their work with efficiency. As the involved organizations are relatively new to each other, the form of communication is rather formal and thus all decisions are taken up with the corresponding supervisors. This additional work load puts pressure on the top of the project team, especially as the attendance of meetings is not stressed and people judge the task of catching up on past work equally important as attending meetings.

Scenario 3:
The project (EPC phase) has not yet started, but the following estimations have been made:
-The contracted Main contractor is new for DSM. All contacts are fresh and thus as a whole the project team is new. From what you have gathered the culture of the MC is based on decentralized operations and expect each division to do his job and gather the required information on its own.
-The project aims of the construction of a new innovative product and thus a lot details are uncertain at the start to both the MC and the client team.

Appendix C.3 Results

From the workshop the following conclusions can be drawn;

Participants were able to relate the scenarios with their own experiences. While not all of the scenarios had personally occurred, the participants were able to identify the behavior that was modeled in each scenario and foresee its effect on project performances.

The participants could identify causes when related to productivity and men hours, but had trouble identifying whether the given organization structure fitted the sketched project. This confirms what is experienced by ePM; An overly focus on man-hours and performance factors, missing the causes behind the performances such as organizational and cultural parameters (Triesch, 2011).

Participants see work processes as organization independent. Focusing on man-hours and performance factors, one could argue that a detailed work process can be optimize to be fitted for a range of projects. However as became clear in section 6.2, each project contains characteristics which always require modifications to generalized work processes to keep productivity on par.

Following the previous conclusions; project, organizational and cultural parameters were not earlier subject of discussion by DSM when discussing the projects work process. These parameters were seen as given if identified at all.

The work processes on the EPC phase of DSM contained a slim partition on the level of organizational structure. The work process is built around the assumption that experienced project managers are in charge and that the projects are too dynamic to relate any useful information in the form of standards.