Supporting risk management for project business processes with a business artifacts tool a case study at CityTec

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Award date:
2020

Eindhoven, 20 December 2019

Supporting risk management for project business processes with a business artifacts tool

A case study at CityTec
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In partial fulfilment of the requirements for the degree of
Master of Science
in Operations Management and Logistics

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TUe School of Industrial Engineering.

Series Master Theses Operations Management and Logistics.

Subject headings: business process modeling, business artifacts, risk management, risk aware business process management, Guard-Stage-Milestone, project business process, tool

Abstract

This research, conducted at CityTec, focuses on integrating risk management in the project business process. The aim of this research is to design a tool to manage and monitor risks within the project business process of CityTec. The project business process is mapped by using the Guard-Stage-Milestone (GSM) notation. The Guard-Stage-Milestone (GSM) notation is a widely used artifact-centric model technique in previous studies for defining these business processes, which allows flexibility in the process execution. While managing risks in activity-centric business process modeling has been a subject of active research in the past few years, managing risks in artifact-centric modeling approaches are not discussed yet. This research introduces the Risk-aware Guard-Stage-Milestone (R-GSM) modeling approach that integrates risk management in an artifact-centric business process model. The tool designed is based on this R-GSM model, which manages and monitors the risks in the project business process for each project conducted by CityTec.

Management summary

This research focuses on integrating risk management in the project business process of CityTec, which is one of the major players in the public lighting market in The Netherlands. The projects conducted by CityTec consist of placing or exchanging streetlights or other related installations. This research focuses on the management of the processes performed to execute these projects and how risks can be managed within these projects.

Problem statement

Projects are playing an important role in the activities of CityTec and form a major part of the yearly revenue. Managing these projects are therefore crucial for the success of the organization. Projects differentiate from standard business processes by its size and complexity, which influence the lead time and costs in a negative way. At the time of writing, CityTec has problems managing and monitoring the projects they conduct which results in projects that are over-budget and/or delayed. The stakeholders assign the areas of communication, information system and risks as main drivers for this problem. In the current situation, departments are working in isolation. The limited communication and transparency between the departments lead to wrong decision making, long throughput times and non-optimal costs during the projects. Beside the communication problem, risks are not managed during the execution of the projects and the information system is not designed for managing and monitoring the processes during the project execution. These findings deliver the following main research question, which is central to this study.

> ***Main research question:***
> How can a tool be designed to manage and monitor risks within the project business process of CityTec?

Research methodology

This research starts by understanding the project business process of CityTec by conducting interviews with the actors involved in this process. The goal of these semi-structured interviews is to gather as much information as possible about their work processes, applications and tools they use, their responsibilities, their communication with other stakeholders etc. . The information gathered in these interviews are processed in a number of models with different viewpoints. First, a communication model is created to give a rough overview of the interactions between actors in the project business process. In addition, a UML class diagram is created to know which information drives the project business process and how these data attributes are interconnected.

The next step in this research is to identify and analyze the risks in the project business process. The framework of PMBOK is used to identify and analyze risks in the project business process. Risks are coupled to the individual classes of the communication model and UML class diagram by the actors involved in the project business process and by analyzing finished projects that had some problems in the past. The probability and impact of these risks are based on both qualitative as quantitative analysis. Thereafter, the risks responses and risk owners are assigned to the risks based on brainstorm sessions with the actors involved in the project business process.

The risks identified are integrated in an artifact-centric business process model. The communication model and the UML class diagram forming the base structure of the Guard-Stage-Milestone (GSM) model, which maps the process by specifying the possible ways that an artifact might progress though the business process and respond to events. This modeling technique is useful for modeling business process that require flexibility in the execution of these processes. After the project business process is designed based on the GSM notation, risk management is integrated within this model.

A tool is designed based on this risk-aware GSM model to monitor and manage risk within the project business process in practice. The design of the tool is based on the requirements that are provided by the stakeholders in the project business process. The tool will visualize the phases of individual projects, the status of the project and the corresponding risks of the phases and the whole project. The tool is evaluated by the judgments of the end users of the tool and by sample cases to indicate the impact of the tool on the project business process of CityTec.

Results

The project business process is mapped with the use of the GSM notation. The GSM model consists of an information model that captures all the business-relevant data about entities of that type, and a lifecycle model, that specifies the possible ways that an entity might progress through the business process. Previous studies do not discussed managing risks in artifact-centric business process models. Therefore, this research introduces a new risk-aware artifact-centric business process modeling approach called the Risk-aware Guard-Stage-Milestone (R-GSM) model. This introduced modeling approach adds risk management to the existing GSM model of Hull, et al., (2010). Risks are linked to stages and milestones in the GSM model and become active when the condition of the risk sensor holds. The risk owner is added to this model for assigning the responsibility of the risk response. Risk management is integrated in the project business process of CityTec according to this new R-GSM modeling approach.

The designed tool is based on the R-GSM model of the project business process of CityTec. Functional and non-functional requirements are drafted by the actors in the project business process. These requirements are the main driver of the tool design. A data flow diagram is created to give an indication of the information input and output of the R-GSM tool. The planner gathers the data of the ERP system and updates the database of the R-GSM tool with the updated data of the ERP system ones a day. Changes performed by the end users in the R-GSM tool are automatically changed in the database.

The R-GSM tool is programmed in Excel VBA. The sentries and risk rules of the R-GSM model are programmed to make the tool dynamic. Projects can be searched in the tool and the data of these projects are searched in the database of the tool. The sentries and rules are applied on this project data to visualize the current status and risks in a particular project. A dashboard is created in the tool, which was one of the requirements, for visualizing the status and risks in the projects at a glance, and the financial overview of the projects.

The evaluation of the tool is performed by applying the tool on test cases and by the judgment of the end users. Because there are no tools in place at the moment, the stakeholders who cooperate in this evaluation, are asked to filter risks in sample project cases manually. The stakeholders are asked individually to point out all risks in the project cases. Thereafter, these projects are searched in the designed tool and the risks assigned by the R-GSM tool are compared to the risks in pointed out by the stakeholders manually. In the test cases, the R-GSM tool identified 3 times as many risks that the stakeholders identified manually. Beside the increase of identified risks, the R-GSM tool identifies all risks in a few seconds while manually risk identification took 10-15 minutes per project.

Conclusion

This research is focused on managing risks in the project business process of CityTec with the use of a tool. The artifact-centric business process modeling technique is a suitable approach to model the project business process of CityTec, due to the flexibility in the execution of the processes in this model. Integrating risk management is though not discussed in literature yet. Therefore, this research introduces a risk-aware artifact-centric business process modeling technique called the Risk-aware Guard-Stage-Milestone (R-GSM) model. This introduced modeling technique adds risk management to the existing GSM model of Hull, et al., (2010). This is the first research that introduces a risk-aware modeling technique based on an artifact-centric business process modeling approach. Therefore, future research should focus on the development of risk-aware artifact-centric business process modeling approaches and compare their usefulness with activity-centric business process modeling approaches.

The research objective was to design a tool to manage and monitor the risks in the project business process of CityTec. The tool provides a significant benefitical contribution to the project business process of CityTec, but still has some improvements. The planner updates the data from the ERP system to the database of the tool once a day. It is recommended to link the ERP system to the R-GSM model to improve the data quality by providing real-time data.

Preface

This thesis is the result of a graduation project for the master program Operations Management and Logistics at Eindhoven University of Technology. This thesis is conducted at CityTec on the location Nieuwegein. Prior to presenting my thesis work throughout this report, I would like to thank the people involved in this project.

First of all, I would like to thank Rik Eshuis from the TU/e for being my first supervisor during this project. I appreciate your feedback and advise that guided me in the right direction. Your expertise in data-driven business process management was very useful during this project and it was pleasant to work with you.

Furthermore, I would like to thank the employees of CityTec who have contributed to my project. Despite the full agendas of the employees involved in my project, they always made time for me to answer my questions. Special thanks to the organization for their flexibility and freedom in the project formulation. I first start my master thesis at another organization, but there was no mutual match regarding our interests. CityTec, which was an old employer of mine, was immediately cooperated and provided ideas when I ask if I could conduct my master thesis project at their organization.

Finishing this graduation project also means the end of my years as student at the TU/e. I would like to thank the people that supported me during my study time at the TU/e, especially for the last few months. In particular, I would like to thank my parents and girlfriend for their love and support during my whole study time. In addition, I would like to thank Rick Corsten, Maaike van der Heijden, and Stefan Oosterom, who are fellow students at OML, for their help and great moments during my study time.

Jeroen Taal

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List of abbreviations

BPM Business Process Management

BPMN Business Process Modeling and Notation

E-GSM Extended Guard-Stage-Milestone

ECA Event-Condition-Action

ICB International Competence Baseline

IPMA International Project Management Association

GSM Guard-Stage-Milestone

OGC Office of Government Commerce

OMG Object Management Group

PMBOK Project Management Body of Knowledge

PMI Project Management Institute

PRINCE2 Projects in Controlled Environments, Version 2

PV Project accountability (“Project Verantwoording”)

PVO Official Report of Delivery (“Proces Verbaal van Oplevering”)

R-BPM Risk-aware Business Process Management

R-GSM Risk-aware Guard-Stage-Milestone

S-BPM Subject-oriented Business Process Management

SID Subject Interaction Diagram

SO-DOP-P Service Order Project Part Client (“Service Order Deelopdracht Project”)

SO-DOP-N Service Order Project Part Grid Operator (“Service Order Deelopdracht Netbeheerder”)

TM Term Justification (“Termijn Motivering”)

UML Unified Modeling Language

V&G Safety and Health (“Veiligheid en Gezondheid”)

WON Work Concerning Grid Operator (“Werk Omtrent Netbeheer”)

1 Introduction

Project management is a challenging business management component in many industries. A need exists for developing efficient plans and systems to increase an organization's efficiency in executing projects (Demirkesen & Ozorhon, 2017). An example of such an organization which has a need for a tool to increase efficiency in executing projects, is CityTec. This study is conducted at CityTec, a service and product provider for dynamic street installations, public lighting and traffic control installations. This research focuses on the management of the processes performed to execute projects and how risk should be managed within these projects. The output of this research will be a tool that monitors and manages the projects and their associated risks within the process of these particular projects.

This chapter will first give a description about the company, followed by the scope and problem statement of this research. The second part of this chapter will provide the objectives and corresponding research questions of this research. The last part of this chapter will introduce the research methodology used for this research project.

1.1 Business description

This research is commissioned by CityTec. This company is one of the major players in the public lighting market, which is their core business. CityTec was a subsidiary company of Joulz. Stedin and Joulz started collaborating in 2014 and created Stedin Group. CityTec became part of Stedin Group, but in 2017 CityTec was sold by Stedin to an investment company called "Strong Root Capital".

Nowadays, CityTec provides products and services in the field of lightning and installations for more than 100 municipalities throughout the Netherlands including the 4 biggest cities in the Netherlands. Not only municipalities, but also provinces and private organizations are clients of CityTec. With more than 200 employees, CityTec is responsible for managing and the maintenance of more than half a million streetlights, 30,000 traffic control installations and 2,000 parking installations. Beside managing and the maintenance of existing streetlights, CityTec also takes care of projects from the begin to end for the installation of new streetlights, wiring and exchange existing streetlights.

1.2 Scope

This research targets the project management area of CityTec. The Project Management Institute defines a project as a "*temporary endeavour undertaken to create a unique product, service or result*" and project management as "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements*" (Project Management Institute, 2017). Project risk management is an important aspect of project management. The Project Management Institute defines project risk management as "*the processes of conducting risk management planning, identification analysis, response planning, and monitoring and control on a project. The objectives of Project Risk Management are to increase the probability and impact of positive events, and decrease the probability and impact of negative events in the projects*" (Project Management Institute, 2017). The definition already sketches that risk management is not only about managing

negative events, but also about increasing opportunities for positive events. The Project Management Institute defines project risk as "*an uncertain event or condition that, if it occurs, has an effect on at least one project objective (such as scope, schedule, cost, and quality) "* (Project Management Institute, 2017).

CityTec is involved in a lot of customer projects. Municipalities or other clients communicate with account managers or engineers of CityTec about new projects. A new project could consist of new streetlights or other installations, but it could also consist of exchange existing materials. This research focuses on the management of the processes performed to execute projects and how risk should be managed within these projects. The output of this research will be a tool that helps the employees of CityTec to be in control of their projects by developing a business process model that monitors and manages risks within the process of the projects.

1.3 Project Statement

Customer projects are an important part of the activities within CityTec. Projects differentiate from standard business processes by its size and complexity, which influence the lead time and costs in a negative way. Multiple stakeholders are involved in the project execution. According to the region manager, processes within these projects are executed too early, too late, are not executed at all or did not have to be executed, due to the lack of information of other stakeholders. In the current situation, the different stakeholders have limited communication and transparency about the work of their co-workers. Projects run through multiple departments within the organization, which all have different assignments, goals and desires. Departments are working in isolation, which leads to wrong decision making, long throughput times and non-optimal costs. Besides, the projects are not monitored correctly, which does not give enough insight in the current state of the projects.

Beside communication and transparency between stakeholders, also project risk management is an important aspect of project management. Risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities (Hubbard, 2009). Effective risk management in projects is important: "*The experience gained in project planning shows that the probability of successful implementation of deterministic project schedules and budgets is very low. Therefore project planning technology should always include risk simulation to produce reliable results*" (Purnus & Bodea, 2013). Still a lot of projects are over-budget and/or delayed, because risk is not considered within the planning of the projects, and the lack of engagement between stakeholders (Flyvbjerg, 2011).

To get a better understanding of the problem that the company faces, multiple semi-structured interviews are executed with stakeholders within the project business process. The main stakeholders within the project business process consist of the engineers, work preparators and executors. Figure 1 shows the causes of poor project execution mentioned by the stakeholders involved in the project business process. These causes can be categorized into six main areas: Knowledge, communication, data, risk, management and information system. Communication and data problems are especially mentioned by

stakeholders later in the project business process. The risk, management and information system problems are more related to the entire project business process which include all stakeholders within this process.

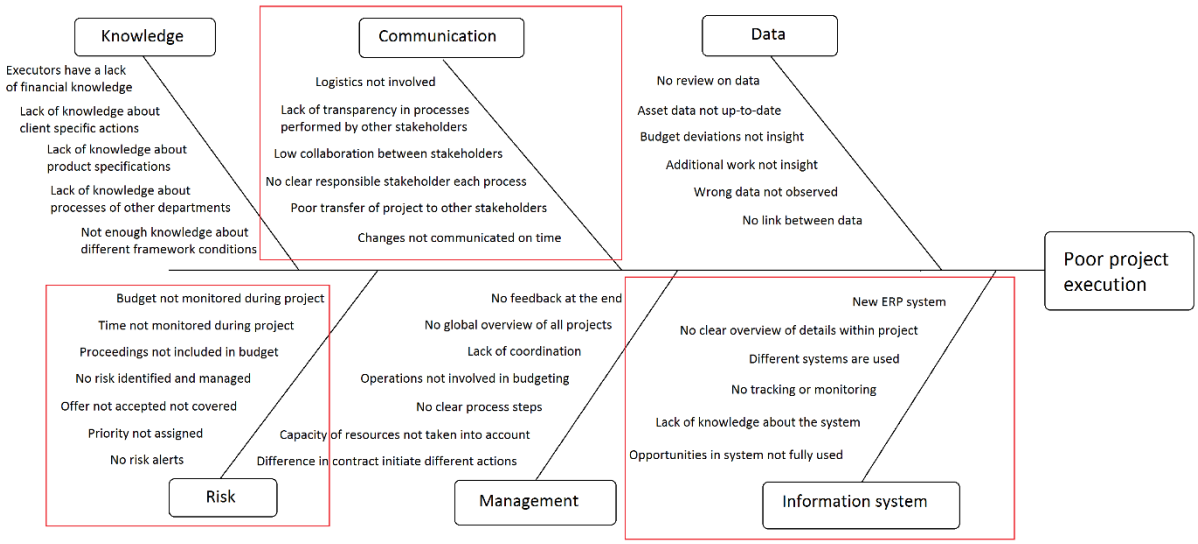

Figure 1: Cause and effect analysis for the project business process of CityTec

The problem of CityTec is that the project business process is not optimal and not under control. Projects are not monitored, the communication between stakeholders is limited and risks within projects are not managed and controlled. The new ERP system is not designed for a project environment, which creates some conflicts for the stakeholders in the project process. Due to these major problems, the focus of research will be the problems in the area of risk, communication and information system mentioned by the stakeholders involved, which is shown in Figure 1. The goal of this research is to design a tool that manage the risk involved in the project business process and improve the communication and transparency between stakeholders within this process.

Problem Statement:
The projects performed by CityTec are not monitored and risks within the current project business process are not managed, which causes project delays and cost overruns.

1.4 Research objective

The objective from the business point of view is to improve the project management of CityTec by designing a tool to monitor and manage the project business process and the associated risks within this process. The objective from the scientific point of view is to design an approach and tool that applies risk management in an artifact-centric business process model. The motivation for artifact-centric business process modeling over activity-centric business process modeling for this research is explained in Appendix A .

The projects performed by CityTec are currently not managed well. There is lack of managing and monitoring these projects, which results in projects that are over-budget and delayed. To increase the performance of the projects, CityTec wants to manage the projects

in such a way that transparency and communication between stakeholders are improved and risks are spotted earlier in the process. Risk management needs to be applied to reduce the chance of project delays and exceeding the budget of a project.

Before risk management is applied, the project business process needs to be established. At the moment, there is no clear integrated overview of this process. Therefore the first objective of this research is to model the current project business process. The next step is to improve the project business process and integrate risk management within this process. The final step is to design a tool that monitor these risks in the project business process.

The objective of CityTec at the end of this research is to have a tool that monitors the processes within projects and the risks associated within these processes. The designed tool is based on business data and uses an artifact-centric approach, which is explained in Appendix A. The risk is defined as every uncertain event or condition that, if it occurs, has an effect on the project objectives (budget, time or quality). The scientific objective is associated with the addition of this research to the literature. This research will come up with an approach and tool to integrate risk management in an artifact-centric business process model.

Business objective:
Improve the project management of CityTec by designing a tool to monitor the project business processes and their associated risks.

Scientific objective:
Integrate risk management in an artifact-centric business process model.

1.4.1 Research questions

With this research, CityTec wants to improve the end-to-end process of customer projects by developing a tool to monitor and manage risk within the project business process. Before a tool can be developed, the project business process needs to be modeled. The current process is not optimal, so after the current situation is modeled, improvements to the process needs to be made. Based on the described problem statement (1.3) and the research objective (1.4) the below main research question is defined.

Main research question:
How can a tool be designed to manage and monitor risks within the project business process of CityTec?

This main research question can be answered via several sub-questions. The sub-questions are based on the problem solving cycle of van Aken, Berends and van der Bij (2012). The following sub-questions related to the five research steps are:

1. Which actors and information flows are involved through the project business process?

2. Which risk factors can be identified within the project business process?
3. How can the metric, probability and impact of these risk factors within a specific process be measured?
4. How can the project business process be modeled in an artifact-centric way and how can risk management be integrated within this model?
5. How can a tool be designed to manage and monitor the project business process and their associated risks, and how does this impact the project business process?

1.4.2 Scientific relevance

Project conceptualization, planning and implementation is a complex, dynamic and evolving process (Jaafari, 2001). Project risk management is presented as a key knowledge area in project management and has been around for more than three decades, but still projects are delivered too late, over budget and often with less benefit than expected (Klakegg, 2016). Project management, business process management and risk management are still treated separately. The literature related to this study, which is reviewed in chapter 2, consists of several gaps. Suriadi, et al. (2014) investigated the research gap in risk-aware business process management (R-BPM). As shown in Figure 2, an obvious research gap in the area of R-BPM can be found in the execution, run-time analysis and post-execution stage. Risks within the project business process of CityTec need to be managed and monitored during the whole project, especially the execution stage. Most research about risk-aware business process modeling use activity-centric business process models. These approaches are not flexible enough to implement in a project environment and are hard to monitor during execution, which is explained in Appendix A. In this research, integration of risk management is examined in a data-centric approach using business artifacts. This research will extent the current literature in two ways. First, risk will be integrated in an artifact-centric business model, which is not performed in the current literature. An risk-aware extension to an existing artifact-centric business process model will be presented. Secondly, a tool will be developed to monitor and manage these risks within the project business process. This contributes to the practical implementation of this new risk-aware artifact-centric business process model.

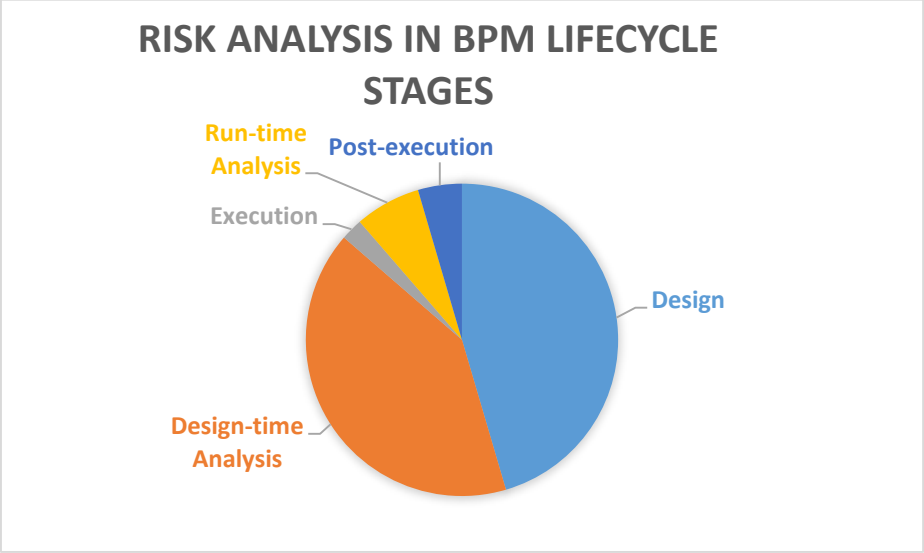

Figure 2: Risk analysis in BPM Lifecycle Stages

1.5 Research methodology

This section describes the methodology used in this research to answer the research question. The main research question is divided into several sub-questions that are determined by the problem solving cycle of van Aken, Berends and van der Bij (2012), which is shown in Figure 3. In the problem solving cycle, all phases are based on the problem mess. The problem definition is the starting point of the cycle and is similar to the earlier described problem statement. In the next stage the problem will be analyzed and the current situation will be diagnosed. The causes of the problem statement will be established through interviews with all stakeholders involved in this problem and through data collection. In the third stage, a solution for this problem will be designed based on design requirements and the analysis done in the previous phase. The solution model will be implemented by creating a tool that represent the designed solution. The evaluation will be performed based on the experience of the stakeholders who are going to use the designed tool, and test cases.

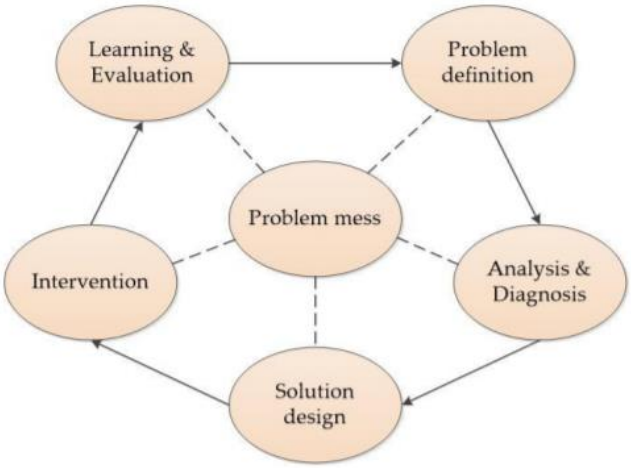

Figure 3: Problem solving cycle of Van Aken, Berends and van der Bij (2012)

The problem definition is already defined in this chapter. The sub-questions of this research are answered in the other stages of the problem solving cycle. The methodology for each sub-question are described in this section.

1.5.1 Which actors and information flows are involved through the project business process?

This sub-question is coupled to analysis phase of the problem solving cycle. Semi-structured interviews are the appropriate way to gather this information, because only the direction of the needed information is known. Semi-structured interviews result in more wider information than structured interviews, which is needed to gather all the information flows and actors within the project business process. Actors that appear in the event logs of projects in the ERP system are chosen for these semi-structured interviews. Interviewees provide names of other actors in the project business process during the interview, which creates a snowball effect. The goal of these semi-structured interviews is to gather as much information as possible about their work processes, applications and tools they use, their responsibilities, their communication with other stakeholders etc.

After all this information is gathered, a communication diagram will be created to give a rough overview of the interactions between actors. In addition, a UML class diagram will be created to know which information drives the project business process and how these data are interconnected. This will give a clear visual representation of the artifacts used within the project business process and their relationship.

1.5.2 Which risk factors can be identified within the project business process?

This sub-question is coupled to the analysis phase of the problem solving cycle. The literature describes some standard risk factors within projects. To specify the risk at company level, the communication model and the UML class diagram are shown to the actors and these actors will provide risk factors corresponding to the individual classes in these models. After the collection of risk factors presented by individual actors, brainstorm sessions are performed. Each brainstorm session consists of all actors of a specific department which are involved in the project business process. These brainstorm sessions translate individual risk factors to general risk factors. Some finished projects that had some problems in the past will also be investigated to gather risks factors that were not mentioned by the actors of the process.

1.5.3 *How can the metric, probability and impact of these risk factors within a specific process be measured?*

A part of this sub-question is coupled to the analysis phase and a part of this sub-question is coupled to the design phase of the problem solving cycle. The risk identified in the previous sub-question requires a method to be measured. Standardized project management methods are analyzed to come up with a metric that represents the risks. The probability and impact are established by quantitative and qualitative analysis. The quantitative analysis is based on the data in the ERP system and the qualitative analysis is based on the subjective judgments by the stakeholders in the project business process.

1.5.4 *How can the project business process be modeled in an artifact-centric way and how can risk management be integrated within this model?*

This sub-question is associated with the design phase of the problem solving cycle. The starting point is the result of the previous sub-questions. The communication model and the UML class diagram are used to design an artifact-centric model. Thereafter, risk management will be integrated into this model. This results in a new risk-aware artifact-centric business process modeling technique. The risks identified in sub-question 2 and their associated measuring method established in sub-question 3, are integrated in this new designed risk-aware artifact-centric model.

1.5.5 *How can a tool be designed to manage and monitor the project business process, and how does this impact the project business process?*

The last sub-question is related to the intervention and evaluation phase of the problem solving cycle. The new designed risk-aware artifact-centric business process model, which is the output of sub-question 4, will be used as input for the tool designed. The tool will be created to monitor and manage risk within the project business process in practice. The design of the tool is based on the requirements that are provided by the stakeholders in the project business process. The tool will visualize the phases of individual projects, the status of the project and the corresponding risks of the phases and the whole project. The tool is evaluated by the judgments of the end users and by comparing the current situation without a tool with the new situation with the tool, to indicate the impact of the tool on the project business process of CityTec.

1.6 Outline

In this chapter, the motivation and context of this research is described and the research questions are established. The report is structured based on the sub-questions in order to answer the main research question: "*How can a tool be designed to manage and monitor risks within the project business process of CityTec?"*. Chapter 2 provides the related work performed within the research area of this study. The two research areas related are the literature about managing risks in business process management and the literature about managing risks in project management. Relevant models in related work provide the fundament of this project. Chapter 3 is dedicated to the analysis and diagnosis phase of the problem solving cycle. The information gathered in this chapter is the foundation for the solution design, which is the risk-aware GSM model. Chapter 4 represents the GSM model creation and integrates risk management within this model. In chapter 5, the tool is created to implement the designed solution. The tool is elaborated from the risk-aware GSM model and is developed with Visual Basics. In chapter 6, the tool is evaluated by the experience of stakeholders involved in the project business process of CityTec and by comparing test cases in situations with and without the designed tool. Finally, the conclusion of this research and the recommendations for further research are described in chapter 7.

2 Literature

This research looks at the project business process problem including project risk management from a data point of view. Any business, no matter what physical goods or services it produces, relies on business records (Nigam & Caswell, 2003). The project business process is not a well-researched topic in literature, especially when risk management is included. The related work is wider drawn and includes risk management in BPM and risk management in project management.

2.1 Risk management in BPM

Nowadays many organizations have developed business process management (BPM) systems to manage their businesses. Through time, many different techniques are developed to model business processes. These techniques can be divided in activity-centric business process modeling and data-centric business process modeling, which are explained in Appendix A.

2.1.1 Risk in business process management

Traditional business process models do not address the problem of uncertainties that organizations face in their day-to-day operations. These uncertainties and their impact on organizations are known commonly as risks, and they need to be managed through the application of relevant principles, frameworks, and processes. The application of this set of principles, frameworks, and processes is known commonly as risk management (Suriadi, et al., 2014). Recent researches address the topic of risk-oriented process management in where researchers aim to develop risk-aware process modeling techniques. Suriadi, et al. (2014) compares and classifies current approaches in the area of risk-aware business process management (R-BPM).

Risk consists of two attributes: impact (the consequence of the risk realization related to the process) and probability (the relative chance that the event will occur) and is mathematically represented as the impact multiplied by the probability of occurrence (Link & Marxt, 2004). This mathematical representation is a quantitative method to measure risk based on monetary or discrete values. Business process performance should not only be measured in cost, but also in time and output quality/performance (Zhou & Chen, 2003).

Researchers integrate risk in different phases of the BPM lifecycle. Most research is performed in integrating risk in the design stage. Articles in the design phase consist both the annotation of business process models with risk-related constructs and risk-informed design principles to generate or modify process models. Extending the BPMN to a more risk-aware business process model is a common approach in literature performed by Schultz & Radloff (2014); Islam et al. (2009); Anton, Lackes & Siepermann (2016) and Conforti, Fink, Manderscheid & Röglinger (2016). Literature focused on integrating risk in the execution (run-time) phase of the BPM lifecycle, use more object-oriented business process models, like UML. Arimoto, Iida and Futatsugi (2011) focused on modeling document flows, because documents play an important role in business processes. All information created during the execution of business activities is recorded in some documents. Documents are easier to detect during run-time than activities and are harder to manipulate.

In the current literature, there is not a lot of research about risk in the post-execution stage. In this phase, risk is detected by historical data and logs and used as feedback for the design phase. Suriadi, et al. (2014) describes that in the ideal and desirable situation, risks are managed as an integral part of the process execution, rather than as separate activities or as an afterthought. R-BPM should be able to identify and analyze process-related risks explicitly during design time, as well as to provide support for risk mitigation actions. Besides, risk should be constantly monitored during runtime and once a risk event has occurred, it should be mitigated immediately to ensure a proper termination of the process. Logs and other data produced in the execution of the business processes should also be analyzed to have a better insight into the occurrence of a risk event and to understand the reasons behind the occurrences.

Anton, Lackes & Siepermann (2016) present a comprehensive approach that integrates risk concepts into business process modeling with BPMN. The extension was made to identify risks much easier when the combined process and risk model is examined. This creates a complete risk map which identifies areas or units that are jeopardized by risks and direct mitigation of these risks could be performed. An example shown in Figure 4.

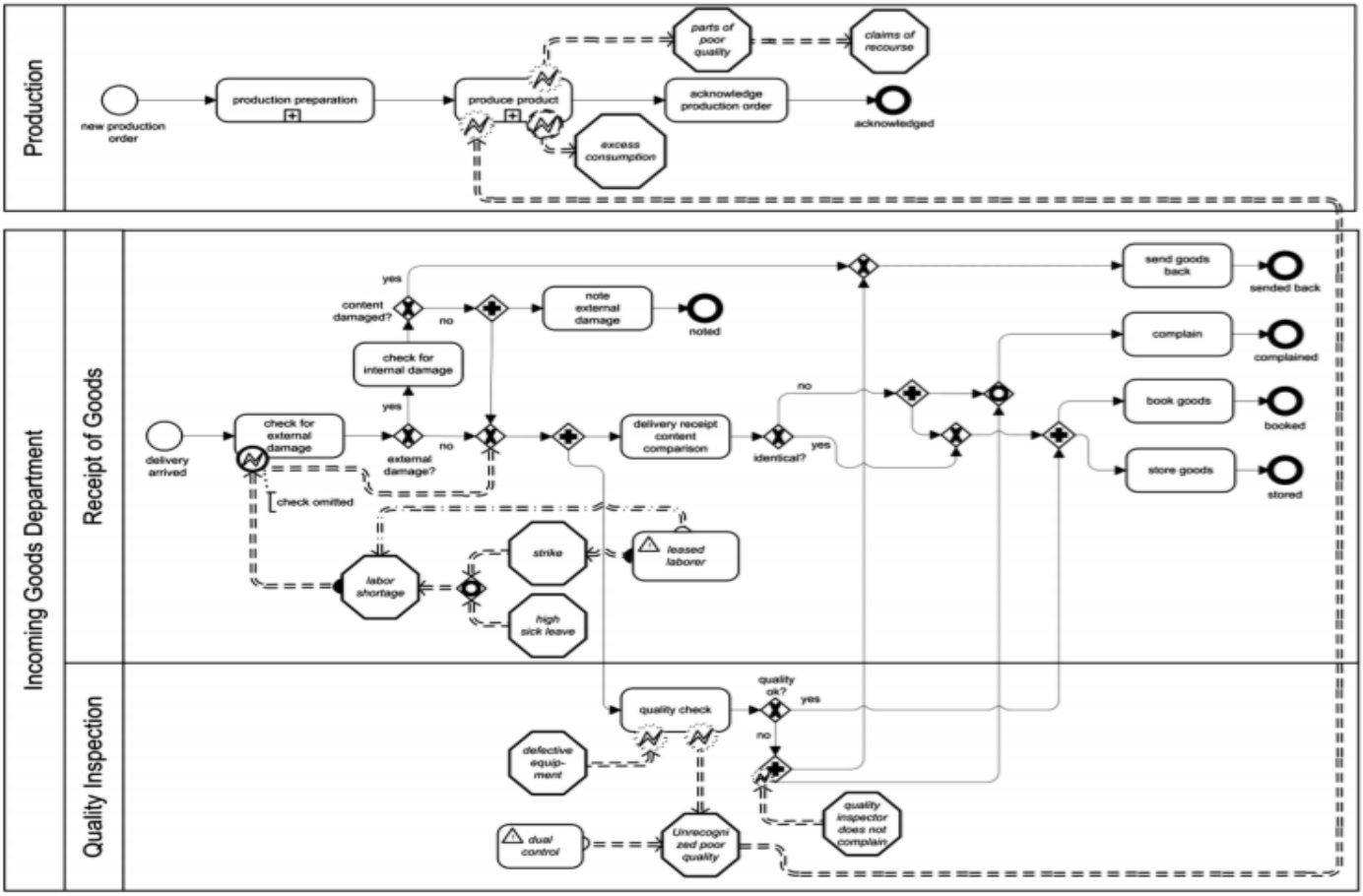

Figure 4: Risk-aware BPMN of Anton, Lackes & Siepermann (2016)

2.2 Risk in project management

This research is performed in a project management environment. A lot of researchers in this area only focus on identifying specific risks for a specific project, but related work in this area interested for this research should include risk identification and measurement methods useful for all kind of projects. Therefore, the three main project management methodologies are reviewed to provide a guideline for project risk management applicable for a project type instead of individual projects. There are always risks involved within projects. These risks effect the main objectives of the project in time, cost and performance.

The mostly used project management techniques are ICB (IPMA), PRINCE2 (OGC) and PMBOK (PMI). PMBOK and PRINCE2 are the most familiar project management techniques in the world, while ICB is more familiar in the country of the organization, which is The Netherlands. The ICB focuses on the skill assessment and capacity of the project manager and project team, while PMBOK and PRINCE2 are mainly focused on the processes in the projects. ICB is focused on the skills of the people in the project more than the process itself, which is therefore not the best method for this research. PRINCE2 and PMBOK do not different that much from each other. The strength of PMBOK is that it provides a large range of useful tools and techniques in the project management, but the weakness is that there is no guidance on project management team responsibilities and on tailoring. The strength of PRINCE2 is that it provides more depth in project management practice by also answering the question *How to,* but the weakness is that detailed techniques are not provided and only little flexibility is offered. PRINCE2 is mostly used for IT project, while the PMBOK is mostly used for technical project.

The latest edition of PMI's Project Management Body of Knowledge (Project Management Institute, 2017) considers six risk management processes: conducting risk management planning, identifying risks, performing qualitative risk analysis, performing quantitative risk analysis planning, risk responding and monitoring and controlling these risks. The objectives of this framework are to increase the probability and impact of positive events, and decrease the probability and impact of negative events in the project. This framework is one of the mostly used research in the field of risk management in projects. Figure 5 shows an overview of this framework of PMI.

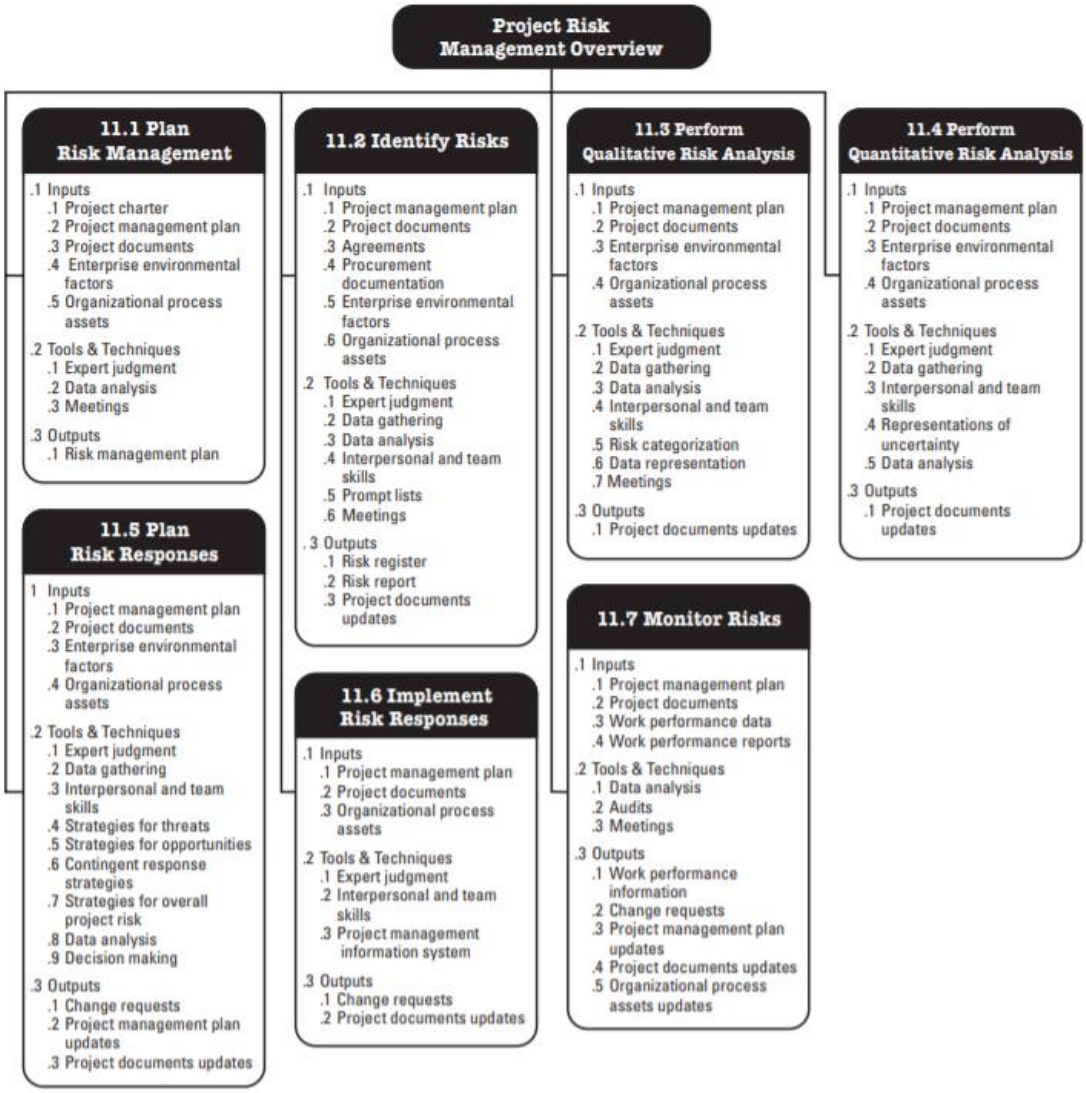

Figure 5: Project Risk Management framework of PMI

In the research of Bahill & Madni (2017), the risk analysis part from the framework of PMI is further specialized. They suggest that frequency of occurrence is a better metric than probability, because humans estimate probabilities poorly. Therefore, they define risk as the product of frequency of occurrence multiplied by the severity of the consequences. The scale frequency of occurrence is thereafter converted to the relative likelihood which is used together with the severity of failure to establish a risk matrix. The data in this risk matrix is derived from the risk register. Risk mitigation is performed on the risks that are too far in the danger zone. An example of a risk matrix is shown in Figure 6, where the numbers indicate different risks.

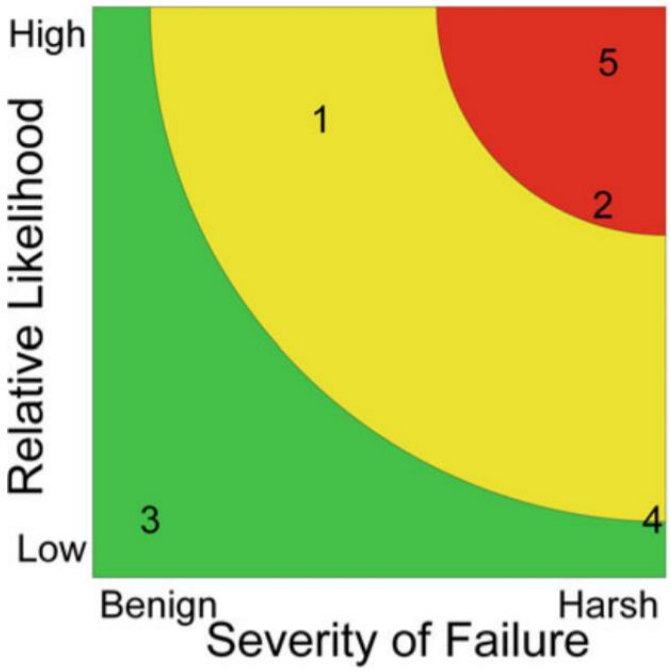

Figure 6: Example of a risk matrix from Bahill & Madni (2017)

2.3 Sub-conclusion

In this chapter, risk management within business process management and project management are described. Project are difference in size, complexity, needs, resources, etc., which results in a complex, hard to formulate business process. A model needs to be created to give insight into the project business process. The business process of projects requires some kind of flexibility. This emphasizes the preference for data-centric business process modeling in a project management. The GSM model matured by Hull, et al. (2010) is the fundament of this research, which is further explained in Appendix A. This model is not used in a project environment before. The GSM model visualized the relation between tasks in an information point of view.

Risk management is implemented within this GSM model in this research, which is also not performed in literature before. The literature only covers risk-aware activity-centric business process modeling techniques. Therefore, this research will introduce a new risk-aware modeling technique for artifact-centric business process modeling.

ICB, PMBOK and PRINCE2 are possible project management methodologies for identifying and analyzing risks in the project business process. ICB is focused on the skills of the actors in the project more than the process itself, which is therefore not the best method for this research. PMBOK and PRINCE2 have a lot in common, but PRINCE2 does not provide detailed techniques and only little flexibility is offered. Therefore, PMBOK is the best method for identifying and analyzing risks in this research.

3 Analysis

The analysis and diagnosis phase is the next step of the problem solving cycle, which will be performed in this chapter. The first three sub-questions established in section 1.4.1 cover the analysis and diagnosis phase. The first part of this chapter analyzes the current state and describes the process with the use of the communication model and UML class diagram. This is essential to fully understand the current situation, which is the foundation of the designed model. These models are conceptual oriented and not implementation oriented. The second part consists of identifying risk factors involved in the project business process. Thereafter, the risk analysis is performed on these factors. Finally, risk responses and risk owners are coupled to these risks.

3.1 Current situation

The current situation is modeled by realizing a communication model and a UML class diagram. A communication model is necessary to give a good representation about the different stakeholders and the relationships between them. So, this model is a good starting point for other models. The framework of Subject-oriented Business Process Management (S-BPM) developed by Fleischmann et al. (2012) is used as communication model. This model is also called the Subject Interaction Diagram (SID) and focuses on the subjects and their explicit communication relationships.

After the communication model is established, a UML class diagram is created to understand which information drives the project business process and how these data attributes are interconnected. This will give a clear visual representation of the artifacts used within the project business process and their interrelationship, which is useful for the design of the GSM model. The UML class diagram is mostly used for software interpretations and is the building block for applications. The deliverable of this research is a software tool, which make the UML class diagram the right model to use as building block.

The information for these models is obtained by interviewing the stakeholders in the project business process. Semi-structured interviews are performed to capture the necessary information for the communication model and UML class diagram. The summary of these interviews can be found in Appendix B.

3.1.1 Communication model

The communication model is established to visualize the stakeholders and systems involved in the project business process and the interactions between them. The goal of this model is to give an rough overview of all the communication flows within the project business process of CityTec on a conceptual level. The Communication Structure Diagram (CSD) of Fleischmann et al. (2012), also called the Subject Interaction Diagram (SID), is used as communication model due to the clear graphical representation of the communication, which is lacking in other communication models. The genesis of this model starts with identification of process-specific roles involved in the process, the subjects, and the messages exchanged between them. This is the start of exploring the unknown project business process of CityTec, which will help to understand the process and as input for other models later in this report.

The project business process of CityTec is a complex process, which involves both multiple departments as external organizations. The communication within the external organizations are not considered in this model, because these steps are not relevant for the internal process.

There are three main internal stakeholders within the project business process of CityTec: Engineers, work preparators, and executors. The other stakeholders within this process all have a supporting or external role. There are individual communication models made based on the interviews and data collection of each main stakeholder group. In Table 1, the definition of the components used in these communication models are illustrated.

Table 1: Definition of components in the communication model

Component	Definition
	The blue background color represents the external organization of the client of the project.
	The orange background color represents the internal organization of CityTec.
	The yellow background color represents the external organization of the grid operator.
	The green background color represents the external organization of the subcontractor.
Subject	The blue rectangles represent the stakeholders involved in the project business process.
System	The green dashed rectangles represent the information systems used for supporting the project business process.
	The arrows indicating the direction of the communication flow between actors or information systems in the process.
[6] Message	The messages are represented by a number which indicate the chronological order, and the content of the information flow.

Figure 7 illustrates the communication flows from and to the engineers, which is one of the main actors of the project business process. In Figure 8 the communication model of the work preparators is shown, which is the second main actor in the project business process. Figure 9 shows the communication model of the executors, the last main actor in the project business process, but certainty not the least important one.

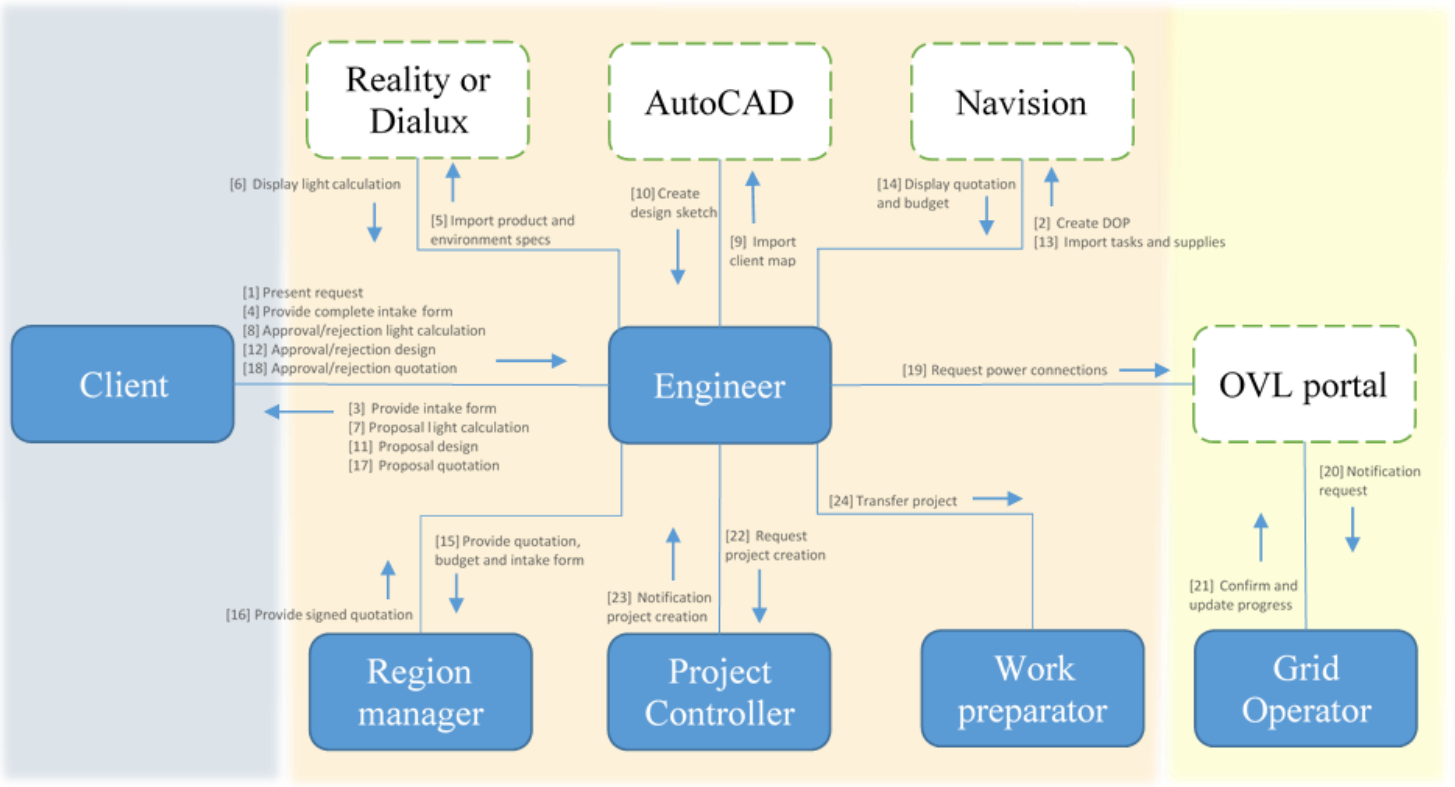

Figure 7: Communication model engineers

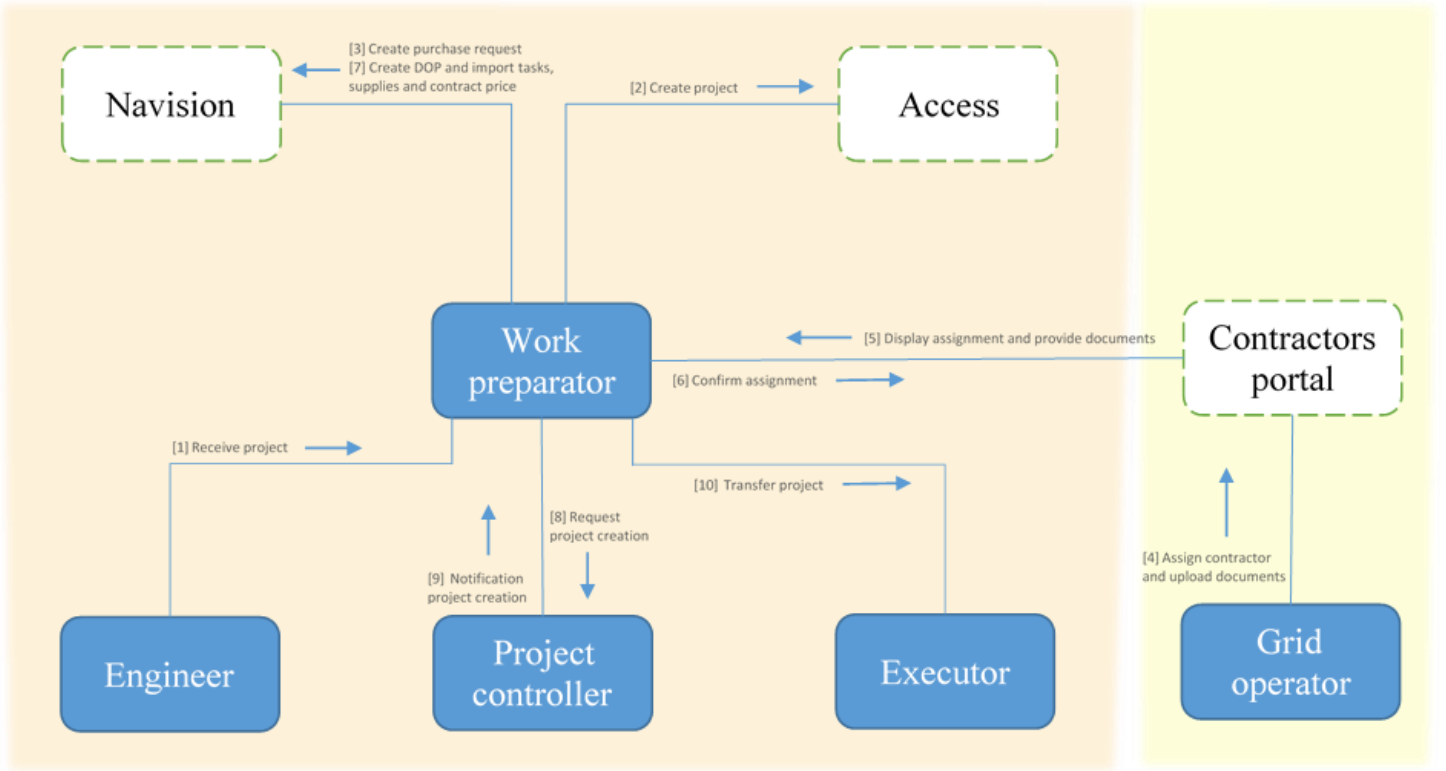

Figure 8: Communication model work preparators

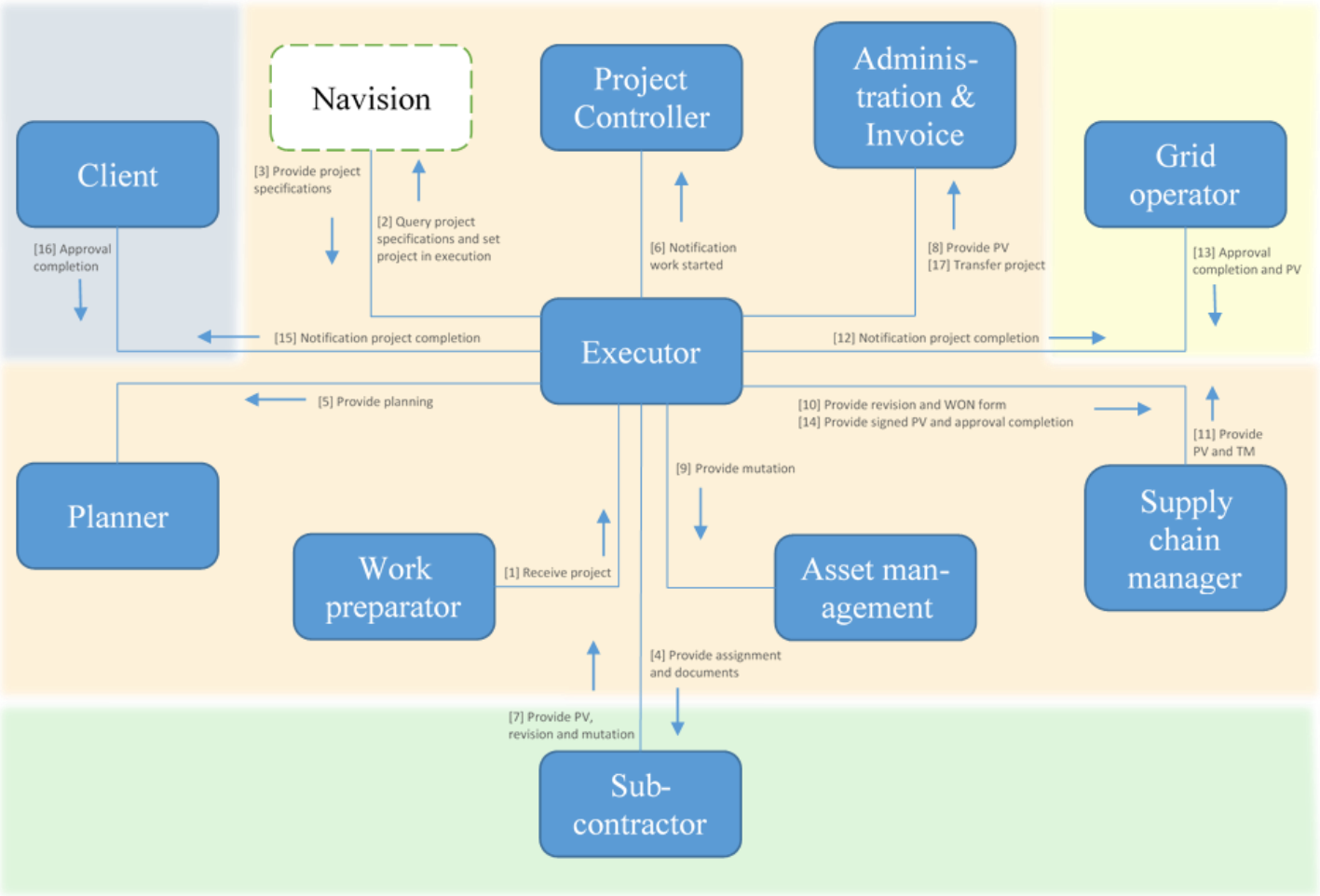

Figure 9: Communication model executors

In this section, three individual communication models are created to get a better understanding of the project business process. These models are kept abstract to prevent readers not fully understand the model due to the amount of detail and information in the model. The models can be interpreted as one model as the steps connect to each other. For example, the information flow number 24 in communication model of the engineers is the same as the information flow number 1 in the communication model of the work preparators, but now from the work preparator point of view. There are three models created instead of one to illustrate a better overview of the information flows.

Only the information flows from and to the main actors in the project business process are considered in these models. The supporting and external stakeholders in the process also have information flows between each other. The full communication model of the project business process is hard to interpreted and has a lot of details, which is useful as input for the other models in this report, but not for a rough visualization to better understand the project business process.

3.1.2 UML class diagram

The UML class diagram is object-oriented and visualizes the objects used in the project business process. An object is something that can be manipulated by subjects, which are defined in the previous section. It does not have be a physical object by definition, but it could also be something more conceptual. A class is a collection of objects of the same type. Not only the classes in the process are described, but also their relationships, interface, association and collaboration.

The UML class diagram normally has three compartments for each class. These compartments exist of the name, the attributes and the operations. The aim of this UML class diagram is to visualize the data attributes and their relationships in the project business process on a conceptual level for better process understanding and not as final model. The operations compartment is software implementation-oriented and is therefore not used in the creation of the UML class diagram for the project business process of CityTec.

Besides the class definitions, the relationships between classes are also important factors of this model. The relationships in a UML class diagram are based on the standards of OMG (2017). After the relationships between the classes are established, the cardinality between the entities can be declared, also called multiplicity. The multiplicity interval has some lower bound and upper bound. A multiplicity of *(m..n)* indicates at least *m* but no more than *n* number of elements. A multiplicity can also only have exactly *m* number of elements. When a multiplicity has an infinite upper bound, the notation is *(m..*)*.

The UML model in Figure 10 visualizes the project business process from an object point of view. The relationships between these objects are described as associations, aggregations and compositions. The association relationship is a straight line between objects and links separate classes in some significant manner. These classes are mutually equal connected with each other, like the relationship between the classes *P-Project* and *Client invoice*. The aggregation relationship presents a whole-part relationship, which means that one object is part of the other object. This relationship is visualized by a line with an empty diamond at one of the objects. The object with the diamond is the aggregate and the other object is the component part, like the relationship between the classes *Design* and *Project folder. The* last relationship is the composition relationship. This relationship is the same as the aggregation, but stronger in a way that the life span of the classes are the same. This means that if the life span of the aggregate object ends, the life of the component part also ends. This is visualized by a filled diamond, like the relationship between the classes *Budget-P* and *SO-DOP-P.*

The execution part of the project business process is visualized in the UML class diagram as a package, which is shown in Figure 11. This package is created for easier understanding and interpretation of the UML class diagram.

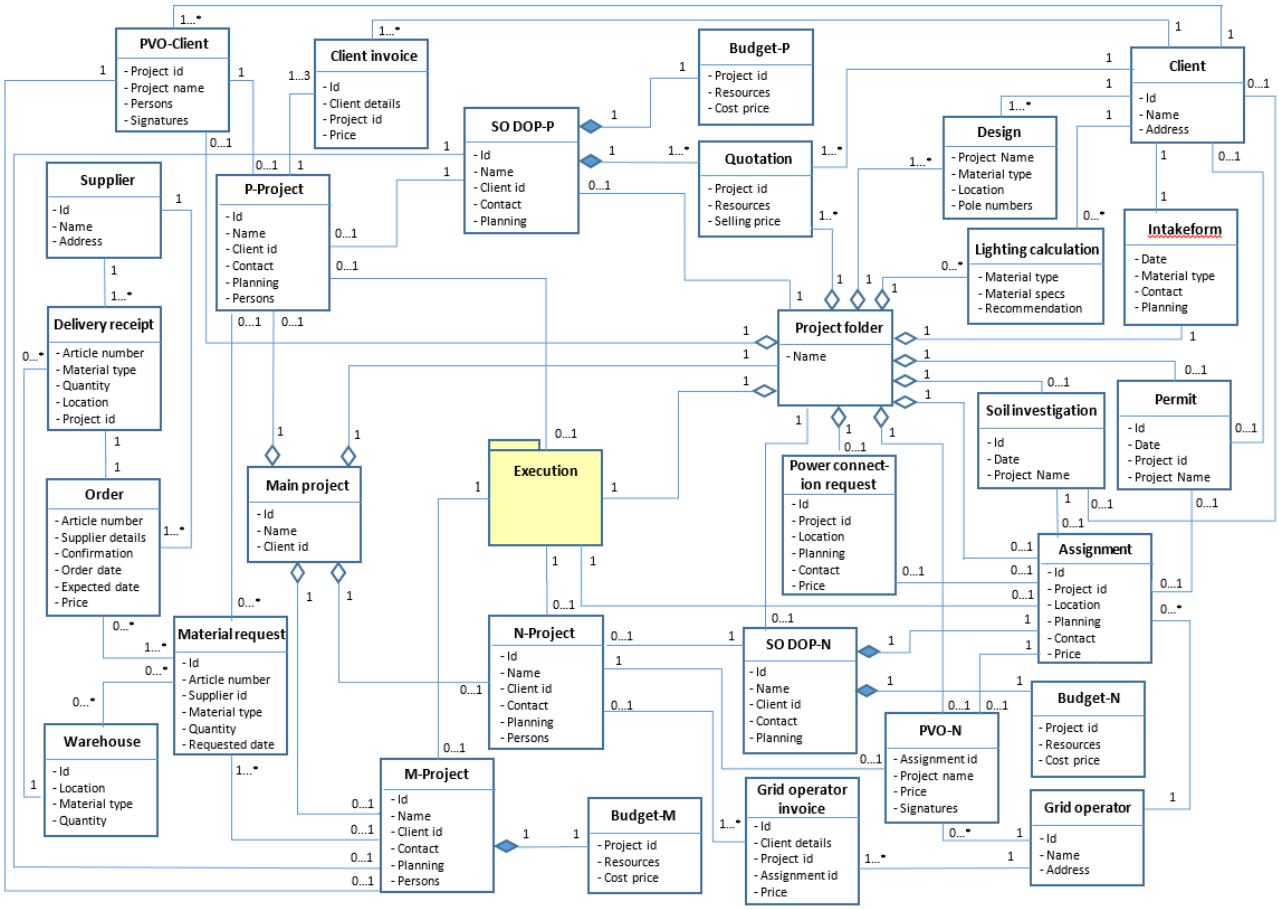

Figure 10: UML class diagram of the project business process

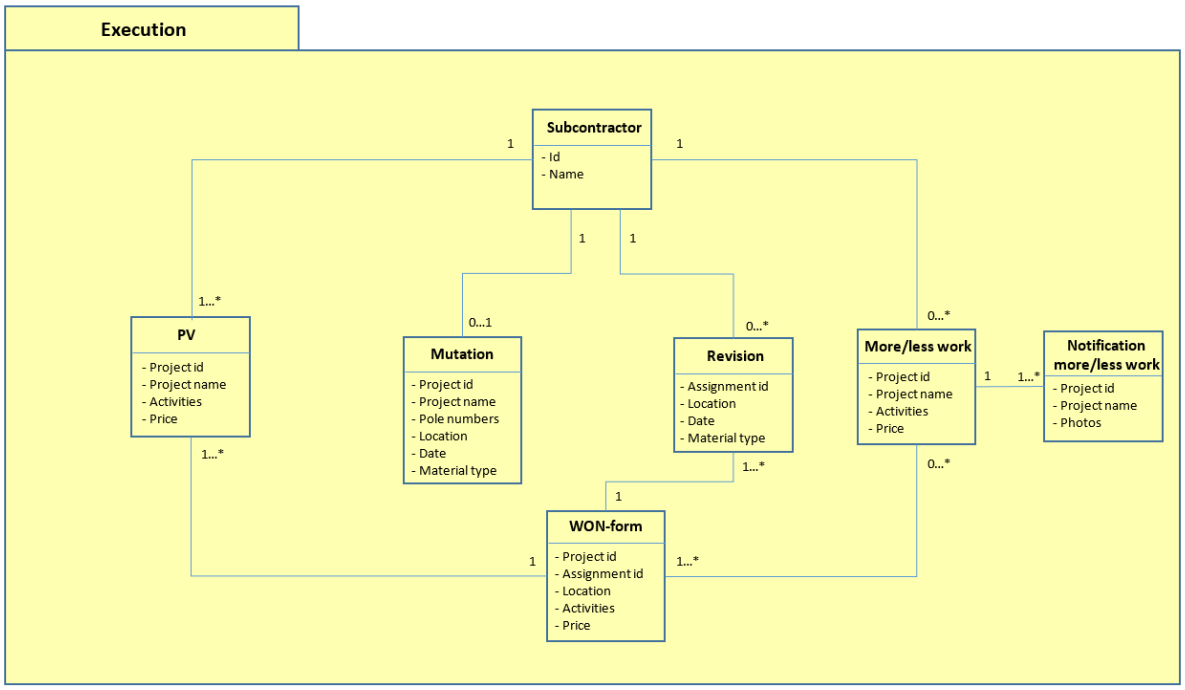

Figure 11: Execution package in the UML class diagram

3.2 Risk factors in the project business process

In this section, the risk factors that influence the output of the project business process are explored. Risk consist of two attributes: the probability that an event will occur and the impact when the event occurs. The impact could either be positive or negative related to the project's objectives. They could have an impact on the time, cost and/or quality.

The PMBOK of the Project Management Institute (PMI), which is the standard norm for project management especially in the United States, is used to describe the risks in the project business process based on the analysis in chapter 2. PMBOK describes the following project risk management steps that need to be performed to increase the probability and/or impact of positive risks and to decrease the probability and/or impact of negative risks (Project Management Institute, 2017):

- **Plan Risk Management**: The process of defining how to conduct risk management activities for a project.
- **Identify Risks**: The process of identifying individual project risks as well as sources of overall project risk, and documenting their characteristics.
- **Perform Qualitative Risk Analysis**: The process of prioritizing individual project risks for further analysis or action by assessing their probability of occurrence and impact as well as other characteristics.
- **Perform Quantitative Risk Analysis**: The process of numerically analyzing the combined effect of identified individual project risks and other sources of uncertainty on overall project objectives.
- **Plan Risk Responses**: The process of developing options, selecting strategies, and agreeing on actions to address overall project risk exposure, as well as to treat individual project risks.
- **Implement Risk Responses**: The process of implementing agreed-upon risk response plans.
- **Monitor Risks**: The process of monitoring the implementation of agreed-upon risk response plans, tracking identified risks, identifying and analyzing new risks, and evaluating risk process effectiveness throughout the project.

This section performs each risk management step according to the PMBOK separately for the project business process of CityTec. These steps are designed for individual projects, but in this section the risks are standardized to relate to each project of CityTec.

3.2.1 Plan Risk Management

This part of the process defines how the risk management activities are conducted. The risk management plan is used as a guide to manage the project risks. The focus of this research is to manage risks in the project business process and not by individual projects, so the risk management plan is standardized for all projects. This section describes the project business process according to the Plan Risk Management step of PMBOK.

3.2.1.1 Risk strategy

The risk strategy describes the general approach to managing risk in the project. In the as-is situation, the risk is reactive managed without control and monitoring. This means that risks are handled when the risks already have occurred. The risks are not controlled and monitored which means that the stakeholders are only aware of the risk when one of the stakeholders obverses the risk. In the to-be situation, the risk will be managed by implementing risk management within an artifact-centric business process model. The GSM model is the foundation for this new model and the risk are connected to the steps in this model. This new risk-aware artifact-centric business process model is implement in a tool that visualizes the risks based on rules within this tool. In the to-be situation, most risks are proactive managed. Some risks are reactive managed, but are immediately observed which mitigate the risk by a quick risk response.

3.2.1.2 Methodology

The methodology defines the specific approaches, tools, and data sources that will be used to perform risk management on the project. In the as-is situation, the V&G plan is the only risk approach in the project performed. The V&G plan is only created in large size projects and is focused on the safety and health of the employees of the project. The to-be situation will provide an Excel VBA tool that performs the risk management in the project business process automatically. The database provides the data for the tool and is updated by the data in the ERP system.

3.2.1.3 Roles and responsibilities

The roles within the project business process in the as-is situation are sketched by the communication model earlier in this chapter. The responsibilities in the as-is situation are not clearly defined. The executor is mainly responsible for the project, because the executor must ensure that the project is performed within budget.

The tool will spread the responsibilities of the risks in the project business process. The GSM model divides the project business process in sub-stages, which again also have sub-stages. The higher level sub-stages are assigned to departments, which are responsible for these sub-stages and their related risks. The planner is responsible for the tool on this own and the updates of the database.

3.2.1.4 Timing

When the data of the tool is updated, the risk management of the project business process is automatically also updated. After each project transfer between the departments, the tool is used to identify risks that have occurred earlier in the process. The stakeholders will be able to use the tool at all time to observe risks in their project and apply the project steps.

3.2.1.5 Risk categories

The scope of this research includes three risk categories: Cost, time, and performance/quality. Financial risk occurs when the project costs exceed budget. Schedule risk occurs when the project takes longer than scheduled. Quality risk occurs when the project is completed, but fails to perform as intended. This happens when the quality standard of the project is not achieved.

3.2.1.6 Stakeholder risk appetite

The risk appetite determines the acceptable level of the overall project risk exposure. The risk appetite of CityTec is low. All risks should be avoided according to the management board of CityTec. The profit of projects need to be at least 17.5% and within this profit there is a 3% risk margin reserved. The risk covered with this margin is only the risk of not getting the assignment while time is invested in the assignment. Risk in the schedule and quality categories have a much higher appetite.

3.2.1.7 Definitions of risk probability and impacts

The research of Bahill & Madni (2017) is used to define the probability and impacts. They suggest that frequency of occurrence is a better metric than probality, because humans estimate probabilities poorly. This metric is thereafter translated to the probability of occurrence.

The probability of risk occurrence and the impact of the consequences are divided into six levels, which are described in Table 2. The risk is therafter defined as the level of probability times the level of impact. This risks can be prioritized according to this risk level.

Table 2: Definitions for probability and impact

Scale	Probability	+/- impact on project objectives		
		Time	Cost	Quality
Very high (5)	> 50%	> 20 weeks	> 15% of budget	Very significant impact on overall functionality
High (4)	31-50%	9-20 weeks	6-15% of budget	Significant impact on overall functionality
Medium (3)	16-30%	3-8 weeks	3-5% of budget	Some impact in key functional areas
Low (2)	6-15%	1-3 weeks	1-3% of budget	Minor impact on overall functionality
Very Low (1)	1-5%	< 1 week	< 1% of budget	Minor impact on secondary functions
Nil (0)	< 1%	No change	No change	No change in functionality

3.2.1.8 Probability and impact matrix

The probability and impact matrix is created for each risk category. The x-as represents the impact of the risk and the y-as represents the probability of occurrence. The scales are from nil to very high which are defined in Table 2. The risk in the probability and impact matrix are divided into the three risk categories defined in 3.2.1.5 and the combination of these categories.

3.2.1.9 Reporting formats

The tool visualizes the risks that occur during the projects. The tool is created in Visual Basic. Each stakeholder will have access to the tool and can evoke each project they want to see. The tool is based on the GSM model and the risk is integrated within this model. The risk are made visible by applying the rules of the model.

3.2.1.10 Tracking

Risks are not tracked in the as-is situation. When a risk is notified, the risk will not be recorded or shared with other stakeholders in the project business process. In the to-be situation, the tool will track these risks. The data extracted from the ERP system is the input for the developed tool that visualizes risks. The processes in a project are recorded by the input of the ERP system and the input of the stakeholders responsible for the particular processes. The documents are recorded in the shared project folder and are added to the tool for easier tracking.

3.2.2 Identify risks

This part identifies individual project risks as well as sources of overall project risk. All internal stakeholders of the project business process are involved in the identification of risks by performing interviews. By involving these stakeholders in the identification of risks, they develop a sense of ownerships and responsibility, which is beneficial for implementing the tool. The output of the risk identification phase is a risk register. The tools and techniques used to gather this output are interviews and brainstorming. The communication model and the UML class diagram are used as aids to link risks to the processes and objects in these models.

3.2.2.1 Risk register

The risk register consists of a list of identified risks. As addition, the object (from the UML class diagram), the risk category, and the risk triggers are also added to the register, because this could be useful in a later state of this report for the design of the risk-aware artifact-centric business process model. The risk register can be found in Appendix C.

3.2.3 Perform qualitative risk analysis

Risk probabilities and impacted are assessed using the definitions defined in the risk management plan (Plan Risk Management3.2.1.7) in Table 2. The risks identified in the previous section are divided in expert judgment and data analysis. The probability and impact of some risks factors could be gathered from data in the ERP system. Others cannot be assessed by data, but are estimated by experts involved in the particular process. The output of this section is an extension of the risk register where the probability and impact are defined, and a probability and impact matrix. This is achieved by the judgment of stakeholders and data analysis.

3.2.3.1 Risk register probability and impact expansion

The risk register that is established in 3.2.2.1 is expanded with the probability and impact. The risk is defined by the probability times the impact. These are defined in section 3.2.1.7. This number prioritizes the individual risks. The expanded risk register with the probability and impact of each risk can be found in Appendix D.

3.2.3.2 *Probability and impact matrix*

The probability and impact matrix, also called risk matrix (Klausmann, Cozzani, Salzano, & Renni, 2011), is developed the risks, probabilities, and impacts in the project business process of CityTec described in the risk register. The probability and impact matrix is shown in Figure 12.

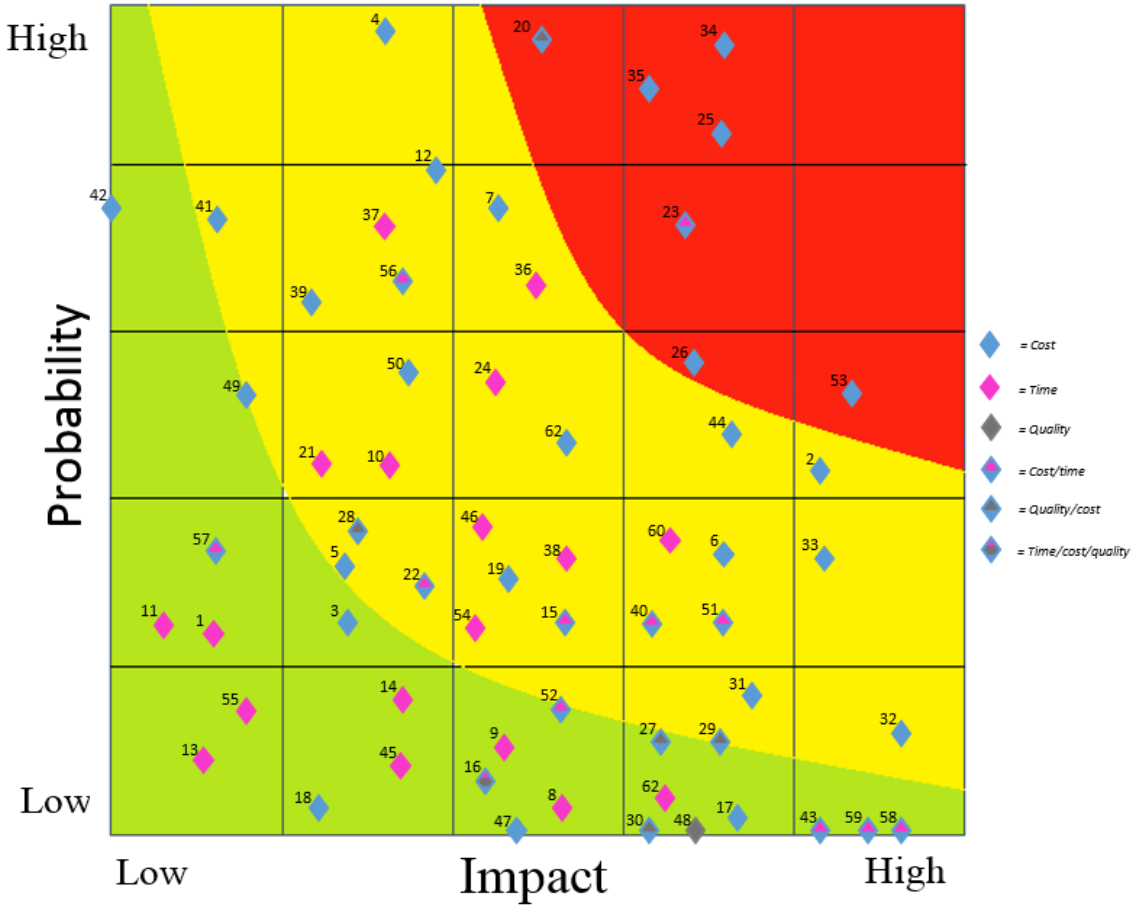

Figure 12: Probability and impact matrix

3.2.4 Perform quantitative risk analysis

Quantitative risk analysis addresses the combined effect of identified individual project risks and other sources of uncertainty on the overall project objectives. Performing quantitative risk analysis is not required for all projects according to PMBOK. It depends on the availability of high-quality data about individual project risks and other sources of uncertainty. Specialized risk software are normally required for quantitative risk analysis, which are based on forecast methods. The analysis technique used for quantitative risk analysis could be a simulation, sensitivity analysis, decision tree analysis, or influence diagrams.

The data quality is too poor to perform quantitative risk analysis. CityTec switched to a new ERP system 18 months ago. A lot of data is lost in this conversion, so only data of the last 18 months is available, which is not enough for a high quantitative risk analysis. Additionally, in the beginning, employees were not familiar with the new system, which created a lot of contaminated data. The outcome of the quantitative risk analysis could therefore be misleading and hence out of scope in the current research.

3.2.5 Plan risk responses

Risk exposure can be minimized by effective and appropriate risk responses that minimize individual threats. Now the individual risks are identified, analyzed and prioritized, the risks are addressed to risk owners in this section. Additionally, the optimal response for these risk owners to particular risks are described. The risk response, which is owned by the risk owner, should be agreed upon by all stakeholders involved and realistic within the project context. Therefore, a brainstorm session with all stakeholders is performed to conduct these risk responses. There are five strategies to respond to risks:

- Escalate: The risk is outside the scope of the project. Escalated risks are not managed on project level, but on a higher level in the organization.
- Avoid: The risk is eliminated by changing some aspects of the project management plan or changing the objective that is in jeopardy.
- Transfer: The ownership of the risk is transferred to a third party to manage the risk and to bear the impact if the risks occurs.
- Mitigate: The probability and impact of the risk are reduced by mitigation actions. Early mitigation actions are often more effective by reacting as quick as possible or even before a risk occurs.
- Accept: The risk has a low priority and it is not cost-effective to take action for this risk. No action is performed for this risk and the risk is only periodic reviewed to ensure that it does not change significantly.

The output of this section is an addition to the risk register, which is established in 3.2.2.1 and supplemented in 3.2.3.1. The risk response addition to the risk register can be found in Appendix E.

3.2.6 Implement risk responses

A common problem with project risk management is that risks are identified, analyzed, and risk responses are developed, but no action is taken to manage these risks. This section describes how the agreed-upon risk responses are actually executed.

The risks identified in the project business process are standardized risks which are not specified for a unique project. Every project is unique and how to react on risks within a project could be different every time. The escalate risk responses are outside the scope of individual projects, so these risk responses will also be outside the scope of this research.

The response on the risk of needing traffic barriers (15) , the risk of a price change by supplier (39), the risk of a price change by the grid operator (44), and the risk of having contaminated soil (59) can immediately be implemented in the terms and conditions of the quotation. Some extra steps need to be created in the project business process to fulfill the risk responses. For example, an extra step after receiving a project request from a client will be created called credit check (5), to ensure that the client is trusted and does not have a lot of outstanding debts to the organization. All risk responses that require extra steps are implemented in the GSM-model and tool created later in this research.

3.2.7 Monitor risks

Risks are not monitored in the as-is situation. In the to-be situation, the described risks will be monitored during the project by the tool developed later in this research. The risk integrated in the tool will be visualized by colors for easy interpretation. A mix between technical performance analysis and reserve analysis is added to the tool to visualize the remaining budget for each category in the project. The next chapter will model this tool and the identified risks will thereafter be implemented in this model. The model will be the input for the tool creation that will monitor the risks in the project business process.

3.3 Sub-conclusion

The analysis and diagnosis phase is covered in this chapter. The analysis with the different models in section 3.1 is the foundation for the design of the GSM model in the next chapter. The GSM model combines these models to present the to-be situation in an artifact perspective. An artifact is a key information entity that is central to guiding operations in a business process and whose content changes while moving through those operations (Hull, et al., 2010).

The risk identified and analyzed in section 3.2 are integrated in this GSM model later in the next chapter. Risks are not managed with the GSM model in literature yet. Therefore, the next chapter provides a new risk-aware artifact-centric business process modeling technique for integrating risk in the GSM model.

4 GSM model

The GSM model includes both an information model that uses attributes to capture, in either materialized or virtual form, all of the business-relevant data about entities of that type, and a lifecycle model, that specifies the possible ways that an entity of this type might progress through the business, and the ways that it will respond to events and invoke external services, including human activities (Hull, et al., 2010). The semantics is focused on how an incoming event can transformed from one snapshot into a next snapshot of the GSM schema. This transformation can be characterized incremental evaluation of Event-Condition-Action (ECA) based rules (Eshuis, Hull, Yutian, & Vaculín, 2014).

The theoretical background of the GSM model is described in Appendix A. The communication model and UML class diagram created in section 3.1, define the objects available in the project business process and the communication between subjects. This information gathered together is the input for the GSM-model, which will be developed in this section. The risk identified and described in section 3.2 are thereafter implemented in this GSM model.

This chapter first describes the method used for the GSM models. In the second part, the GSM models are developed for the project business process. Thereafter the risks are implemented in these models by introducing a new risk-aware artifact-centric process modeling technique.

4.1 Introduction

The lifecycle model describes the possible path and timings that tasks can be invoked on objects. The data about these objects that is created during their lifecycle, is gathered in the information model. The possible paths depend on the rules given to guards and milestones for opening and closing stages. These rules most likely depend on each other, which means that if a stage is closed, another stage opens. The ECA rules are used to define these possible paths. This is based on the syntax "**on** *event* **if** *condition*".

Eshuis, Hull, Yutian, & Vaculín (2014) used sentries for opening/closing stages and achieving/invalidating milestones. Some sentries reference internal events that correspond to status changes of stages or milestones. Sentries can be triggered by certain conditions, but also by a task completion event (C) or by an external incoming event (E). After the sentries of the guard are met, the stage will be opened. The stage will be closed after the terminating sentry is met, which is most of the time related to the milestone of that stage. The sentries method of Eshuis, Hull, Yutian, & Vaculín (2014) for opening and terminating stages, and achieving and invalidating milestones are used in this chapter.

The visualization of the GSM model is based on the study of Hull, et al., (2010), which is the first study that introduced the GSM model. The represetation is expanded later on in this research by adding risk management to this model. The GSM model is specified using stages, where each stage consists in one or multiple milestones, one stage body, and one or multiple guards. A stage is defined atomic if it has no substages and non-atomic if the stage concists of other sub-stages.

The architecture of the GSM models with respect to the projects, have some overlapping in their structure. The P-Project, M-Project and N-Project could be individually designed, but the paper of Eshuis (2018) suggests an approach for composing model fragments, abstracted into features. This variant selects the relevant features and defines their composition order. The GSM model is then derived by composing the GSM schema fragments corresponding to the selected features in the defined order. A base model that is extended with features depending on certain conditions, reduces the complexity of the GSM models. This approach reduces the complexity and the amount of GSM models.

The symbol '•' is used as function composition operator to define feature composition and the symbol 'Γ' is used to indicate a GSM schema, where each feature denotes a GSM schema. When a new feature is added to a feature composition, it is denoted as $\Gamma^{add} \bullet \Gamma^{comp}$. The entire schema of Γ^{add} is embedded into Γ^{comp}. If sentries of stages and milestones are defined in both GSM schemas, the Γ^{comp} sentries are overridden by the Γ^{add} sentries. Sometimes, it is not desired to override these sentries, but rather to merged. The keyword 'orig' is used in the Γ^{add} sentries to refer to the original sentries in Γ^{comp}. The 'orig' keyword keeps the original sentry intact and additions to this sentry can be made in the Γ^{add} sentry. If a feature corresponds to a base GSM schema, the feature is called complete, because it is executable by itself. Otherwise, the feature corresponds to a GSM schema fragment, which is called a partial feature, because composition with other features is required to derive a executable base GSM schema.

4.2 GSM model of the project business process

The method to create the GSM model described in the previous section, is used in this section for the development of the GSM models for the project business process. Six GSM models are developed, which are combined in a more abstract GSM model for a combined overview of all aspects of a certain project. The following seven artifacts are determined for the development of the GSM models:

1. Main-Project
2. SO-DOP-P
3. SO-DOP-N
4. P-Project
5. M-Project
6. N-Project
7. Materials

Some of these artifacts are connected to each other, which becomes clear later in this chapter. The Main-Project GSM model will contain the top-level stages of other artifacts. The models contain some kind of flexibility to perform tasks, which means that data attributes need to be created, but how these data attributes are established is not imposed. Before the GSM lifecycles of these artifacts are created, the related information models need to be established, which will be described in the next section.

4.2.1 Information model

The information model captures in a materialized or virtual form, all of the business-relevant data about entities of that type. This information typically includes data provided by stakeholders in the process, data about external services that have been called, and log data of previous states of the entity instance.

The attributes in the information model are broken down into three categories: Data attributes, event attributes and milestone and stage info. The data attributes contain information about the progress of an entity instance. Event attributes contain information about event occurrences of external event types that are relevant to a given entity instance. The milestone and stage info include Boolean attributes which hold the statuses of milestones and stages and how they change over time. The stage info is only relevant during a project, so is not included in the information model. The information models that represent the project business process are shown in Figure 13.

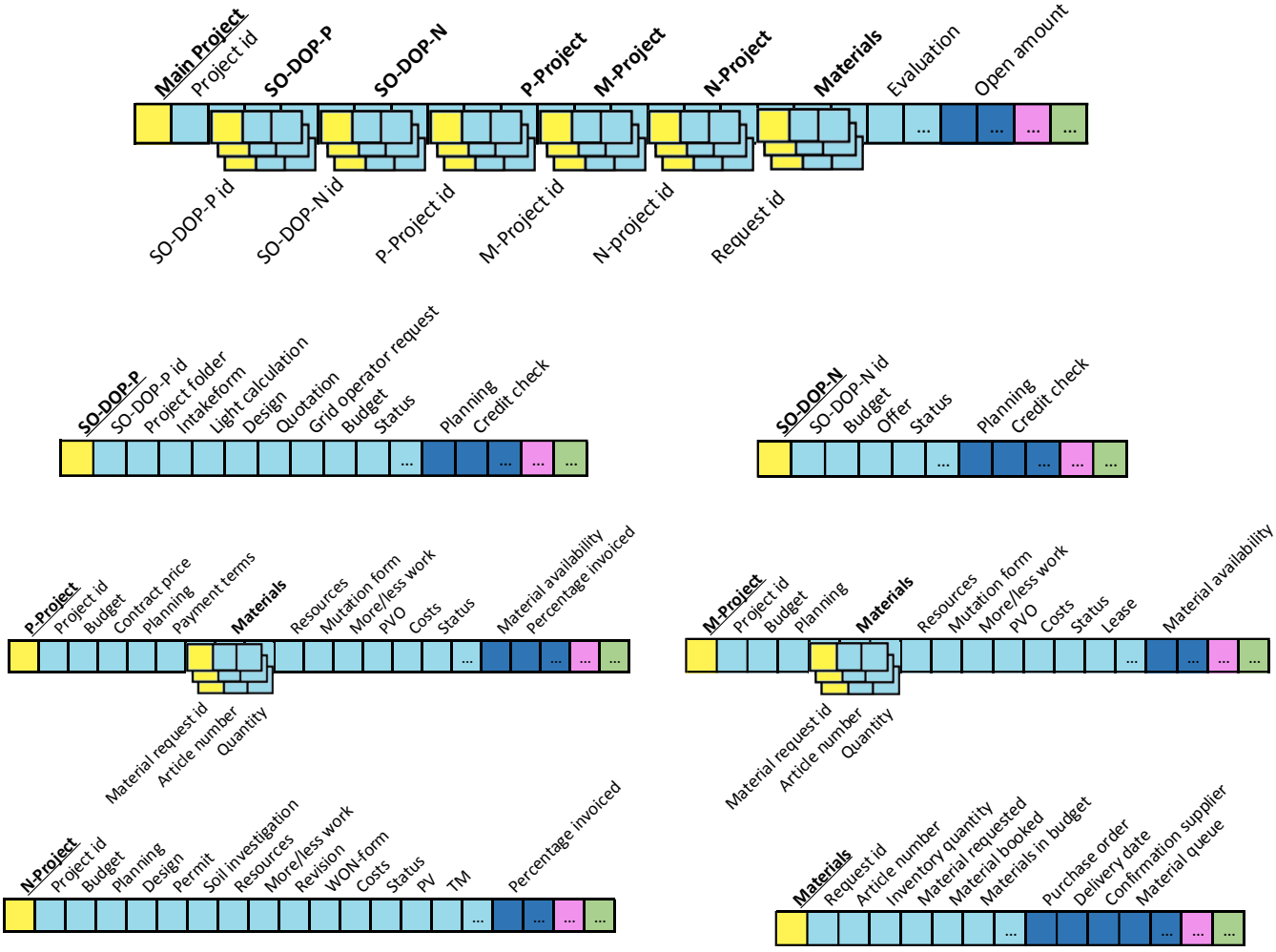

Figure 13: GSM information models

4.2.2 SO-DOP-P

The first artifact of the project business process is the SO-DOP-P. 'SO' is the abbreviation of 'Service order' and 'DOP-P' means that this service order is part of a project from the client

side. Figure 14 presents the lifecycle of the SO-DOP-P and the corresponding rules for this lifecycle model are presented in Appendix G.1.

The SO-DOP-P lifecycle contains four non-atomic stages: Preparation, Offer, Power connection, and Project transfer. These non-atomic stages are described in more detail in Appendix F.1. The lifecycle of the SO-DOP-P starts with a creating guard, which is triggered after a new project request from a client. During the *Preparation* and *Offer* stage, the project could be canceled by the client at each moment.

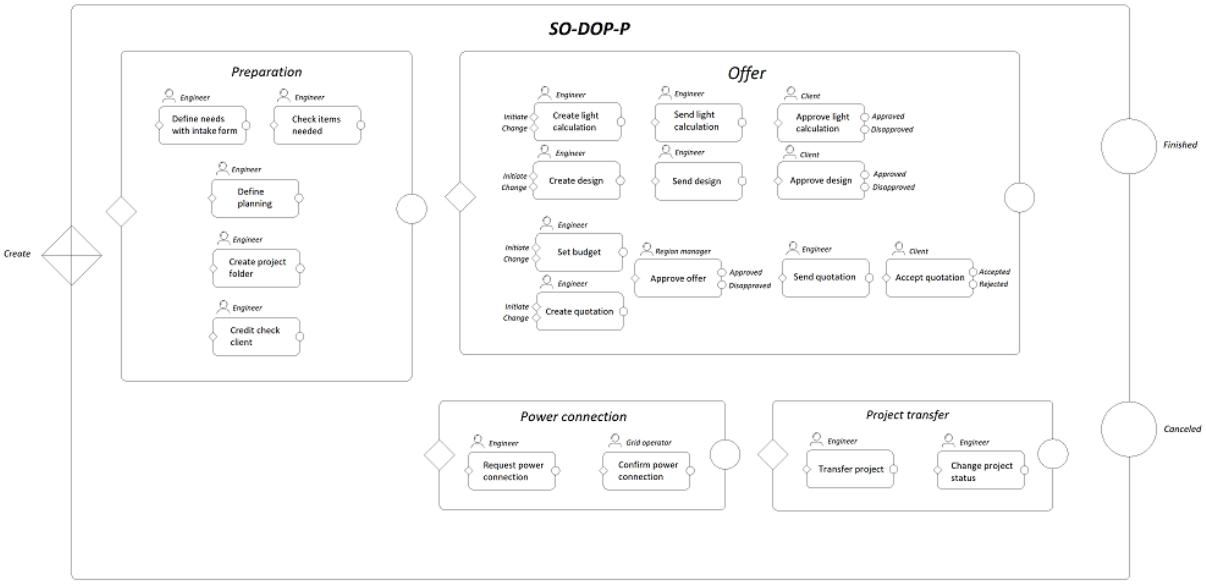

Figure 14: GSM SO-DOP-P

4.2.3 SO-DOP-N

The SO-DOP-N artifact is created when an assignment by the grid operator is procured to CityTec. This could be the same assignment CityTec requested to the grid operator in the SO-DOP-P, but could also be a separate assignment. Most of the time when CityTec sends a request to the grid operator, they also get the assignment, but the grid operator is free in his choose. Figure 15 presents the lifecycle of the SO-DOP-N and the corresponding rules for this lifecycle model are presented in Appendix G.2.

The SO-DOP-N GSM model only consists of atomic stages all performed by the work preparator. The lifecycle of the SO-DOP-N starts with a creating guard, which is triggered after a new assignment from the grid operator is received. The planning of this assignment is transferred to the ERP system. The unit prices of the assignment are also transferred in the ERP system and the budget to perform these activities is established. After the planning, unit prices and budget are created in the ERP system, the work preparator contacts the project controller for the creation of a project and changes the SO-DOP-N status in the ERP system to technically ready. Thereafter all processes of the SO-DOP-N are performed, so the finished milestone of the SO-DOP-N stage is reached.

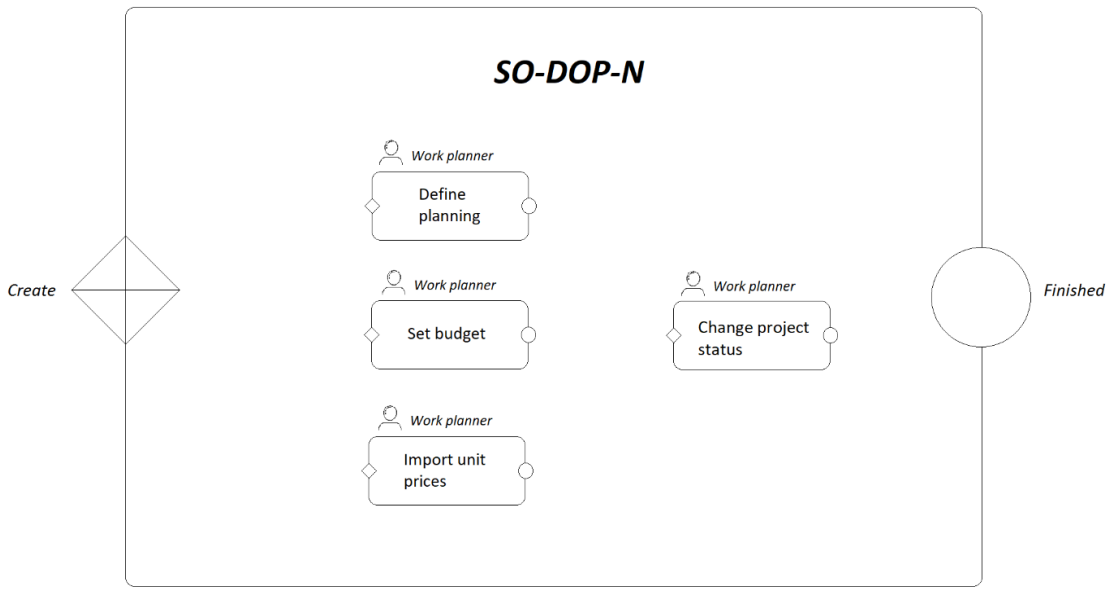

Figure 15: GSM SO-DOP-N

4.2.4 P-Project, M-Project and N-Project

The P-Project, M-Project and N-Project have a lot of overlapping fragments in the GSM model. Therefore, there is chosen to create a base model and features that are added to this base model for distinction between the GSM models. The process architecture of the projects have the same base principles. The models consist of three main non-atomic stages: Work preparation, execution and administration. The order of these stages are visualized in Figure 16. These non-atomic stages are similar in the different projects, but the underlying stages within these non-atomic stages are different from each other. Therefore, base models for these non-atomic stages are introduced and features are added to these models. The base model and the added features combined representing the whole GSM model for the P-Project, M-Project and N-Project.

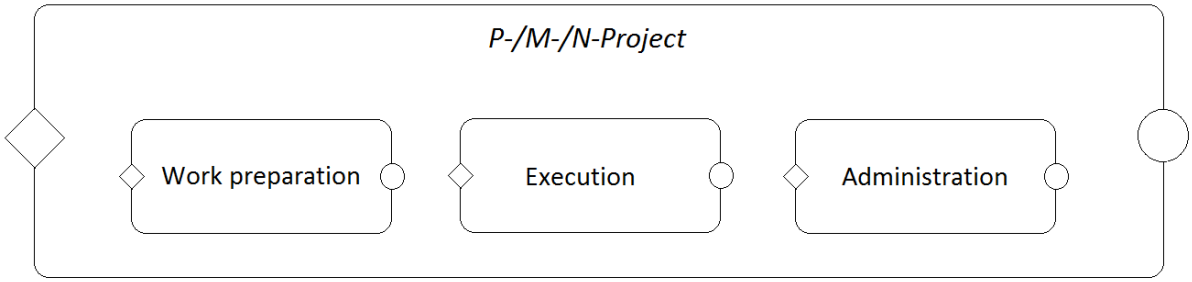

Figure 16: GSM P-/M-/N-Project

The base models and features of the non-atomic stages work preparation, execution and administration are described in more detail in Appendix F.2. The *Work preparation* stage, the *Execution* stage, and the *Administration* stage are specified for each project type by adding features to the base model. The composition of these features with the base model presents the complete GSM schema of that particular stage for a particular project type. The corresponding rules for this lifecycle model are presented in Appendix G.3.

4.2.5 Materials

The Materials GSM model is separated from the project GSM models. The processes in this GSM model are namely not directly part of the project business process. The purchase and logistics department are considered as an external organization in the project business process, due to the fact that this department is centrally controlled, while the project process is regionally controlled.

The materials are requested in the *Work preparation* stage of the project, which activate the trigger of this GSM model. The work preparator gives a desired receipt date for the materials and expect the purchase and logistics department to fulfill this desire. The communication with the purchase and logistics department is minimal and the processes between the material request and the materials receipt is not clear for the regional stakeholders of the project business process.

The Materials GSM model visualizes the process between the material request and the materials receipt. The GSM model is coupled to the *Materials* stages in the M-Project GSM model and the P-Project GSM model. This gives a rough overview related to the materials in the M-Project GSM model and the P-Project GSM model, and a detailed overview in the Materials GSM model, which is presented in Figure 17. The corresponding rules for this lifecycle model are presented in Appendix G.4.

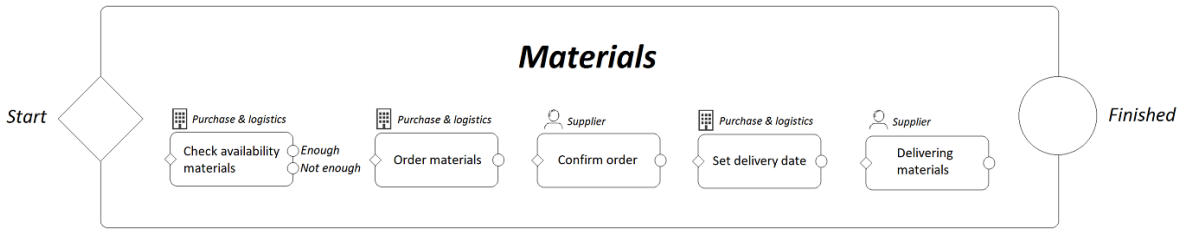

Figure 17: GSM Materials

The first atomic stage in the GSM model Materials checks the availability of the materials. This is based on the inventory in the warehouse and the open material requests for other projects. When there is not enough material to fulfill the request, the material is ordered by the purchase and logistics department. An IOR number is created in the ERP system to order this material. The supplier receives this order and confirm this order with an indicated delivering date. The purchase and logistics department set this delivering date in the ERP system. On the indicated delivering date, the supplier delivers the material ordered.

The GSM model Materials only indicates the pipeline of the purchase and logistics department of open orders. This means that if an order is delivered, the inventory of that particular materials increases. The milestone 'Enough' of the first atomic stage that checks the availability could be achieved, which closes the entire 'Materials' stage. The other stages in this model become empty because there are no open orders for this project anymore.

4.2.6 Main Project

The GSM model of the Main Project is based on the combination of all other GSM models. The Main Project GSM model is created to give a rough overview over the whole project. The main project combines the projects from the client, lease, and grid operator side. The P-

Project, M-Project, and N-Project of a main project are all related to each other. The main project indicates this relationship between these projects and keeps them ordered together.

The GSM model of the Main project adds a new atomic stage to the model that already exists of four stages that represent other GSM models. The P-Project, M-Project, N-Project, and Materials GSM models are the four stages that give the overview of the main project. The GSM models that represent project types, are visualized with the main non-atomic stages within this model for a better overview about the statuses of the projects. The new atomic stage that is added is the *Evaluating* stage. All project combined are evaluated in this stage. In this stage, the projects are checked on their combined correctness. This means that there is one last check to control the correctness of the administrative processing. This is performed by the project controller. The project controller checks the correctness and if everything is correct, the project is closed. The GSM model of the Main project is presented in Figure 18.

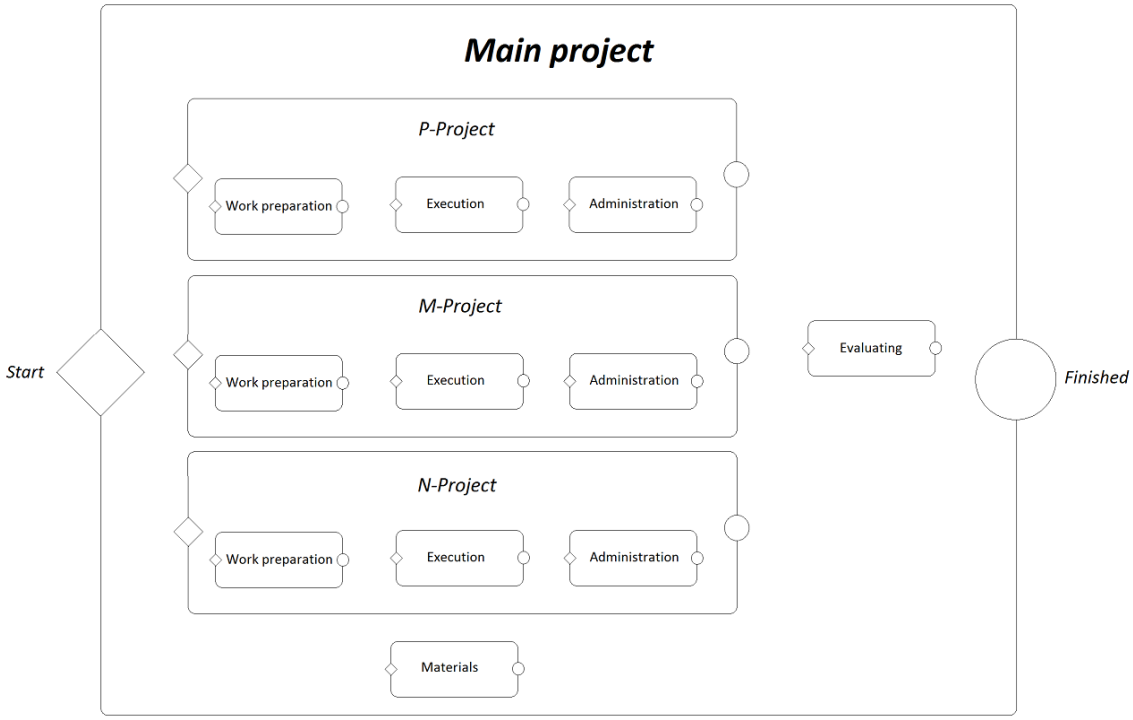

Figure 18: GSM Main project

4.3 Implement risk management in the GSM model

In the previous section, all GSM models related to the project business process are developed. The risks and the corresponding responses in the project business process were already established in chapter 3. This section combines these deliverables and integrates risk management in the GSM model. The integrating of risk management in the GSM model is not performed in literature yet. Therefore, a new risk-aware modeling technique is introduced for the integration of risk management in the GSM model. This new risk-aware artifact-centric business process modeling technique is applied on the project business process of CityTec by integrating the risks assigned in chapter 3 to the GSM models developed in the previous section.

The agreed-upon risk responses are implement in the GSM models as much as possible to decrease the probability and/or impact of the entiry project business process. The probability, impact and risk responses used in this section are developed in chapter 3 and presented in Appendix D and Appendix E.

4.3.1 Introduction

In literature, risk management is not yet implemented in the GSM model. The research of Suriadi, et al. (2014) evaluates the reports about the risk-aware business process management, but these reports all apply activity-centric modeling techniques. Risk management in artifact-centric business models are not introduced yet. The risk-oriented approaches used in business process management are evaluated in this introduction and the best fitted approach for the GSM model is implemented in the model.

The literature considered for the implemenation of risk management in the GSM model needs to satisfy certain criteria. One of these criteria is that the approach needs to propose a set of graphical notations that are sufficient for the purpose of the approach. Another criteria is that the approach needs to use a form of risk analysis, which is also performed in this research. The last criteria is that the approach needs to propose a risk modeling construction that can monitor risks during runtime.

Conforti, Forino, La Rosa, & ter Hofstede (2011) is one of these papers that monitors risks and applies mitigation actions during runtime. This paper provides a language that triggers alerts to notify the users of the existence of the risky process instance and the specific risk involved. Sensors are defined at the design of the process model and are triggered during the runtime of the process model. The sensors represent conditions and if these conditions hold, the sensor manager is notified that a risk has occurred. Historical data in process logs, and current execution data are filtered, aggregated and analyzed. When a condition of a sensor in the process evaluates to true, the interested user is notified. The sensor condition is defined as a boolean expression.

Kang, Cho, & Kang (2009) propose a method to measure the risk level in real-time for Business Activity Monitoring (BAM). The decision-tree methodology is employed to analyze the effect of the process attributes on the results of the process execution. Historical data is used for the probability estimation calculation. These probability estimations are coupled to the decision-tree methodology, which provides the probability of entering an abnormal termination stage.

The paper of Nafie & Eltahir (2016) also uses Business Activity Monitoring (BAM) for risk visualization. BAM is a software that aids in monitoring of business activities, where these activities are implemented in computer systems. The GSM model in this research is also implemented in a computer system, which make these studies interesting. This paper uses BAM as monitoring tool that compares real-time case data with pre-defined KPIs. The aim of the case study performed in this study, is to visualize the real-time performance for a account payable process regarding the time. The visualization is performed by using three colors. The green color means on time, the orange color means at risk, and the red color means overdue.

Meroni, Baresi, & Plebani (2016) translated the BPMN to E-GSM in their research. The E-GSM is an extension to the GSM model. They intoduced Fault Loggers, which are also following ECA rules to become active. If the Fault Logger becomes true, the stage is declared as faulty because something went wrong. These Fault Loggers are intended for exception handling. The Fault Loggers trigger alternative or control flows, which differs from risk management perspective.

The paper of Betz, Hickl, & Oberweis (2011) does not handle the execution stage of the business process lifecycle, so does not meet all criteria. This study is evaluated due to the clear visualization of risks in the business process model. This paper suggests icons as a red flash linked to the activities in the business process model to indicate risks. This is in contrast to the other papers evaluated, where side paths are created to handle risks.

4.3.2 The R-GSM model

The implementation technique for integrating risk in the GSM model is established by a mix of the studies evaluated. The risks are visualized in the GSM model as discussed in Betz, Hickl, & Oberweis (2011) with an icon instead of side paths, and added to the GSM model as in Meroni, Baresi, & Plebani (2016) as extension. The sensor conditions of Conforti, Forino, La Rosa, & ter Hofstede (2011) are coupled to these risk to indicate if these risks occur. The three color indication of Nafie & Eltahir (2016) visualizes the real-time risks in the tool created regarding the model established in this chapter.

A meta-model is created to introduce the new risk-aware artifact-centric modeling technique. The model presented in Figure 19, visualizes the artifacts in the implementation of risk management in the GSM model. Among with the meta-model, the graphical representation of these elements in the GSM model is presented. The new model is called the Risk-aware Guard-Stage-Milestone model (R-GSM).

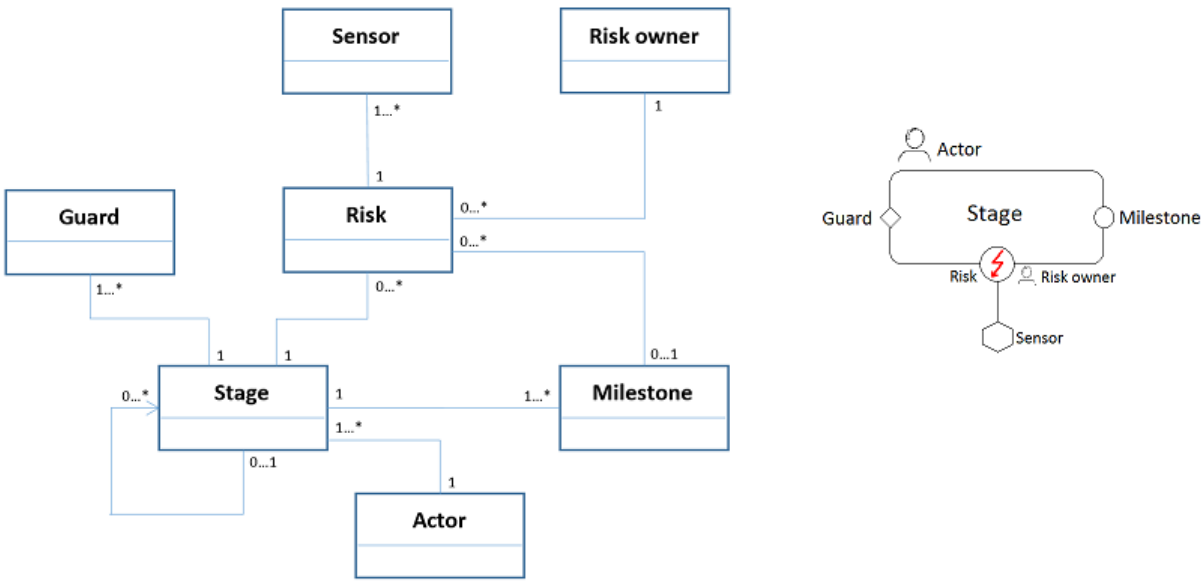

Figure 19: R-GSM meta-model and the graphical representation

The *Guard* is activated via the conditions of the corresponding sentry. The sentries are based on the Event-Condition-Action (ECA) rules. The *Guard* opens the contiguous *Stage*, which provides the task that needs to be performed by the *Actor* of that *Stage*. The *Stage* could be active via multiple *Guards*, which have their own sentries. The *Stage* is closed when a *Milestone* is reached, which is activated via the conditions of the corresponding sentry. A *Stage* could also have multiple *Milestones*, which have their own sentries. Only one of the contiguous *Milestones* has to become active for closing the *Stage*.

The proposed extension adds *Risk* to the existing GSM model. The *Risk* becomes active when the *Sensor* is triggered. The *Sensor* is based on a boolean condition. When this condition holds, the *Sensor* is triggered and the *Risk* becomes active. The *Risk owner* is notified about the risk that has occurred. The *Risk owner* is responsible for risk response to mitigate or solve this *Risk*. The *Risk owner* is not by definition the actor who must take action, but is the one responsible that these actions are taken. The risk affects the status of the *Stage*, but could also affect the *Milestone* if this *Milestone* is already reached.

4.3.3 The R-GSM model of the project business process

The implementation of the R-GSM model in the project business process can be found in Appendix H. The individual risks defined in chapter 3, are coupled to the stages in the GSM models of the project business process. Not all risks are included in the R-GSM model, due to different risk response strategies. Another reason that the risk is not integrated in the R-GSM model is that the probability and impact are too low or nothing can be done about this risk. Risks can also be partial integrated in the R-GSM model, which means that the risk could be triggered in the R-GSM model, but the risk response is outside the scope of the project. Table 3 shows the risks identified in the project business process of CityTec and which of these risks are covered in the R-GSM model.

Table 3: Risks integrated in the R-GSM model of the project business process of CityTec

Nr.	Risk event	R-GSM	Nr.	Risk event	R-GSM
1	Not all documents in assignment	✓	**32**	Project closed without having all payments	✓
2	Not all materials included in budget	✓	**33**	Project closed without having all invoices	✓
3	Not all labor included in budget	✓	**34**	Too many internal labor booked on a project	✗
4	Labor costs from other subcontractor	✓	**35**	Costs booked on wrong project	✗
5	Client does not pay invoice	✓	**36**	Materials ordered too late	✓
6	Not invoicing more/less work	✓	**37**	Materials delivered too late	✓/✗
7	Forget to invoice client during project	✓	**38**	Materials not ordered	✓
8	Wrong material delivered	✗	**39**	Price change by supplier	✓/✗
9	Order not fully received	✗	**40**	Wrong material ordered	✗
10	Client forgets to approve design	✓	**41**	No confirmation for delivering material	✓
11	Bad weather	✗	**42**	Materials delivered too early	✗

12	Price change by subcontractor	✓/✗	**43**	No permit when permit needed	✗
13	No resources/subcontractor available	✗	**44**	Price change by grid operator	✓/✗
14	Other parties not ready	✗	**45**	Power connections not requested	✓
15	Traffic barrier needed	✓/✗	**46**	Power connections request takes too long	✗
16	Material damage	✗	**47**	Wrong activities requested for power connections	✗
17	Not invoicing more/less work	✓	**48**	No project folder created	✓
18	Grid operator does not pay invoice	✓	**49**	Wrong activities or costs on PV	✓
19	Forget to invoice grid operator	✓	**50**	PV booking not on right project	✓
20	Intake form not performed	✓	**51**	Project not transmitted to client/approved by client	✓
21	Client forgets to approve light calculation	✓	**52**	Project not transmitted to grid operator/approved by grid operator	✓
22	Light calculation, design or quotation not approved	✓	**53**	Materials not included in quotation	✓
23	Wrong material requested	✗	**54**	Labor not included in quotation	✓
24	Too much or too less materials requested	✓	**55**	Region manager forgets to approve quotation	✓
25	More/less work not booked on project	✓	**56**	Quotation is expired	✓
26	No client or grid operator approval for more/less work	✓	**57**	Revision not approved by grid operator	✗
27	No mutation form created	✓	**58**	No soil investigation performed	✓
28	Wrong data in mutation form	✓	**59**	Soil is contaminated	✓
29	Mutation form not sent to asset management	✓	**60**	Materials taken for other project/service order	✗
30	Lamppost numbers already exist	✗	**61**	Wrong inventory quantity in system	✗
31	Budget components assigned to wrong project	✗	**62**	Wrong activities in WON-form	✓

✓: Fully integrated, ✓/✗: Partial integrated, ✗: Not integrated

4.3.4 Partial- and not integrated risks

Some risks are not integrated or only partial integrated in the R-GSM model. There are various reasons why these risks are not (fully) integrated. One of these reasons is that the risk response has an escalate or transfer strategy. These risk are outside the scope of the project business process. The managing board needs to discuss these risks and are responsible for managing these risks. One of these risks is for example that the wrong inventory quantity is provided in the ERP system. The risk response strategy is to escalate the risk, which means that the risk response is outside the authority of the stakeholders

involved in the project business process. The managing board could instruct the warehouse for more frequent inventory counts.

Another reason that the risk is not integrated in the R-GSM model is that the probability and impact are too low or nothing can be done about this risk. An example is the risk that the lamppost numbers already exist. The probability of this risk is almost zero and the risk is easy to fix. It is not profitable for these kind of risks to take action in advance and include in the R-GSM.

The last reason that the risk is not integrated in the R-GSM model is because the risk is financial related instead of process related. These risks will be handled by visualizing a financial overview in the tool. This overview shows the open amount of the budget. An example of this risk is the risk that too many internal hours are booked on the project. This is visualized by the open amount of the budget in the project. This risk is triggered when the open amount for the internal hours becomes negative.

4.4 Sub-conclusion

This chapter provides a new risk-aware artifact-centric business process modeling technique called R-GSM. The designed models in this chapter are the foundation for the tool in the next chapter. The GSM models created in this chapter are made visual in the Excel VBA. The sentries corresponding the R-GSM models are transformed in the next chapter to VBA code to make a dynamic tool. Risks that have significant impact on the project objectives but which are not integrated in the R-GSM model, are also added to the tool design as much as possible. The literature in section 4.3.1 will also be used for the tool design of the project business process in the next chapter.

5 R-GSM tool design

This chapter provides a tool that is based on the R-GSM model for the project business process of CityTec. The tool is established based on the created models in the previous chapters, related literature, and the requirements by the stakeholders within the project business process. After the requirements are drafted, the system architecture is created. Thereafter, the process model of the R-GSM tool is provided to visualize how the tool will be used in the organization on daily basis.

5.1 Requirements

The requirements are drafted with the use of the stakeholders within the project business process. The stakeholders are missing a lot of transparency of the data in the current situation. The data and the relationship between this data is not clear. In addition, there is no overview of the status of the project and potential risks. Therefore, functional and non-functional requirements are established by the stakeholders. These requirements are stated in Table 4.

Table 4: Tool requirements

Functional requirements	
1	The tool will provide process steps which need to be go through by the stakeholders.
2	The tool will visualize risks that occur during the project.
3	The tool will provide a financial overview of the current status of the project.
4	The tool will provide quick access to relevant documents.
5	The tool will visualize relevant data about the project.
6	The tool will be accessible by stakeholder within the project business process at the same time.
7	The tool will have a dashboard that visualizes the connected projects and a quick overview of the status of these projects.
Non-functional requirements	
8	The tool must be well structured and easy to use.
9	The tool must visualize the risk in the process clearly.
10	The tool must visualize all risks in the project and not only the risk for a specific stakeholder.
11	The tool must have a quick overview for all related project and a detailed overview specific for each project.

Stakeholders are not personally coupled to the stages and risks in the tool because CityTec does not want to create a individualistic mentality. Therefore, the phases of the project are coupled to a group of stakeholders. The engineers are responsible for the SO-DOP-P, the work preparator of the SO-DOP-N and the work preparation stage in the project, the executor for the execution stage in the project, and the project controller for the administration stage in the project.

The tool is developed using Excel VBA. This program language is used because the stakeholder in the project business process are most familiar with Excel. When end users are familiar with a software program, they will earlier accept the tool (Coronel & Morris, 2014).

5.2 System architecture

The tool is designed based on the R-GSM model created in the previous chapter, and the system requirements assigned in the previous section. First the data flow of the tool is described based on the Level-0 Data Flow Diagram, also called context diagram, which represents functions and data flows at a high level view of abstraction (France & Docker, 1989). Thereafter, the visualization of the tool is described.

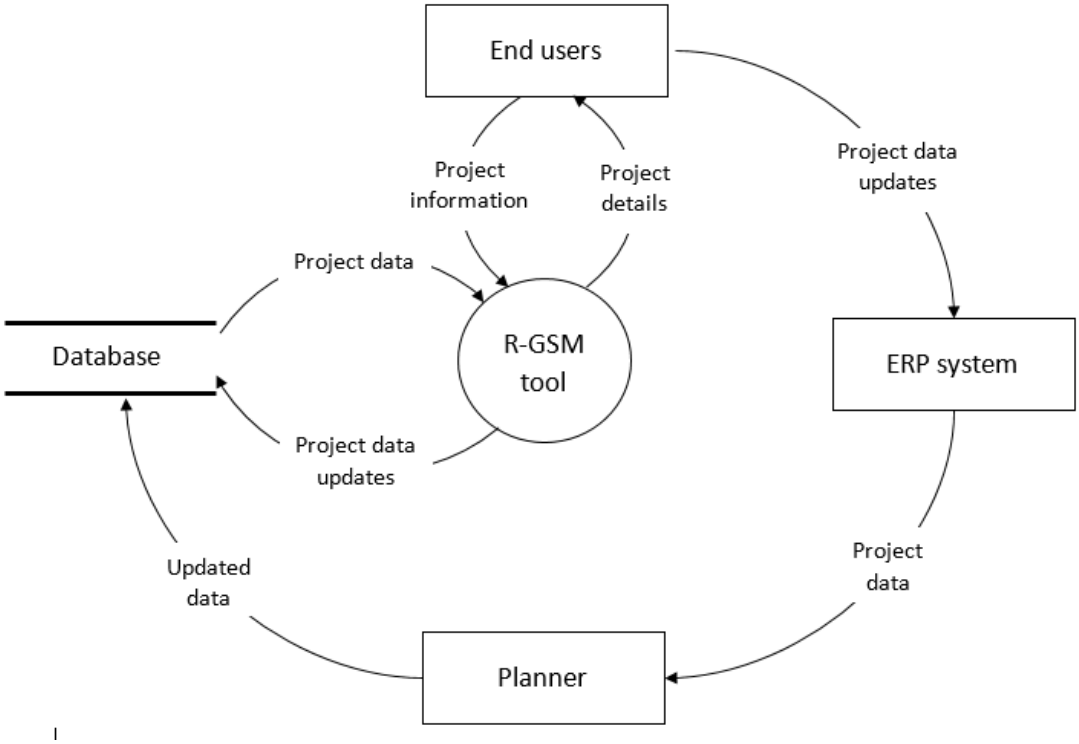

Figure 20: Data flow diagram

Figure 20 describes the data architecture of the R-GSM tool based on the notation of DeMarco (1979). The data flow diagram is established to give an indication of the information input and output of the R-GSM tool. The planner gathers the data of the ERP system and updates the database of the R-GSM tool with the updated data of the ERP system. Changes performed by the end users in the R-GSM tool are automatically changed in the database.

The visualization of the tool is already described by the R-GSM model. Only the dashboard is one of the requirements which needs to be add to the tool. Architecture of this dashboard is described with the UML modeling language shown in Figure 22. The dashboard will also be design according to the GSM model.

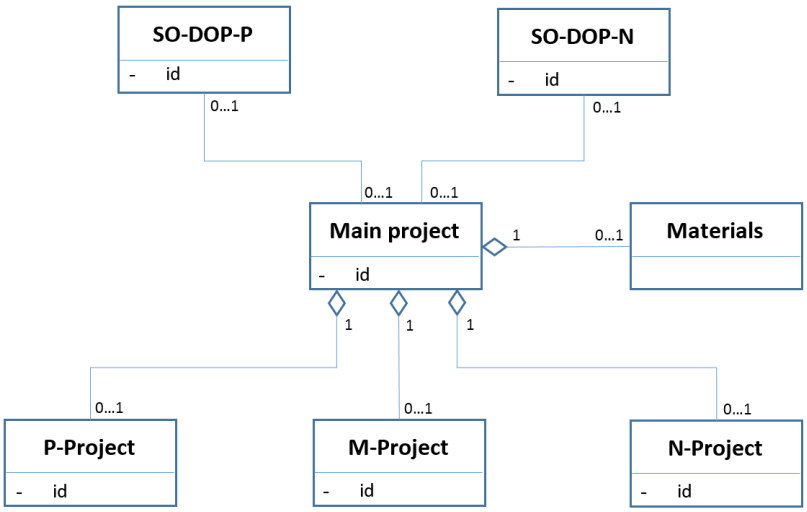

Figure 22: Architecture of the dashboard

The structure of the tool is now almost clear. The architecture of the dashboard is provided and the architecture of the SO-DOPs and the projects are based on the GSM models designed in chapter 4. Only the architecture of the risk rules are not designed yet. The paper of Nafie & Eltahir (2016) uses the colors green, orange and red to visualize the risk in the business process. This logic will also be used in the tool to indicate the risk potentials. The project business process is described in the R-GSM model and the stages could have take different statuses. These statuses are presented in Figure 21.

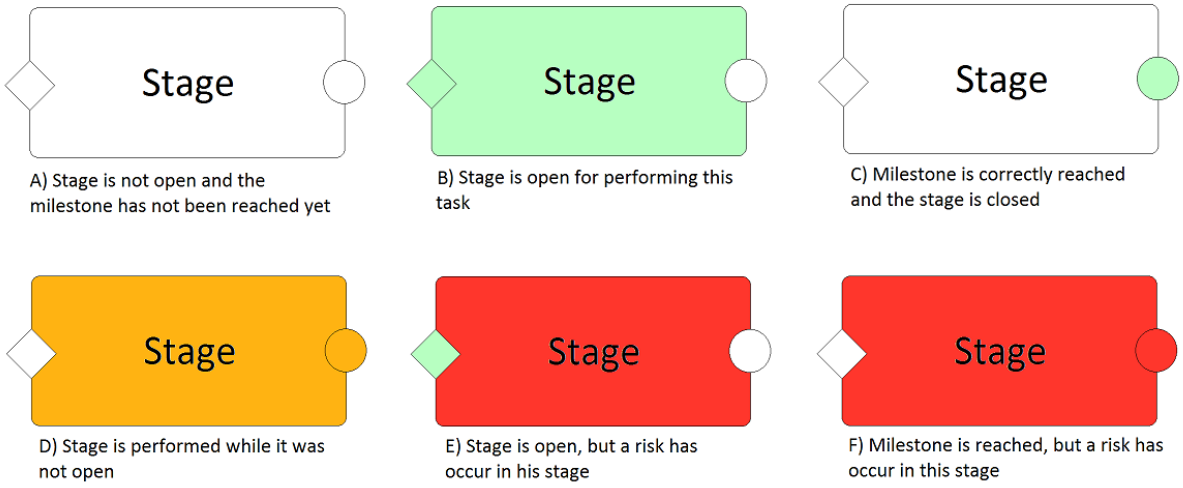

Figure 21: Stage status

The *D*, *E* and *F* statuses contain risks. The *D* status is added to the R-GSM model, because this status does not contains a direct risk as in *E* and *F*, but an indirect risk. The indirect risk is this stage is that this stage is performed, while the stage was not open. This means that another stage is not performed, which is necessary to open this stage. In other words, if the stage becomes orange the stage is performed too early in the process. The *E* and *F* statuses are reached when the risk sensor of the stage holds and the risk becomes active. These risk conditions of the risk sensors are described in the previous chapter.

5.3 Work analysis refinement model of the R-GSM tool

A Work Analysis Refinement Model (WARM) is created to describe all steps that are taken by the different subjects and systems. The WARM consists of two start point. One for the planner, who updates the data in the tool, and one for the other stakeholders in the project business process. The planner is assigned by the organization to be responsible for the daily data updates. The data in the tool is protected with a code that only the planner is aware of. This ensures that the data is not manipulated by other stakeholders. The WARM is shown in Figure 23. The first part of the WARM is the process of updating the tool and the second part after the second start point, is the use of the tool in the project business process.

The steps in the WARM are refined by adding the execution type. The steps in the WARM are split in human steps and automatic steps (Domingos, Rito-Silva, & Veiga, 2004). The human steps are performed by human workers, while the automatic steps are executed by a software system. A human step could be a human task or a tool task. The human task is performed by a human worker without any information system, while the tool task is also performed by a human worker but with the assistance of an information system tool. The automatic steps are presented by diamonds in the WARM, the human tasks by rectangles, and the tool tasks by triangles.

5.4 R-GSM tool usage

The goals of the R-GSM tool is to visualize the current status of the project and make the risks observable for the stakeholders in the project business process. The stakeholders need to follow the process steps created in this model. The tool is designed to make these process steps insightful and is made interactive. The tool is divided in two functionalities. One of these functionalities is that the data of the model is updated and the other functionality is the project visualization.

5.4.1 Updating data

The data is updated every day by the planner. This data is gather from the ERP system of CityTec. The ERP system of CityTec is Navision, also called Microsoft Dynamics NAV. The template of the data is prepared in advance in the ERP system. The planner unlocks the security of the tool and load this data in the Excel VBA tool. There are twenty templates extracted from the ERP system by the planner and loaded in the tool. After these templates are loaded, the database is updated based on this data. Project specification are now updated in the R-GSM tool.

5.4.2 Searching projects

The main functionality of the tool is to visualize the status and risk of the projects. The stakeholders in the project business process have all access to the tool. The stakeholder search for a project to see the status and risk of the project. The dashboard visualizes all related projects corresponding the search project number, and the status of these project. The rules of the R-GSM model are applied on the data of the project in the database. The open stages and stages at risk are made visible through these sentries. The stakeholder can now performs the stages that are open. The stakeholder can also see which stages are at risk and can take risk response actions. Some stages are performed in the tool, while other

stages need to be performed in the ERP system. The data about the project that is changed, is saved in the database.

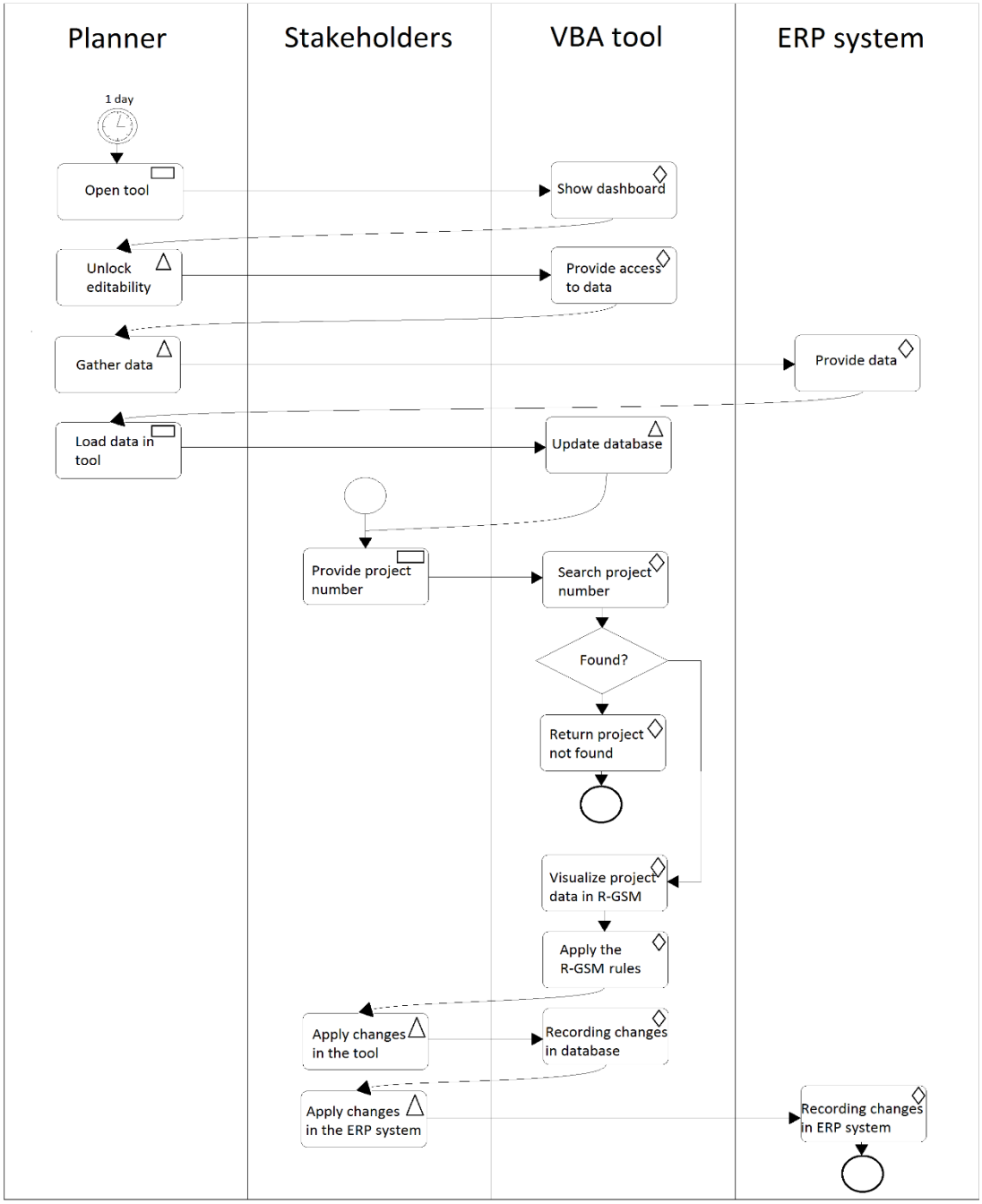

Figure 23: WARM for the R-GSM tool

5.5 Sub-conclusion

This chapter provides the design of the R-GSM tool for the project business process of CityTec. The tool is designed by using Excel VBA in which the end users can search for a project number. The tool will visualize the status of the project based on the data in the database and by apply the rules programmed in VBA. The tool is made dynamic, which means that the tool reacts on constant changes in the project data. The tool is evaluated in the next chapter by test cases and by the judgment of stakeholders.

6 Results and evaluation

This section discusses the results and the evaluation of the R-GSM tool. First, the final tool design is presented with project search example. Thereafter, the solution design is evaluated by the user experiences of the end users of the designed R-GSM tool and validated by comparing the tool with a manual check performed by different stakeholders.

6.1 Results

The R-GSM tool is created in Excel VBA. This program language is chosen because the stakeholders are most familiar with this the program. The tool is easier accepted by the stakeholders of the project business process when the program is familiar by the end users. The system architecture established in the previous chapter is used for the design of the tool. The sentries and risk rules defined in chapter 4 are programmed to make the tool dynamic. Projects can be searched in the tool and the data of these projects are searched in the database of the tool. The sentries and rules are applied on this project data to visualize the current status and risks in a particular project. Figure 24 shows the dashboard of the tool. The related projects and SO-DOPs are also visualized and analyzed. The dashboard visualizes the status and risks in the projects, and the financial overview of the projects. In this case, the main project consists of a P-Project and N-Project which are both at risk. The materials of the project are also at risk and the financial overview shows that the amount for the power connection exceed the budget. The amount in the budget for the internal hours and materials are also already exceeded.

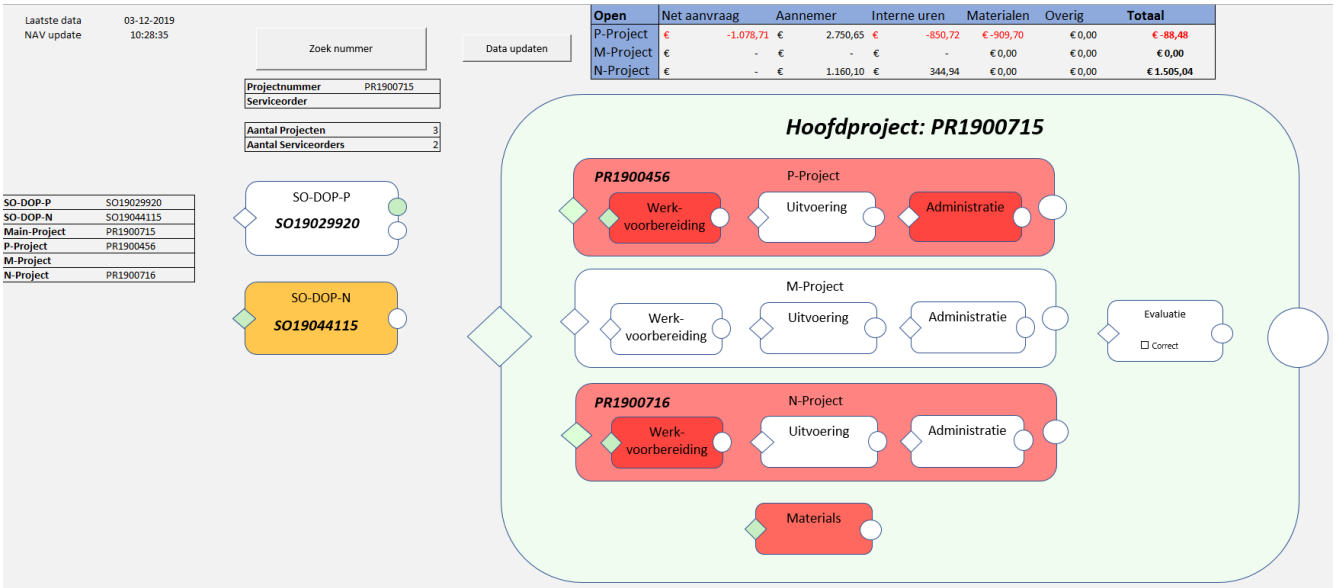

Figure 24: Dashboard of the R-GSM tool

Examples of the detailed R-GSM models of the SODOPs and projects are visualized in Appendix I. The SO-DOP-P in this example case is correctly performed with all milestones reached. The SO-DOP-N has an orange stage, which means that the project status is changed while the planning stage is not performed yet. In the Work preparation stage of the P-Project are three risks found. The stage *Transfer contract price* is at risk. This means that the contact price is not correctly transferred from the SO-DOP-P to the project. The price in the quotation in the SO-DOP-P is €25,903.54, while the contract price in the P-Project is €27,134.27. The *Transfer planning to project* is also at risk. This means that the planning of

the projects are not synchronized. The end date in the P-Project is 31-12-2019, while the end date in the N-Project is 6-12-2019. The last risk in the work preparation stage of the P-Project is the material request. This stage shows that there are too much materials requested than included in the budget. The details of this risk is presented in the materials R-GSM model. The execution stage is not performed yet in this example case. The execution stage and administration stage are therefore visualized in the appendix of another project to show the processes and risks in these stages.

The work preparation stage of the N-Project of the example case visualized in the dashboard, also consists of a risk in the planning. The planning of the P-Project is not the same as the planning in the N-Project, so the planning of both projects are at risk.

The dashboard shows also risk in the materials stage. The materials R-GSM model provide more detail overview as shown in Appendix I. The risk in this stage is that the materials are delivered by the supplier on 12-12-2019, while the start date of the project is 5-12-2019. The materials will be too late for the start of the project. Risk response is required for this risk.

6.2 Test cases

The validation of the solution design is established by comparing the to-be situation, which includes the R-GSM tool, with the as-is situation. Because there are no tools in place at the moment, the stakeholders are asked to filter risks in sample project cases manually. The R-GSM tool is compared with manual checks. The stakeholders are asked individually to point out all risks in the project cases. Thereafter, these projects are searched in the designed tool and the risks assigned by the R-GSM tool are compared to the risks in pointed out by the stakeholders manually.

A sample size is needed to validate the performance of the tool. To control all projects requires too much time of the stakeholders. The sample size is defined by the formula of Yamane (1967):

$$n = \frac{N}{1 + N(e)^2}$$

The *n* is the sample size needed, the *N* is the population size, and the *e* is the level of error. The sample size does not need to be too large, because the stakeholders need to check the project manually. Otherwise, the manual check costs too much time and the stakeholders will not cooperate. Therefore, the error level of 10% is chosen. Currently, there are 255 project open in the ERP system for this region. This results in a sample size of 70 projects, which is still time-consuming to check manually. Therefore, the sample size is divided over seven stakeholders.

The complete sample size is manually checked by two engineers, two work preparators, two executors and a project controller. Each stakeholder checks ten project cases and delivers the risks found. This resulted in an average of 1.26 risks per project found manually in the sample size. To find these risks manually is time-consuming. The stakeholders indicated that 10-15 minutes were necessary per project to point out all risks. The same

projects are checked in the R-GSM tool, which only needs 5 seconds to find all risks in the project when the data in the database is up-to-date. The tool found on average 3.79 risks per project. The stakeholders are ask if these risks were rightly identified. In all situations, the stakeholders agreed on the risk concerns. This concludes that the R-GSM tool identifies approximately 3 times as many risks than stakeholders identify manually.

Moreover, manually risk identification is not performed in the as-is situation, because it is too time-consuming. Risks are reactive managed or even not managed at all if they are not observed. By applying the tool, more risks are identified is less amount of time. The main advantage of this tool is that the stakeholders can see all potential risks in the project and risks could now be proactive managed.

6.3 Stakeholders judgment

Additionally to the test cases, the solution design is evaluated by the judgment of the main end users of the tool. The main end users of the tool are the engineers, work preparators and executors. The stakeholders in the project business process are free to use the R-GSM tool for two weeks before their judgment is collected. The judgment of the end users are asked individually to require more unique feedback. The judgment of the end users will be their own opinion instead of agreeing on the opinion of another stakeholder. Their judgment are based on the requirement of the tool described in chapter 5. The main end users judge (from 1 to 10) how good the requirement are covered in the as-is situation without the R-GSM tool, and in the to-be situation with the R-GSM tool. This judgment is visualized in Figure 25.

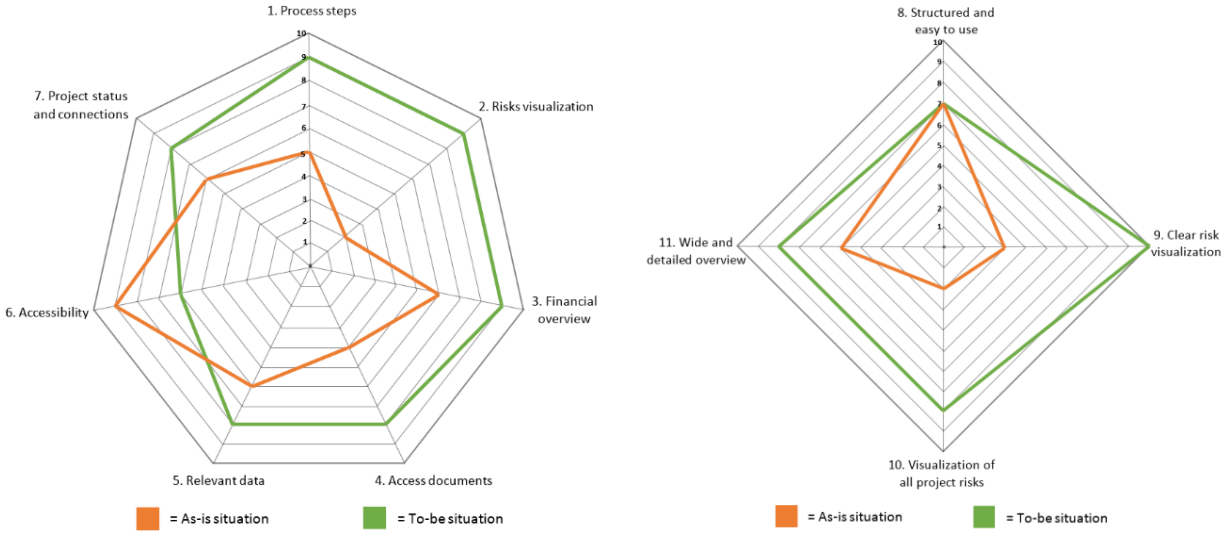

Figure 25: End users judgment of the R-GSM tool

In general, the stakeholders found the models and tool well organized and clear. The stakeholders found it especially useful during the transfer of the project. The projects are not transferred to the next phase if not all previous processes are performed and risks in these processes are not handled. In the as-is situation, the project transfer is quite chaotic and time-consuming because the stakeholder were the project is transferred to, needs to delve into the project and needs to check all previous processes. The R-GSM tool makes this

much easier by providing an organized overview of the project status and processes performed.

The stakeholders also found the financial overview in the dashboard really useful. The stakeholders were in the as-is situation only aware of the total remaining budget. The R-GSM tool divides this remaining budget into sub-categories, which makes it much easier for the stakeholder to control the financial status of the project.

The stakeholders are overall very enthusiastic about the R-GSM tool. The stakeholders has problems in the ERP system with requiring the relevant information for the project. The information in the ERP system is not well organized and multiple transactions in the system are required to reach the information needed. In addition, the information in this ERP system are not compared to each other. The stakeholders like the fact that the R-GSM tool gives a better organized overview of this data and indicates risks by comparing this data with each other.

The only downsides of the R-GSM tool notified by the stakeholders are the indirect link with the ERP system and the accessibility of the tool. Changes in the ERP system are not immediately noticeable in the R-GSM tool. The data of the ERP system is updated daily by the planner and not automatically real-time. This downside could be tackled in the future by linking the data in the ERP system directly to the tool, but this needs to be done by an expert of the EPR system which is too expensive for the current state of the project. The tool is created in Excel VBA which causes the accessibility downside. The tool is created with the co-creation function of Excel, which allows multiple users in the tool. This function is not optimal for a multiple users tool. In the future, the tool could be transformed to a new software program, but this is too expensive for the current state of the project.

7 Conclusion

The research questions are discussed and answered in the previous chapters. The conclusion chapter describes the conclusion of this research by answering the main research question and describes the scientific contribution of this study. Thereafter, the limitations and recommendation for further research are described.

7.1 Research conclusions

The main research question which is the guideline of this research has been formulated as follows:

How can a tool be designed to manage and monitor risks within the project business process of CityTec?

The research question can be split in multiple components. One of these component is the project business process of CityTec. First, the project business process of CityTec needs to be understand and modeled before risk management can be integrated in this process. The project business process is mapped by creating a communication model and a UML class diagram. These models are giving a rough overview of the project business process from a subject and object point of view and are established by interviewing the actors involved in the project business process.

The second component of the research question to investigate, is the risk component. The risks in the project business process are identified and analyzed according to framework of PMBOK. The probability and impact of these risks are established with the use of both qualitative as quantitative analysis. The framework of PMBOK also assigns risk owners and risk responses to the risks.

The third component of the research question discussed in this study, is the manage and monitor component. To manage and monitor the risks in the project business process, the project business process is modeled and risk management in integrated in this model. Flexibility is required in the project business process model because projects differentiate from standard business processes by its size and complexity. Artifact-centric business process modeling, especially the Guard-Stage-Milestone (GSM) model, provides this flexibility in the execution of the project business process. The GSM model is based on artifacts, which are data attributes that flow through the process while carrying information of that process. The project business process of CityTec distinguishes seven artifacts: Main-Project, SO-DOP-P, SO-DOP-N, P-Project, M-Project, N-Project and Materials. These artifacts all have their own lifecycle that contains stages with tasks and the execution of these tasks change the information of the artifact. Stages are opened and closed by the corresponding sentries, which change the state of the lifecycle.

After the project business process is designed according to the GSM notation, risk management is integrated in this model. Integrating risk management in an artifact-centric business process model is not discussed in literature yet. Therefore, this research introduces the Risk-aware Guard-Stage-Milestone (R-GSM) model. This introduced modeling technique adds risk management to the existing GSM model of Hull, et al., (2010). The added risk

component to the existing GSM model consists of the risk itself, a risk sensor, and a risk owner. The risk becomes active when the condition of the risk sensor holds and the risk owner is responsible for the correct risk response for this particular risk.

The last component of the research question is the tool design. The tool design is based on this new risk-aware artifact-centric business process modeling technique for the project business process and the requirements proposed by the end users of the R-GSM tool. The tool is developed in Excel VBA because Excel is a familiar system for the end users of the tool. The designed tool helps the stakeholders to identify the risk in the project business process. The R-GSM tool identifies approximately 3 times as many risks in the projects than manual risk identification. Moreover, identifying risk manually is time-consuming, which is saved by using the R-GSM tool.

To conclude, a tool to manage and monitor risks in the project business process of CityTec can be designed by modeling the project business project using an artifact-centric modeling technique and integrate risk management in this artifact-centric business process model in order to implement this risk-aware business process model in a tool based on the requirements of the end users.

7.2 Scientific contribution

This research contributes to literature in multiple ways. The risk-aware business process models in literature are all activity-centric modeled. This research provides a new modeling technique that manages risk in an artifact-centric business process model. This new modeling technique is an extension of the existing GSM model of Hull, et al., (2010). This risk-aware artifact-centric modeling technique is called the Risk-aware Guard-Stage-Milestone (R-GSM) model. The risks added in this model are triggered by sensors, which are based on certain conditions. When the condition of the sensor holds, the risk becomes active and the risk owner, which is also added in the model, becomes responsible for the risk response.

Moreover, the theoretical model of the R-GSM is immediately made practical in this research by designing a R-GSM tool for CityTec. This tool contributes to the literature by describing the different steps of making such a tool.

In addition, this research contributes also to literature by apply the GSM of Hull, et al., (2010) in a case study. The project business process is succesfully modeled with the artifact-centric GSM notation. The advantage of this modeling technique is the amount of flexiblity in this model, which is proven in this flexible project environment.

7.3 Limitations

The first limitation is the amount of available data within the organization. CityTec switched from ERP system one and a half year ago. Most of the data in the old ERP system is lost. There is not enough data available for some quantitative analyses for significant results. The original plan was to analyze risks based on the dataset, but these risks are now analyzed in a more qualitative way. This results in a less precise probability and impact of the risks.

Another limitation is the evaluation time of the R-GSM tool. The stakeholders only used the tool for two weeks before they were ask to evaluate the tool. This research is limited in time and therefore the tool could not be tested of a longer time. The R-GSM model is created in this research and thus not tested in other studies. Future research is necessary for the implementation of this model.

There is also a limitation in the user friendliness of the R-GSM tool. Data is visualized in the tool but needs to be added in the ERP system of the organization and not in the tool. The user needs to have both systems open when the project business process is performed. Subsequently, the data of the tool is not real-time data of the ERP system, but is updated ones every day. This means that changes made in the ERP system are not immediately noticeable in the R-GSM tool.

The tool is only implemented in one of the regions of the organization and not through the whole organization. The project business process of other regions are quite similar, but these regions are not included design process of the tool. This often gives more resistance to changes in the working method of the stakeholders.

The last limitation is the privacy policy of CityTec. Stakeholders are not personally coupled to the stages and risks in the tool because CityTec does not want to create a individualistic mentality. This results in a limitation related to the triggers in the R-GSM tool. Stakeholders cannot be personally triggered about the occurrence of risks in the project business process of a certain project.

7.4 Recommendations

The limitations described in the previous section automatically results in recommendations. This research provides a risk-aware artifact-centric business process model, which is not provided in literature yet. Additional research is recommended to validate this new designed modeling technique, since this research is the first study in the area of risk-aware artifact-centric business process modeling.

Furthermore, it is recommended to link the ERP system to the R-GSM tool. The tool is now daily updated by the planner. Real-time data improves the data quality of the R-GSM tool. The direct link to the ERP system could also be established by purchasing an ERP-connected software application and designing the R-GSM tool in that particular software application. Further research is recommended to investigate the possibilities for this link.

It is also recommended to implement the R-GSM tool through the whole organization. Stakeholder is the region where the tool is implemented found this tool very useful to control and manage their project. The organization will benefit by sharing this system and the knowledge about this tool.

The last recommendation is related to the escalate and transfer risk responses. These risk responses are outside the scope of this research because they are managed on a higher level of the organization. Appropriate actions are recommended to the managing board considering these risks.

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Appendix A

Two major process modeling paradigms exist: activity-centric and data-centric. They focus on different modeling constructs and are therefore, eligible for different scenarios. The two process modeling paradigms are described in this appendix to eventually choose the modeling technique best fitted for this research.

A.1 Activity-centric business process modeling

Most traditional techniques are activity-centric process models . These techniques emphasize on the set of activities that stakeholders need to execute, the relations between them and their order of execution. The most basic form of business process modeling in an activity-centric way, is a flowchart. A flowchart is a diagram that represents a process as a sequence of activities and decisions. Each flowchart consists of a start point, an end point and some activities and decisions between them, in which everything is either directly or indirectly connected with each other.

More recent approaches of activity-centric business process modeling which are also widely used, are BPMN and UML activity diagrams. BPMN is an abbreviation of Business Process Modeling Notation, which is created by the Business Process Management Initiative (BPMI). BPMN differs from the traditional flowchart in a way that BPMN assigns actors to tasks and decisions, can handle tasks that someone forgets to perform and can implement triggers.

UML activity diagram is an activity-centric business process modeling technique created by the Object Management Group (OMG). The BPMI gave OMG the rights to maintain the BPMN approach, so the OMG owned both notations. The main difference between the UML activity diagram and the BPMN is that the UML activity diagram is designed for software engineering while the BPMN is designed for business users.

In general, activity-centric paradigm is effective when supporting standardized and production-oriented domains (Redding G. , Dumas, ter Hofstede, & Iordachescu, 2010). This means that the processes are highly structured and repetitive. The processes in the activity-centric paradigm are highly restrictive, which has a negative impact on the flexibility of the process execution.

A.2 Data-centric business process modeling

This modeling technique focuses on the information entities handled in a process. This could be data, documents, products, objects, artifacts, etc. Due to the fact that a lot of entity types could be used within this technique, multiple methods are developed, like product-based, artifact-centric, document-driven and object-centric process modeling approaches (Garcia, 2011). All these methods part of the data-centric business process modeling technique. While activity-centric techniques focus on the tasks and their sequence, data-centric business modeling emphasizes on the objects manipulated in the process.

Data-centric approaches enable more flexible ways of performing business processes than activity-centric approaches, which are typically rigid (Redding, Dumas, ter Hofstede, & Iordachescu, 2010). Data-centric modeling approaches support the specification and

execution of semi-structured, knowledge-intensive business processes, which are more difficult to support using classic process modeling (Swenson, 2010).

The project-based approach defines the business processes from the Bill of Materials (BOM). The BOM is a tree-like structure with the end product as root and raw materials and purchased products as leafs. Several data elements are used in this approach and linked to each other through operations. Each operation can have multiple input data elements, but the output will always be exactly one data element. An operation is executable when all input elements needed are available (Vanderfeesten, Reijers, & van der Aalst, 2008).

The artifact-centric approach considers data as an integral part of business processes, and it defines the business processes and its operations in terms of interacting key business artifacts. An artifact is a key information entity that is central to guiding operations in a business process and whose content changes while moving through those operations (Hull, et al., 2010). The difference between artifacts and objects is that artifacts are pure instances rather than instances of a given predefined class. Artifacts combine both data and behavioral properties that are used as primitive driving the process modeling. (Bhattacharya, Hull, & Su, 2009). Business processes are defined as business entities walking through their lifecycle. The state of a process is given by a snapshot of all artifacts at any time.

The document-driven approach describes document dependencies within the business process. The tasks of the process are instantiated when the corresponding input documents exists. The tasks are completed when the desired output documents are created. This approach is pure document-based and does not include the visualization of the derived processes (Garcia, 2011).

The object-centric approach describes a collection of objects that contain values of instance variables found within an object. This approach is used to modeling applications at the beginning of the software lifecycle. The abstract descriptions of the problem are transformed into a design, which is thereafter transformed into code. The UML class diagram is one of the popular object-centric modeling techniques. This diagram describes the structure of a system by defining the classes, attributes, operations, and the relationships among objects.

In general, data-centric approaches have a high level of process flexibility. Data objects are the main drivers for process modeling and execution. The processes in the data-centric approaches can start additional processes by update their own data state.

A.3 Conclusion business process modeling

Projects are never the same, which leads to a flexibility requirement for defining the process. Activity-centric approaches have difficulties supporting dynamic business processes because they tend to impose a given execution order between activities and decision points (Redding G. , Dumas, ter Hofstede, & Iordachescu, 2010). Data is easier to detect during run-time than activities and is harder to manipulate. Centralize data in the modeling paradigm plays a central role in increasing flexibility. The object in the process are predefined, but the process for these object creations are not defined, which created flexibility in the process execution.

Data-centric process modeling is therefore more suitable than activity-centric process modeling.

Several data-centric process modeling techniques are discussed in this chapter. Steinau, et al. (2019) conducted a systematic literature review with the goal of evaluating the capabilities of data-centric process management approaches. Their literature review puts extra focus on the tooling and software of the approaches, which is also needed in the project business process of CityTec. Figure 26 provides the number of studies found in this literuture study for the approaches discussed in this chapter. The majority of papers belongs to the artifact-centric approach, which is an hugh advantage of this approach. The papers of the artifact-centric approach are also more citated as the papers of the other approaches.

Approach	# of studies
Document-based Approach	1
Artifact-centric Approach	13
Object-centric Approach	3
Product-based Approach	1

Figure 26: Part of the process modeling approaches studies found by Steinau et al. (2019)

The study of Steinau, et al. (2019) also indicates which approaches are tool supportive shown in Figure 27. The goal of this reseach is to design a tool that manages and monitors the project business process of CityTec. Therefore, the applied approach needs to have tool support for modeling and monitoring processes. The project-based and the document-based approaches have a lack of tool support. The object-centric approach has only tool support in the design phase, but not in the implementation and execution phase. The artifact-centric approach has tool support in both phases and is therefore chosen as best suitable approach to model the project business processs of CityTec.

Approach	Design	Implementation and execution
Document-based Approach	–	–
Artifact-centric Approach	✓	✓
Object-centric Approach	✓	–
Product-based Approach	–	–

✓: Has support, –: Unknown

Figure 27: Tool support for different phases of the process lifecycle found by Steinau et al. (2019)

Each business artifact type is characterized by an information model and a lifecycle model. The information model records all business-relevant information about a business artifact instance as it moves through the business and the lifecycle specifies all possible evolutions of a business artifact instance over time (Vaculin, et al., 2011). The Guard-Stage-Milestone (GSM) modeling technique is a way to represent such an artifact lifecycle. The GSM model consists of four key elements: (a) *Information Model* for business artifacts, as in all variations of the artifact paradigm; (b) *Milestones*, which correspond to business-relevant

operational objectives, and are achieved (and possibly invalidated) based on triggering events and/or conditions over the information models of active artifact instances; (c) *Stages*, which correspond to clusters of activity intended to achieve milestones; and (d) *Guards*, which control when stages are activated, and as with milestones are controlled through triggering events and/or conditions (Damaggio, Hull, & Vaculin, 2012).

Figure 28 illustrate a GSM model which contained in the bottom part an information model and in the upper part a lifecycle model. This information model captures the data attributes and status attributes, which contain all business-relevant data about entities related in either materialized or virtual form. The entity information typically includes data contributed by human actors, data from external services that have been called and data about the current and previous phases of the entity instance (Hull, et al., 2010). This data reflects the lifecycle model, which specifies the possible ways that an entity instance evolves in time, as the entity passes through the business operations. A lifecycle model includes multiple stages. These stages are made up of one or multiple guards to enter the stage, one stage body which contains the activity, and one or multiple milestones to express when a particular condition is obtained.

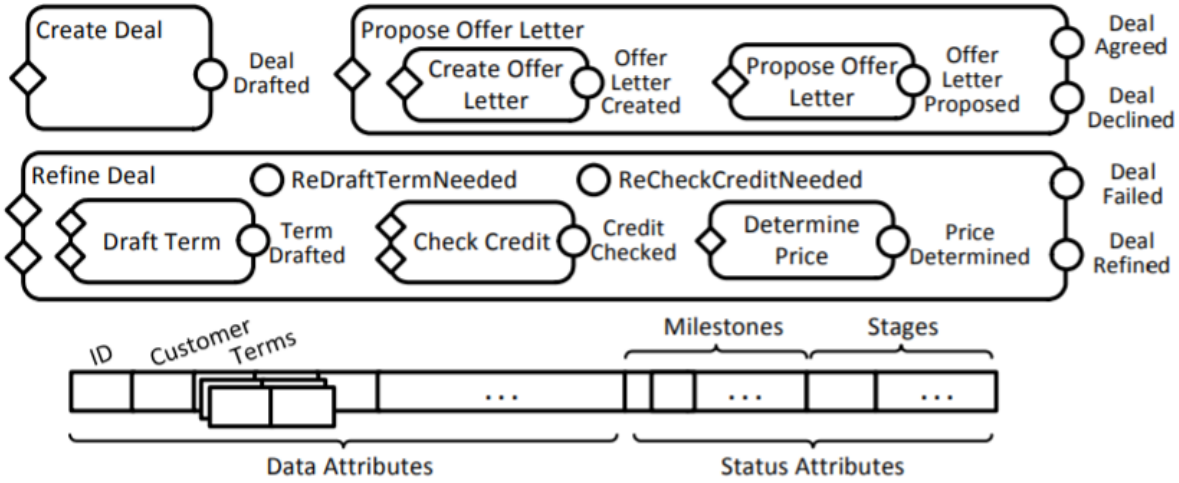

Figure 28: Example of the GSM model from Eshuis, Hull, Sun & Vaculín (2014)

Appendix B

The project business process is explored by talking to stakeholders in this process. The stakeholders explain their role and involvement in the project business project during these interviews. The interviews all have the same approach. First a quick overview of the department is sketched. Thereafter, the incoming triggers are described, followed by the tasks performed in the project business process in a sequence way and the objects made within these tasks. Consequently, the involved information systems used in the department and the communication with other actors in the process are described. The interview is ended by describing the challenges and bottlenecks in their department related to the project business process. This appendix summaries these interviews.

B.1 Departments

The departments are first introduced involved in the project business process:

- Engineering department: The engineers are responsible for the pre-project phase. The engineers ensure that the project request by the client is elaborated in a design and financial consideration.
- Work preparation department: The work preparations are responsible for the preparation phase of the project. They ensure that everything is available at the start of the project execution, like materials and required documents.
- Execution department: The executors are responsible for the physical execution of the project.
- Finance department: The employees in the finance department ensure that the invoices are sent to the client and grid operator. One the other hands, they are also responsible for the payments of the invoices of the suppliers.
- Purchase & logistics department: The employees in the purchase & logistics department are responsible for the materials used in the projects and the warehouse.
- The planner: The planner is responsible for the schedule of the projects and the communication of this schedule to the client and grid operator.
- The project controller: The project controller is not part of a department, but is the connector of these departments. The project controller provides a helicopter view over the projects.
- The supply chain manager: The supply chain manager is also not part of a department, but is the connector to the grid operator. The supply chain manager is responsible for the relationship and communication between the organization and the grid operator.

B.2 Engineering department

The engineering department is starting point of a project. The client request is elaborated by the engineers in design and corresponding quotation for the client. This phase is the pre-project phase because an agreement about the project is only reached when the quotation is signed by the client.

B.2.1 Incoming triggers

The process in the department related to projects is triggered when a request of the client is received. The new project request can come from the account manager, who is the point of contract for the existing clients. The account manager is frequently on the location of the existing clients to maintain the relationship with the client. A new project request of the client can also directly be mailed to the engineer when the client is frequently in contact with the engineer. The last incoming trigger is the shared mailbox, which is the general mailbox for the engineers and is especially used by clients who do not have close contact with the organization.

B.2.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Receive mail for a project request from client with DWG file.
2. Create SO-DOP in Navision.
3. Create project folder in shared documents environment.
4. Define needs with intake form.
5. Fill in the desired start and end date by the client in Navision.
6. Create light calculation and put in the online project folder.
7. Send light calculation to client.
8. Create design with the use of the DWG file of the client and put in the online project folder.
9. Send design to client.
10. Make a quotation and budget in Navision.
11. Generate the quotation letter out of Navision and control and adjust the specifications.
12. Fill in the contract price in the Navision.
13. Print the quotation, budget and intake form.
14. Provide the quotation, budget and intake form to the region manager for approval.
15. Scan the approved quotation by the region manager and put in the online project folder.
16. Send quotation to client.
17. Receive the approved quotation by the client and put it in the online project folder.
18. Request the power connection in the portal of the grid operator.
19. Receive the confirmation of the power connection request and put it in the online project folder.
20. Contract the project controller for creating a new project.
21. Transfer the project to work preparation department.

B.2.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the engineer:

- SO-DOP in Navision.
- Intake form in the online project folder.
- Light calculation in the online project folder.

- Design in the online project folder.
- Quotation in Navision.
- Budget in Navision.
- Desired start date and end date in Navision.
- Signed quotation by the region manager in the online project folder.
- Signed quotation by the client in the online project folder.
- Confirmation and quotation of the power connection in the online project folder.

B.2.4 Information systems involved

The following information systems are involved in the task execution of the engineer:

- Navision.
- Shared documents environment.
- AutoCAD.
- Portal of the grid operator.
- Reality.
- Dialux.

B.2.5 Communication with other actors

The engineer communicates with the following actors during the execution of their tasks:

- Controller.
- Client.
- Account manager.
- Work preparotors.
- Region manager.
- Grid operator.

B.2.6 Challenges and bottlenecks

At the end of the interview, the engineers mentioned some challenges and bottlenecks. One of these problems is that the client is not contacted after the quotation is sent. The engineering department waiting until the quotation is signed, but does not send a reminder to the client. Another problem is that a lot of data is saved locally on the computer of the engineer, which does not give an indication of the status of the project.

B.3 Work preparation department

The work preparation department is responsible for all things that are necessary for the execution of the project. The work preparation department is responsible for the preparation of the project execution. Materials and documents are need to perform the execution of the project. The work preparotor will provide these needs.

B.3.1 Incoming triggers

The tasks of the work preparation department are triggered when the project is received in the shared mailbox sent by the engineer. The engineer transfers the project after his tasks are performed, to the work preparation department. Another trigger is an assignment in the

portal of the grid operator. The grid operator can assign CityTec for the execution of their projects. These projects are related to the underground infrastructure of the grid operator.

B.3.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Control the quotation, budget, and start and end date.
2. Import the budget in the material request transaction.
3. Control availability of materials in Navision.
4. Set desired delivery date for the materials in the material request transaction.
5. Generate the material request in Navision.
6. Create a new project in Access and fill in all information about the project.
7. Receive assignment from grid operator and put all documents in the online project folder.
8. Create SO-DOP in Navision.
9. Fill the unit price of the assignment in the SO-DOP.
10. Make the budget in Navision.
11. Fill in the desired start and end date of the project.
12. Contact the project controller for creating a new project.
13. Assign numbers to the new lampposts.
14. Create a mutation form.
15. Create two hardcopy project folders with all documents (one for the executor and one for the subcontractor or mechanic).
16. Transfer the project to execution department.

B.3.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the work preparator:

- Two hardcopy project folders.
- SO-DOP in Navision.
- Material request in Navision.
- Stickers of lamppost numbers.
- Unit prices in Navision.
- Budget in Navision.
- Project description in Access.
- Mutation form.

B.3.4 Information systems involved

The following information systems are involved in the task execution of the work preparator:

- Navision.
- Shared documents environment.
- Access.
- Portal of the grid operator.

B.3.5 Communication with other actors

The work preparator communicates with the following actors during the execution of their tasks:

- Engineer.
- Executors.
- Grid operator.
- Project controller.
- Planner.

B.3.6 Challenges and bottlenecks

At the end of the interview, the work preparators mentioned some challenges and bottlenecks. The biggest problem of the work preparators is the communication with the purchase and logistics department. As we can see, the purchase and logistics department is not part of the communication with other actors. The materials are requested to the purchase and logistics department, but there is no feedback from the purchase and logistics department. The delivery date of the materials given by the supplier is not insight by the work preparators. Another problem is the SO-DOP is not always closed when a project is created. This is confusing for the work preparator because they do not know if the engineer is still working on the project. The last problem mentioned by the work preparator is that the start and end date is not always indicated in Navision. The work preparator does not know when the project needs to be executed which influence the material request.

B.4 Execution department

The execution department is responsible for the physical execution of the project. The project designed by the engineer and prepared by the work preparator will now be executed. The physical execution is performed by the mechanic or subcontract, but the executor directs the project execution and makes sure that everything runs smoothly.

B.4.1 Incoming triggers

There is only one way to trigger the tasks of the execution department. This trigger is the transfer of the project from the work preparator to the executor. This is physically performed ones every week. The hardcopy project folder is handed over to the executor during this transfer.

B.4.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Receive hardcopy project folder from the work preparator.
2. Control completeness of the project folder.
3. Check the budget, quotation, costs made and start and end date in Navision.
4. Assign subcontractor or mechanic to the project.
5. Inform the planner with the execution dates.
6. Inform the client when more or less work occurs.
7. Receive an approval for the more or less work when more or less work is indicated.

8. Process the more or less work in Navision when more or less work is indicated.
9. Receive PV of subcontractor.
10. Approve PV and send to the finance department.
11. Receive mutation form and revision from the subcontractor or the mechanic.
12. Approve the mutation form and revision.
13. Send the revision to the project controller.
14. Send the mutation form to the asset management department.
15. Fill in the WON form and send to the supply chain manager.
16. Make an appointment with the client and grid operator the deliver the project.
17. Receive the approval of the project.
18. Send the approval of the project to the project controller.
19. Transfer the project to the project controller.

B.4.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the executor:

- WON form in the online project folder.
- More/less work form in the online project folder.
- PVO in the online project folder.
- TM in the online project folder.
- Revision in the online project folder.
- Mutation form in the online project folder.

B.4.4 Information systems involved

The following information systems are involved in the task execution of the executor:

- Navision.
- Access.
- Shared documents environment.

B.4.5 Communication with other actors

The executor communicates with the following actors during the execution of their tasks:

- Subcontractors.
- Mechanics.
- Project controller.
- Finance department.
- Work preparators.
- Grid operator.
- Client.
- Planner.

B.4.6 Challenges and bottlenecks

At the end of the interview, the executors mentioned some challenges and bottlenecks. The biggest problem for the executor is that the costs in the project cannot be clearly monitored and controlled. They are responsible to stay within the budget of the project, while they have no clear overview of the costs made and if these costs exceed the budget.

B.5 Finance department

The finance department is mainly responsible for the administrative tasks in the project business project. The invoices to the client and grid operator and the payments to the suppliers are part of these administrative process. The core business of the finance department is not in the project business process. The finance department has only a small role in the project business process.

B.5.1 Incoming triggers

The finance department is multiple times triggered during the project lifecycle. They are triggered when the project controller checks the invoice checkbox in Navision. When a project has for example payment terms of 50%-40%-10%, the project controller activates the checkbox 50% when the project is created, the 40% at the start of the execution, and 10% when the project is delivered to the client. The activation of these checkboxes automatically generates a signal to the finance department to create an invoice for the client. Another incoming trigger are the PVs of the subcontractor. The finance department makes an IOR and ION number for the subcontractor. The last trigger are all incoming invoices from suppliers, grid operators, subcontractors, etc. . The finance department is responsible for these payments.

B.5.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Create invoice when checkbox for first term is checked.
2. Send first invoice to the client.
3. Receive invoice for the power connection.
4. Pay power connection invoice when executor approves the invoice.
5. Receive and pay invoice for the materials.
6. Create invoice when checkbox for second term is checked.
7. Send second invoice to the client.
8. Receive PV of the subcontractor.
9. Create IOR and ION number.
10. Provide IOR and ION number to the subcontractor.
11. Receive invoice from the subcontractor.
12. Pay subcontractor invoice when executor approves the invoice.
13. Create last invoice including the more/less work when checkbox for last term is checked.
14. Send last invoice to the client.
15. Create invoice including the more/less work for the grid operator when checkbox is checked.
16. Send invoice to the grid operator.

B.5.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the finance department:

- IOR number.

- ION number.
- Invoices.

B.5.4 Information systems involved

The following information systems are involved in the task execution of the finance department:

- Navision.
- Shared documents environment.

B.5.5 Communication with other actors

The finance department communicates with the following actors during the execution of their tasks:

- Project controller.
- Executors.
- Clients.
- Grid operators.
- Suppliers.

B.5.6 Challenges and bottleneck

The core business of the finance department is not the project business process. The finance department has only a supporting role in this process. Therefore, challenges and bottleneck in the project business process are not mentioned actors of the finance department.

B.6 Purchase and logistics department

The purchase and logistics department has also only a supporting role in the project business process. The purchase and logistics department is responsible for having enough materials available at the time the materials are needed. When there are not enough materials available in the warehouse, the materials are ordered by the supplier.

B.6.1 Incoming triggers

The work preparator sends a material request in Navision to the purchase and logistics department. The purchase and logistics department will check if enough materials are in inventory. Otherwise, an order is sent to the supplier for these materials.

B.6.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Check if enough materials are in inventory.
2. When there is not enough materials, order the materials.
3. Receive a confirmation from the supplier.
4. Set delivering date given by the supplier in Navision.
5. Book materials in warehouse when they are delivered.

B.6.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the purchase and logistics department:

- IOR number.
- ION number.

B.6.4 Information systems involved

The following information systems are involved in the task execution of the purchase and logistics department:

Navision.

B.6.5 Communication with other actors

The purchase and logistics department communicates with the following actors during the execution of their tasks:

- Suppliers.

B.6.6 Challenges and bottleneck

The core business of the purchase and logistics department is not the project business process. Even though the purchase and logistics department only has a supporting role in this process, problem in the project business process were mentioned by the actors within this department. One of these problems is that there are no fine if the supplier delivers to late. Another, problem in the project business process mentioned by these actors is that the purchase and logistics department are most of the time blamed for the project delay, but are most of the time too late informed.

B.7 The planner

The planner ensures that the project is performed within schedule. The planner keeps track of the schedule of all projects that still need to be executed. The planner communicates the schedule of projects to the client and grid operator and address changes in the schedule to the actors involved in the project.

B.7.1 Incoming triggers

The planner is responsible for the planning of all project in preparation and execution stage. The planner gets triggered by a project overdue or by a closely overdue. The project is overdue when the current date exceeds the end date. The projects are also triggered with an end date within 2 weeks.

B.7.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Make a list of all projects that are overdue or with an end date within 2 weeks.
2. Provide this list weekly to the executors.
3. Receive feedback of the status of these projects.
4. Change the planning of these projects in Navision.
5. Provide the planning of the projects weekly to the client.
6. Provide the planning of the projects daily to the grid operator.

B.7.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the planner:

- 14 days planning for each client in the online project folder.
- 14 days planning for each grid operator in the online project folder.
- Week planning of all projects in the online project folder.

B.7.4 Information systems involved

The following information systems are involved in the task execution of the planner:

- Navision.
- Shared documents environment.

B.7.5 Communication with other actors

The planner communicates with the following actors during the execution of their tasks:

- Executors.
- Work preparators.
- Clients.
- Grid operators.

B.7.6 Challenges and bottleneck

At the end of the interview, the planner mentioned some challenges and bottlenecks. The start and end date are not always provided in Navision, which gives a lot of trouble in the schedule. Another problem mentioned by the planner is the project statuses in Navision. The end date is the date that the project needs to be physically finished, but there is no project status in Navision for this status.

B.8 Project controller

The project controller is the person that keeps a helicopter view over the projects. The project controller is responsible for a smooth project transfer between the stakeholders in the project business process. The project controller is checks all the data about the project in Navision.

B.8.1 Incoming triggers

The project controller is responsible for the transfer of the project between different departments and data transfer in Navision. The project controller is triggered by a mail from the engineers or work preparator for project creation. The project controller creates this project for them. The project controller is also triggered during project transfers.

B.8.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Receive mail from the engineer of work preparator.
2. Control quotation, budget, assignment and contract price on the correctness and completeness.
3. Create new project numbers in Navision and link the related projects with each other.
4. Transfer the budget, contract price, planning and costs from the SO-DOP to the project.
5. Set the status of the SO-DOP on technically ready.
6. Set the payment terms in the project in Navision.
7. Activate the checkbox of the first invoice.
8. Notify the engineer or work preparator about the project creation.
9. Change the project status if the work preparator transfers the project to the executor.
10. Activate the checkbox of the second invoice.
11. Change the project status if the executor transfers the project to the finance department.
12. Activate the checkbox of the third invoice.
13. Receive the project from the finance department.
14. Check all data of the project and correctness of the data.
15. Change the project status to project finished.

B.8.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the project controller:

- The project in Navision.

B.8.4 Information systems involved

The following information systems are involved in the task execution of the project controller:

- Navision.
- Shared documents environment.

B.8.5 Communication with other actors

The project controller communicates with the following actors during the execution of their tasks:

- Engineers.
- Work preparators.
- Executors.
- Finance department.
- Purchase and logistics department.

B.8.6 Challenges and bottleneck

At the end of the interview, the project controller mentioned some challenges and bottlenecks. The problem mentioned by the project controller is that the invoices are not sent to the client during the project. Another problem mentioned by the project controller is that the budget in the project is not made quite accurate.

B.9 Supply chain manager

The supply chain manager is responsible for the communication with the grid operator. The supply chain manager has only a small role in the project business process. The supply chain manager provides the data to the grid operator and is responsible for the project delivery to the grid operator.

B.9.1 Incoming triggers

The supply chain manager is triggered by the executor for delivering the project to the grid operator. This is part of the administrative processing. The supply chain manager provides the PV, TM and the revision to the grid operator when the project is delivered.

B.9.2 Sequence of tasks

The interviewees are asked to describe their tasks from begin to end as detailed as possible. The combination of these interviews provides the following sequence of tasks:

1. Receive project documents from the executor.
2. Create PV based on the WON form.
3. Create TM.
4. Provide TM to the executor.
5. Receive TM signed by the grid operator from the executor.
6. Upload PV and revision in the portal of the grid operator.
7. Receive approval of the PV and revision from the grid operator.
8. Activate checkbox for invoicing the grid operator.

B.9.3 Objects made during the tasks and their location

The following objects are created during the tasks execution of the supply chain manager:

- PV for grid operator.
- TM.

B.9.4 Information systems involved

The following information systems are involved in the task execution of the supply chain manager:

- Navision.
- Shared documents environment.
- Portal of the grid operator.

B.9.5 Communication with other actors

The supply chain managaer communicates with the following actors during the execution of their tasks:

- Executors.
- Finance department.
- Grid operators.

B.9.6 Challenges and bottleneck

At the end of the interview, the supply chain manager mentioned some challenges and bottlenecks. The problem mentioned by the supply chain manager is that more or less work is a lot of the time not booked on the project, which created problem for invoicing the grid operator. Another problem is that the planning of the N-Project is not synchronized in the system with the other project.

Appendix C

Table 5: Risk register

Nr.	Risk Event	In	Consequence on	Triggers
1	Not all documents in assignment	Assignment	Time	Soil investigation, LS-scheme, LS-net, permit or offer is missing when needed.
2	Not all materials included in budget	Budget	Cost	Material in budget differs from material in quotation.
3	Not all labor included in budget	Budget	Cost	Labor does not match material or quotation.
4	Labor costs from other subcontractor	Budget	Cost	Execution performed by other subcontractor than calculated in the budget.
5	Client does not pay invoice	Client invoice	Cost	Payment term of 30 days after invoicing is exceeded.
6	Not invoicing more/less work	Client invoice	Cost	More/less work is booked on project, but not taken in last invoice.
7	Forget to invoice client	Client invoice	Cost	The state of the project does not correspond with the payment terms.
8	Wrong material delivered	Delivery receipt	Time	Material ordered in IOR differs than the ION.
9	Order not fully received	Delivery receipt	Time	Material quantity ordered in IOR differs than the ION.
10	Client forgets to approve design	Design	Time	No reaction for 2 weeks after the design is proposed.
11	Bad weather	Execution	Time	Thunder or below zero degrees in weather forecast.
12	Price change by subcontractor	Execution	Cost	Project execution date after new subcontractor specifications or after indexation.
13	No resources/subcontractor available	Execution	Time	Exceeding the number of activities per day.
14	Other parties not ready	Execution	Time	During construction consultation
15	Traffic barrier needed	Execution	Cost/time	CROW-requirements
16	Material damage	Execution	Time/cost/ quality	Material is damaged or does not work before project is finished.
17	Not invoicing more/less work	Grid operator invoice	Cost	More/less work is booked on project, but not taken in last invoice.

18	Grid operator does not pay invoice	Grid operator invoice	Cost	Payment term of 30 days after invoicing is exceeded.
19	Forget to invoice grid operator	Grid operator invoice	Cost	State of the project does not correspond with the payment terms.
20	Intake form not performed	Intake form	Quality/cost	Intake form not present in the project folder.
21	Client forgets to approve light calculation	Light calculation	Time	No reaction for 2 weeks after the design is proposed.
22	Light calculation, design or quotation not approved	Light calculation/ Design/Quotation	Cost/time	Mail by client that project needs to be changed or project is cancelled.
23	Wrong material requested	Material request	Cost/time	Material request differs from budget and/or quotation.
24	Too much or too less materials requested	Material request	Cost/time	The number of materials requested differs from the numbers of materials in the budget and/or quotation.
25	More/less work not booked on project	More/less-work	Cost	More/less work document performed, but no booking on project.
26	No client or grid operator approval for more/less work	More/less-work	Cost	No notification mail sent to client/grid operator.
27	No mutation form created	Mutation	Quality/cost	No mutation form in project folder.
28	Wrong data in mutation form	Mutation	Quality/cost	Material booked on project differs from material in mutation form.
29	Mutation form not sent to asset management	Mutation	Quality/cost	Data not implemented in Navision.
30	Lamppost numbers already exist	Mutation	Quality/cost	Lamppost numbers in mutation are already used for other project in Navision.
31	Budget components assigned to wrong project	N-/M-/P-project	Cost	Fixed component types of the budget in the wrong project part.
32	Project closed without having all payments	N-/M-/P-project	Cost	Project status is administrative finished, but the client has not paid 100%.
33	Project closed without having all invoices	N-/M-/P-project	Cost	Project status is administrative finished, but invoices still coming in the near future.
34	Too many internal labor booked on a project	N-/M-/P-project	Cost	Quantity of hours booked on a project exceed the norm.
35	Costs booked on wrong project	N-/M-/P-project	Cost	Things booked on project which are not included in the budget.

36	Materials ordered too late	Order	Time	Date in material request earlier than date in order.
37	Materials delivered too late	Order	Time	No ION created on the day the supplier should deliver.
38	Materials not ordered	Order	Time	Material request cannot be fulfilled by the inventory and quantity ordered.
39	Price change by supplier	Order	Cost	Price in invoice is different than price for product in Navision.
40	Wrong material ordered	Order	Cost/time	Material in IOR number differs from material request.
41	No confirmation for delivering material	Order	Time	No notification mail received from supplier.
42	Materials delivered too early	Order	Cost	ION created before date material needed.
43	No permit when permit needed	Permit	Cost/time	Client specific triggers.
44	Price change by grid operator	Power connection request	Cost	Project execution date after date new prices.
45	Power connections not requested	Power connection request	Time	SO-DOP-P has activities where power connection request is needed, but is not requested.
46	Power connections request takes too long	Power connection request	Time	Request is beyond the time the grid operator has to process the power connection request.
47	Wrong activities requested for power connections	Power connection request	Cost	Activities in power connection request differs from the activities in budget/quotation.
48	No project folder created	Project folder	Quality	Project folder is could not be found in the shared document environment
49	Wrong activities or costs on PV	PV	Cost	Activities in PV differs from the activities in budget.
50	PV booking not on right project	PV	Cost	Fixed component types of the PV in the wrong project part.
51	Project not delivered to client/approved by client	PVO-Client	Cost/time	No PVO-client signed in the project folder when project needs to be transmitted.
52	Project not delivered to grid operator/approved by grid operator	PVO-N	Cost/time	No PVO-N signed in the project folder when project needs to be transmitted.
53	Materials not included in quotation	Quotation	Cost	Client is not lease client and materials are not in quotation or materials in

				Navision differs from materials in quotation.
54	Labor not included in quotation	Quotation	Cost	Labor does not match material or budget.
55	Region manager forgets to approve quotation	Quotation	Time	Quotation not signed by region manager.
56	Quotation is expired	Quotation	Cost/time	No signed quotation back from client after 30 days.
57	Revision not approved by grid operator	Revision	Cost/time	Notification in portal that revision is not accepted
58	No soil investigation performed	Soil investigation	Cost/time	Assignment from grid operator without soil investigation document or activities on own power grid without soil investigation document, except only placing/exchanging luminaires.
59	Soil is contaminated	Soil investigation	Cost/time	CROW 400 is not standard basic hygiene.
60	Materials taken for other project/service order	Warehouse	Time	Material booked on other project/serviceorder while the project was first to serve according to the ERP system.
61	Wrong inventory quantity in system	Warehouse	Time	Subcontractor wants to have materials for execution, but are not available.
62	Wrong activities in WON-form	WON-form	Cost	Activities in WON-form differs from the activities in the assignment plus the more/less-work.

Appendix D

Table 6: Risk register with probability and impact expansion

Nr.	Risk Event	Probability	Impact	Risk
1	Not all documents in assignment	2	1	2
2	Not all materials included in budget	3	5	15
3	Not all labor included in budget	2	2	4
4	Labor costs from other subcontractor	5	2	10
5	Client does not pay invoice	2	2	4
6	Not invoicing more/less work	2	4	8
7	Forget to invoice client during project	4	3	12
8	Wrong material delivered	1	3	3
9	Order not fully received	1	3	3
10	Client forgets to approve design	3	2	6
11	Bad weather	2	1	2
12	Price change by subcontractor	4	2	8
13	No resources/subcontractor available	1	1	1
14	Other parties not ready	1	2	2
15	Traffic barrier needed	2	3	6
16	Material damage	1	3	3
17	Not invoicing more/less work	1	4	4
18	Grid operator does not pay invoice	1	2	2
19	Forget to invoice grid operator	2	3	6
20	Intake form not performed	5	3	15
21	Client forgets to approve light calculation	3	2	6
22	Light calculation, design or quotation not approved	2	2	4
23	Wrong material requested	4	4	16
24	Too much or too less materials requested	3	3	9

25	More/less work not booked on project	5	4	20
26	No client or grid operator approval for more/less work	3	4	12
27	No mutation form created	1	4	4
28	Wrong data in mutation form	2	2	4
29	Mutation form not sent to asset management	1	4	4
30	Lamppost numbers already exist	0	4	0
31	Budget components assigned to wrong project	1	4	4
32	Project closed without having all payments	1	5	5
33	Project closed without having all invoices	2	5	10
34	Too many internal labor booked on a project	5	4	20
35	Costs booked on wrong project	5	4	20
36	Materials ordered too late	4	3	12
37	Materials delivered too late	4	2	8
38	Materials not ordered	2	3	6
39	Price change by supplier	4	2	8
40	Wrong material ordered	2	4	8
41	No confirmation for delivering material	4	1	4
42	Materials delivered too early	4	0	0
43	No permit when permit needed	0	5	0
44	Price change by grid operator	3	4	12
45	Power connections not requested	1	2	2
46	Power connections request takes too long	2	3	6
47	Wrong activities requested for power connections	0	3	0
48	No project folder created	0	4	0
49	Wrong activities or costs on PV	3	1	3
50	PV booking not on right project	3	2	6
51	Project not delivered to client/approved by client	2	4	8

52	Project not delivered to grid operator/approved by grid operator	1	3	3
53	Materials not included in quotation	3	5	15
54	Labor not included in quotation	2	3	6
55	Region manager forgets to approve quotation	1	1	1
56	Quotation is expired	2	4	8
57	Revision not approved by grid operator	1	1	1
58	No soil investigation performed	0	5	0
59	Soil is contaminated	0	5	0
60	Materials taken for other project/serviceorder	2	4	8
61	Wrong inventory quantity in system	1	4	4
62	Wrong activities in WON-form	3	3	9

Appendix E

Table 7: Risk register with risk owner and risk response expansion

Nr.	Risk Event	Risk owner	Risk response
1	Not all documents in assignment	Work preparator	1) Mitigate: add to checklist. 2) Transfer/escalate: make the grid operator responsible for the delay and corresponding consequences.
2	Not all materials included in budget	Region manager	1) Mitigate: four-eyes principle, the region manager checks the budget created by the engineer before sending.
3	Not all labor included in budget	Region manager	1) Mitigate: four-eyes principle, the region manager checks the budget created by the engineer before sending.
4	Labor costs from other subcontractor	Work preparator	1) Mitigate: add to checklist.
5	Client does not pay invoice	Finance	1) Avoid: perform a credit check and change the payment terms if needed. 2) Mitigate: send a reminder.
6	Not invoicing more/less work	Project controller	1) Mitigate: add to checklist.
7	Forget to invoice client during project	Project controller	1) Mitigate: add to checklist.
8	Wrong material delivered	Purchase & logistics	1) Transfer/escalate: make the supplier responsible for the delay and corresponding consequences.
9	Order not fully received	Purchase & logistics	1) Transfer/escalate: make the supplier responsible for the delay and corresponding consequences.
10	Client forgets to approve design	Engineer	1) Mitigrate: trigger and send a reminder after 2 weeks.
11	Bad weather	Planner	1) Accept: keep some reserve in the planning especially in the winter.
12	Price change by subcontractor	Finance	1) Mitigrate: trigger when subcontractor prices are higher than in budget and immediately react.
13	No resources/subcontractor available	Planner	1) Accept: keep the number of subcontractors high to spread the risk.

14	Other parties not ready	Executor	1) Accept: keep frequently in contact with the other parties involved.
15	Traffic barrier needed	Work preparator	1) Avoid: Appoint that extra cost can be charged if traffic barriers are needed in the terms and conditions of the quotation.
16	Material damage	Executor	1) Transfer/escalate: make the subcontractor responsible for the damage and corresponding consequences. 2) Transfer/escalate: make the supplier responsible for the damaged materials with guarantees in the contract.
17	Not invoicing more/less work	Project controller	1) Mitigate: add to checklist.
18	Grid operator does not pay invoice	Finance	1) Mitigate: send a reminder.
19	Forget to invoice grid operator	Project controller	1) Mitigate: add to checklist.
20	Intake form not performed	Engineer	1) Mitigate: add to checklist.
21	Client forgets to approve light calculation	Engineer	1) Mitigate: trigger and send a reminder after 2 weeks.
22	Light calculation, design or quotation not approved	Engineer	1) Accept: integrate the risk of cancelation in the profit margin of all project. 2) Transfer/escalate: when the agreements in the intake form are not met due to a change in the project plan, the futile hours are charged.
23	Wrong material requested	Work preparator	1) Mitigate: create a better overview which materials are in the budget, requested, purchased and booked.
24	Too much or too less materials requested	Work preparator	1) Mitigate: trigger the task for the material request and control if this task is corrected executed.
25	More/less work not booked on project	Executor	1) Mitigate: add to checklist. 2) Mitigate: create sub-steps for earlier detection of more/less work.
26	No client or grid operator approval for more/less work	Executor	1) Mitigate: add to checklist.
27	No mutation form created	Work preparator	1) Mitigate: add to checklist.

28	Wrong data in mutation form	Executor	1) Mitigate: four-eyes principle, the executor checks the mutation form edited by the subcontractor before sending it to asset management.
29	Mutation form not sent to asset management	Executor	1) Mitigate: add to checklist.
30	Lamppost numbers already exist	Asset management	1) Accept: renumber after this risk occurs.
31	Budget components assigned to wrong project	Project controller	1) Mitigate: four-eyes principle, the work preparator checks if the budget components are assigned to the right project before accepting the project transfer.
32	Project closed without having all payments	Project controller	1) Mitigate: make an easier financial overview.
33	Project closed without having all invoices	Project controller	1) Mitigate: make an easier financial overview.
34	Too many internal labor booked on a project	Region manager	1) Mitigate: have periodic evaluation interviews with each stakeholder involved. 2) Escalate: release more hours for certain activities.
35	Costs booked on wrong project	Project controller	1) Mitigate: make an easier financial overview.
36	Materials ordered too late	Work preparator	1) Mitigate: contact the purchase and logistics department for alternatives.
37	Materials delivered too late	Purchase & logistics	1) Transfer: fine the supplier for goods that are delivered too late.
38	Materials not ordered	Work preparator	1) Escalate: the managing board can pressure the performance of the purchase and logistics department. 2) Mitigate: contact the purchase and logistics department
39	Price change by supplier	Purchase & logistics	1) Avoid: Appoint that extra cost can be charged when the supplier increases the price in the terms and conditions of the quotation.
40	Wrong material ordered	Work preparator	1) Mitigate: create a better overview which materials are in the budget, requested, purchased and booked.
41	No confirmation for delivering material	Purchase & logistics	1) Escalate: the managing board can pressure the performance of

			the purchase and logistics department.
42	Materials delivered too early	Purchase & logistics	1) Accept: make sure that enough space is available in the warehouse for early deliveries.
43	No permit when permit needed	Work preparator	1) Transfer: make the grid operator responsible for not requesting a permit when needed.
44	Price change by grid operator	Project controller	1) Avoid: Appoint that extra cost can be charged when the grid operator increases the price in the terms and conditions of the quotation.
45	Power connections not requested	Engineer	1) Mitigate: add to checklist.
46	Power connections request takes too long	Work preparator	1) Transfer: fine the grid operator for exceeding the process time.
47	Wrong activities requested for power connections	Project controller	1) Mitigate: four-eyes principle, the project controller checks if the right activities are requested before creating projects.
48	No project folder created	Engineer	1) Mitigate: add to checklist.
49	Wrong activities or costs on PV	Executor	1) Mitigate: make a better financial overview of the total budget for the subcontractor and the total expenses to the subcontractor. 2) Mitigate: edit budget to the specific price of the subcontractor.
50	PV booking not on right project	Executor	1) Mitigate: make a better financial overview of the total budget for the subcontractor and the total expenses to the subcontractor.
51	Project not delivered to client/approved by client	Executor	1) Mitigate: add to checklist.
52	Project not delivered to grid operator/approved by grid operator	Executor	1) Mitigate: add to checklist.
53	Materials not included in quotation	Region manager	1) Mitigate: four-eyes principle, the region manager checks the budget created by the engineer before sending.
54	Labor not included in quotation	Region manager	1) Mitigate: four-eyes principle, the region manager checks the budget created by the engineer before sending.

55	Region manager forgets to approve quotation	Engineer	1) Mitigrate: trigger and send a reminder after 1 week.
56	Quotation is expired	Engineer	1) Mitigrate: trigger and send a reminder after 30 weeks. 2) Avoid: only accept a quotation after 30 days if prices are not changed.
57	Revision not approved by grid operator	Supply chain manager	1) Accept: probability and impact is too low to take action.
58	No soil investigation performed	Work preparator	1) Transfer: make the grid operator responsible for not providing a soil investigation when needed.
59	Soil is contaminated	Work preparator	1) Avoid: Appoint that extra cost can be charged if the soil is contaminated in the terms and conditions of the quotation.
60	Materials taken for other project/serviceorder	Warehouse	1) Escalate: the managing board can influence the behavior of the personel in the warehouse.
61	Wrong inventory quantity in system	Warehouse	1) Escalate: the managing board can instruct the warehouse for frequent inventory counts.
62	Wrong activities in WON-form	Project controller	1) Mititgate: make it easier to compare the WON-form with the data in Navision.

Appendix F

F.1 SO-DOP-P

F.1.1 Preparation

The non-atomic stage ‘Preparation’ contains five atomic stages. All these stages are performed by the engineer. The engineer defines the needs of the client with an intake form. Simultaneously, a project folder is created in the shared documents environment and a credit check is performed. The project folder will contain all documents produced during the project. The credit check is based on the debt of the client to the organization. The credit check is added to model to avoid the occurrence of the risk that the client does not pay the invoice. Thereafter, the items needed for the project are defined. The items needed are established from the intake form, where this is agreed with the client. This stage is created for the activation or deactivation of other stages. For example, a light calculation is not needed, then all stages that are related to the light calculation in the non-atomic stage ‘Offer’ can be skipped. The planning is also discussed in the intake form. Atomic stage ‘Define planning’ is intended to transform this data from the intake form to the ERP system.

F.1.2 Offer

This non-atomic stage contains of eleven atomic stages. The non-atomic ‘Offer’ stage has a direct link with the ‘Preparation’ stage. The ‘Offer’ stage opens when the milestone of the ‘Preparation’ stage is reached. The stage ‘Check items needed’ influences the structure of the ‘Offer’ stage. In Figure 14 all stages are displayed, but when for example a light calculation is not needed, the stages ‘Create light calculation’, ‘Send light calculation’, and ‘Approve light calculation’, will be skipped.

A light calculation visualizes the technical performance of the materials used in the project. It indicates the amount of light that the installation will provide. This could be too less or too much light. Then, other materials need to be chosen or the position of the lightpole needs to be changed. A light calculation is not always necessary. It is most of the time not created when the client is familiar with the materials, or when the project is a direct exchange of materials. In a project where a light calculation needs to be created, the engineer creates and send the light calcution to the client. Thereafter, the client approves or disapproves the lightcalculation.

After the light calculation is created when needed and approved, the design is created. The design is sometimes performed by another party and provided to CityTec. When the design is internal created, the design is sent to the client and the client will approve or disapprove the design.

Thereafter, the budget and quotation for this project are established in the ERP system. These need to be approved by the region manager before sending the quotation to the client. After the region manager signs the quotation, the quotation is sent to the client. The quotation is 30 days valid and the client can accept or reject this quotation.

F.1.3 Power connection

The non-atomic stage ‘Power connection’ opens when the offer is accepted and a power connection request is needed. This is earlier discussed in the stage ‘Check items needed’.

The power connection will be requested by the engineer. The grid operator responsible in that area will approve this request and the corresponding quotation. If a power connection request is not needed, the whole non-atomic stage will be skipped.

F.1.4 Transfer project

After all processes are completed, the engineer contact the project controller for the creation of a project and will transfer the project to the work preparator. When the project is transferred, the SO-DOP-P status in the ERP system is changed to technically ready. Thereafter all processes of the SO-DOP-P are finished, so the finished milestone of the SO-DOP-P stage is reached.

F.2 P-/M-/N-Project

F.2.1 Work preparation

The non-atomic stage 'Work preparation' is the first main stage of the GSM project architecture. This stage contains a base model GSM schema and additional features that differs between projects. Schema fragments are added to the base schema, which all together form the final GSM model for that particular project type. The base schema for the 'Work preparation' stage is presented in Figure 29.

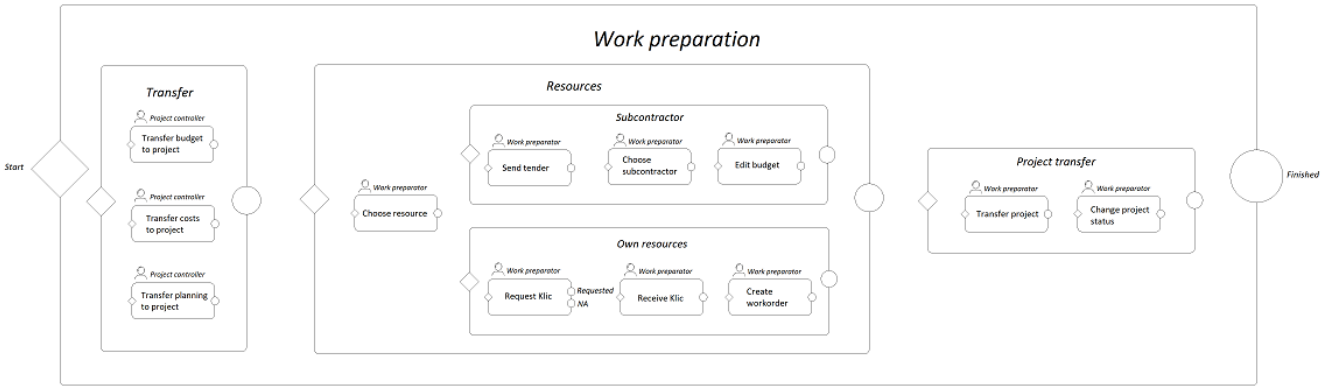

Figure 29: Base GSM schema 'Work preparation'

The base model of the 'Work preparation' stage opens when the project is created and consists of five non-atomic stages: Transfer, resources, subcontractor, own resources, and project transfer. In the non-atomic stage 'Transfer', the budget is transferred from the SO-DOP to the project. Additionally, the costs made in the SO-DOP are also transferred to the project. These costs contain for example the internal hours booked and/or the grid operator cost. The planning of the project is adopted from the SO-DOP and filled in the ERP system. All these processes are performed by the project controller.

The non-atomic stage 'Resources' describes which resources are used to perform the project. The atomic stage 'Choose resources' is intended to open the stage of the particular resource used. The project could be executed by a subcontract, by own personnel or by both. When a subcontractor is used to perform the execution of the project, the non-atomic stage 'subcontractor' opens and the stage 'own resources' is skipped. In the 'subcontractor' stage, a tender is sent if the combined activities in the budget exceed €25.000,-. This stage is skipped if this amount is below €25.000,-. Thereafter, the subcontractor for this project is chosen. The budget is edited based on the inscribed price of the subcontractor to specify the

budget more accurate. When the project is executed by own resources, a KLIC is requested. This provides all information about the underground infrastructure, like cables and pipes in that area. In the case that the project is executed by the subcontractor, the KLIC request is outsourced. Thereafter, the work preparator receives the KLIC and creates a work order to plan internal employees for the project.

The 'Project transfer' stage is the last non-atomic stage in the 'Work preparation' stage. After all other processes are completed in the 'Work preparation' stage, the project is transferred to the executor. Every week, there is one transfer moment where the projects are physically transferred and particularities are discussed between the work preparator and the executor. When the project is transferred, the status of the project in the ERP system is changed from preparation to execution.

F.2.1.1 Features

This section provides the features added to the 'Work preparation' GSM schema. All feature compositions for all types of projects are presented in this section. Thereafter the partial features are added to the base model depending on the project type. The project type and the combinations between the project types in the main project, indicate the variations used in that stage. The 'Work preparation' stage has the following variations depending on the project type:

- The contract price and corresponding payment terms are part of the 'Transfer' stage.
- The mutation form is created as part of the 'Work preparation' stage.
- The materials are requested and the availability is checked as part of the 'Work preparation' stage.
- The first invoice to the client is sent as part of the 'Work preparation' stage.
- The documents provided by the grid operator are checked and consequences are handled as part of the 'Work preparation' stage.

Features are created that represent these variations. The combinations of these features and the base model form the complete GSM schema for the 'Work preparation' stage of a particular project type.

F.2.1.1.1 Transfer ($\Gamma^{Tranfer}$)

The first feature adds the atomic stage ‘Transfer contract price to project’ and ‘Set payment terms’ to the non-atomic stage ‘Transfer’. The GSM schema of this feature is presented in Figure 30. The contract price comes from the SO-DOP-P and is the same as the price in the quotation that is accepted by the client. The payment terms are set conform the agreement in the quotation.

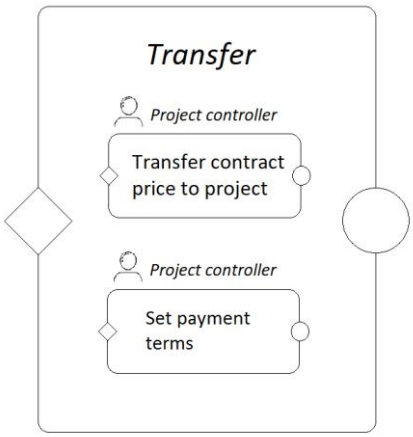

Figure 30: GSM schema for partial feature in 'Transfer' in ‘Work preparation’

F.2.1.1.2 Mutation form ($\Gamma^{WP\ Mutation\ form}$)

The second feature adds a new atomic stage within a new non-atomic stage. The non-atomic stage ‘Mutation form’ is only performed ones in the main project. If the main project consists of a M-Project, the ‘Mutation form’ stage is part of the M-Project. Otherwise, this stage is part of the P-Project. Therefore, the sentry for opening this non-atomic stage is related to the M-Project. The GSM schema of this feature is presented in Figure 31. This non-atomic stage consists of only one atomic stage, which is ‘Create mutation form’. In this stage the design is translated to a spreadsheet, which contains the used materials and the locations of the streetlights.

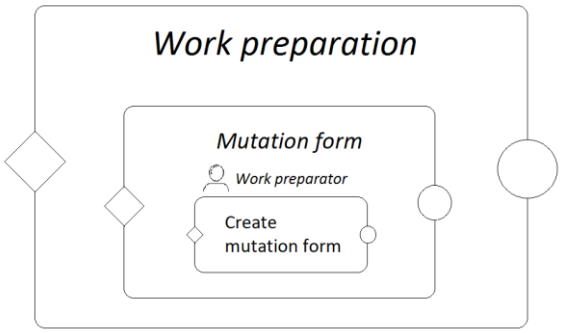

Figure 31: GSM schema for partial feature 'Mutation form' in ‘Work preparation’

F.2.1.1.3 Materials ($\Gamma^{WP\ Materials}$)

The third feature adds two new atomic stages within a new non-atomic stage. This stage only occurs ones in the main project. If the client of the project is a lease client, a M-Project type is created and the 'Materials' stage is performed in the M-Project. Otherwise, the 'Materials' stage is performed in the P-Project. Therefore, the sentry for opening this non-atomic stage is related to the M-Project. The GSM schema of this feature is presented in Figure 32. The non-atomic stage 'Materials' consists of the atomic stages 'Request materials' and 'Check availability materials', which are both performed by the work preparator. The work preparator request the materials in the ERP system, which triggers the Materials GSM model. The availability of the materials is also connected to the Materials GSM model.

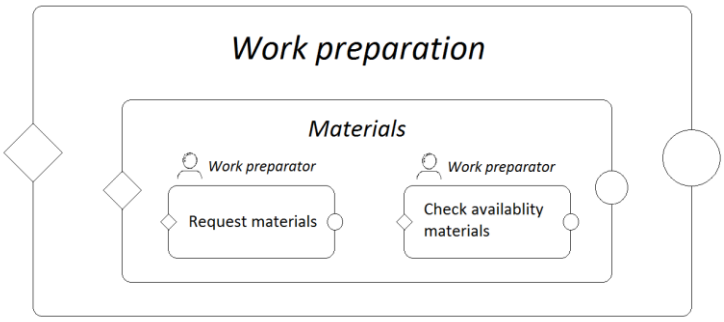

Figure 32: GSM schema for partial feature 'Materials' in 'Work preparation'

F.2.1.1.4 Client payment ($\Gamma^{WP\ Client\ payment}$)

The fourth feature also adds a new atomic stage within a new non-atomic stage. This 'Client payment' stage only occurs in the P-Project, because the P-Project is the only project directly related to the client. This non-atomic stage consists of only one atomic stage called 'Invoicing first part'. The GSM schema is presented in Figure 33. The stage in this schema is performed by the finance department, which sends the first invoice corresponding the payment terms. The most frequently used payment term is 50%-40%-10%, which means that 50% is invoiced in the preparation stage, 40% is invoiced when the project is executed and 10% is invoiced after the project is delivered to the client.

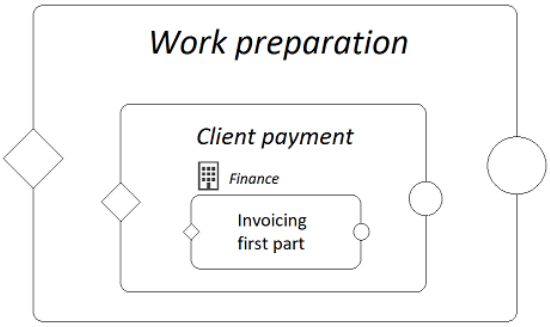

Figure 33: GSM schema for partial feature 'Client payments' in 'Work preparation'

F.2.1.1.5 Documents ($\Gamma^{Documents}$)

The fifth and last feature in the 'Work preparation' stage consists of a non-atomic stage with three atomic stage in this non-atomic stage. This 'Documents' stage only occurs in the N-Project, because this N-Project is the only project directly linked to the grid operator, which provided these documents. The documents that are present in the assignment are the design (underground), the permit and the soil investigation. The requirement of these documents depend on the assignment. The first atomic stage in the 'Documents' stage, checks if all necessary documents are provided by the grid operator. The second atomic stages checks the consequences of the information provided combined with the information that was already known about this project. The soil could be contaminated, a V&G plan needs to be created, or traffic barriers are needed. If one or more of these consequences apply, the third stage is created that handles these problems. The GSM schema of the 'Documents' stage is presented in Figure 34.

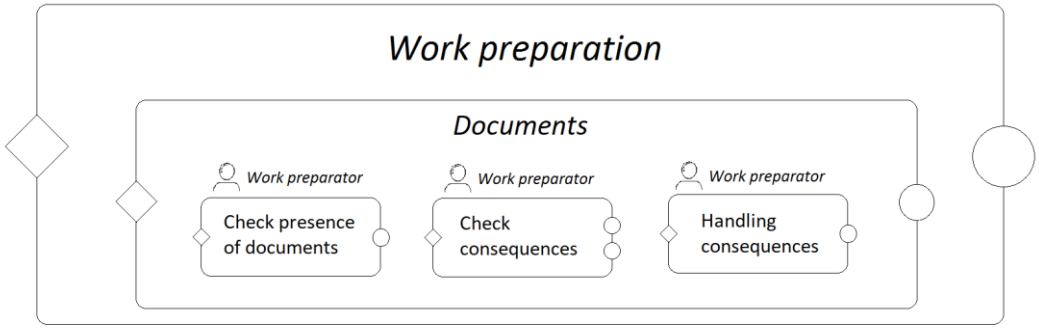

Figure 34: GSM schema for partial feature in 'Documents' in 'Work preparation'

F.2.1.2 P-Project

The P-Project is the project from the client side and is the continuation of the SO-DOP-P together with the M-Project. This project type consists of the following variations compared to the base model 'Work preparation' :

- The contract price and corresponding payment terms are part of the 'Transfer' stage.
- The mutation form is created as part of the 'Work preparation' stage if there is no related M-Project.
- The materials are requested and the availability is checked as part of the 'Work preparation' stage if there is no related M-Project.
- The first invoice to the client is sent as part of the 'Work preparation' stage.

The base GSM schema of the non-atomic stage 'Work preparation' is composed with features to come up with the complete 'Work preparation' stage specified for the P-Project. These features are also defined in GSM schemas. The 'Work preparation' stage of the P-Project consists of one complete feature, the base GSM schema 'Work preparation', and four partial features related to the variations defined earlier in this section. These four features are added to the base model. The method of combining these models is already discussed in the introduction of this chapter. The ordering in of these features in a composition chain influences the outcome. The chain is applied from right to left, so the base model stands on the right end. The feature composition chain that represents the

'Work preparation' stage of the P-Project is as follows, where 'WPP' is the abbreviation of the 'Work preparation' stage of the P-Project:

$$\Gamma^{WPP} = \Gamma^{WP\ Client\ payment} \bullet \Gamma^{WP\ Materials} \bullet \Gamma^{WP\ Mutation\ form} \bullet \Gamma^{Transfer} \bullet \Gamma^{WP\ Base}$$

The sentries of the 'Materials' and 'Mutation form' stages in the P-Project differs from the sentries of these stages in the M-Project. These stages are only performed in the P-Project if there is no M-Project in the main project.

F.2.1.3 M-Project

The M-Project is the project type that is created when the client of the project is a lease client. This means that the materials and activities in this project are not directly charged. There is no contract price for this type of project. The ownership of these materials stays at CityTec. CityTec is responsible for these materials and the client pays a monthly lease amount for this service. The grid operator costs are not part of the lease construction and are part of the P-Project, except the costs for disconnection and connection lampposts. Therefore the M-Project is together with the P-Project the continuation of the SO-DOP-P. This project type consists of the following variations compared to the base model 'Work preparation' :

- The mutation form is created as part of the 'Work preparation' stage.
- The materials are requested and the availability is checked as part of the 'Work preparation' stage.

The base GSM schema of the non-atomic stage 'Work preparation' is composed with features to come up with the complete 'Work preparation' stage specified for the M-Project. The 'Work preparation' stage of the M-Project consists of one complete feature, the base GSM schema 'Work preparation', and two partial features related to the variations defined earlier in this section. The feature composition chain that represents the 'Work preparation' stage of the M-Project is as follows, where 'WPM' is the abbreviation of the 'Work preparation' stage of the M-Project:

$$\Gamma^{WPM} = \Gamma^{WP\ Materials} \bullet \Gamma^{WP\ Mutation\ form} \bullet \Gamma^{WP\ Base}$$

As discussed in the previous section, the sentries of the 'Materials' and 'Mutation form' stages differs between the M-Project and the P-Project. The M-Project is the superior project, which means that if a M-Project is present in the main project, the 'Materials' and 'Mutation form' stages are part of the M-Project. Only when a M-Project is not present in the main project the stages are part of the P-Project.

F.2.1.4 N-Project

The N-Project is the project from the grid operator side. The N-Project is the continuation of the SO-DOP-N. This project type is created if the grid operator outsource their activities to CityTec. The grid operator is responsible for the electronic underground infrastructure to which the installations of CityTec are connected. When the electronic underground infrastructure needs to be changed, the grid operator could outsource this to CityTec. These assignments consist of individual project assignments or assignments that are related to a P-Project and/or M-Project. The related assignments are requested in the SO-DOP-P and the

same request returns in an assignment. The N-Project consists of the following variations compared to the base model 'Work preparation' :

- The contract price and corresponding payment terms are part of the 'Transfer' stage.
- The provided documents by the grid operator are checked and consequences are handled as part of the 'Work preparation' stage.

The base GSM schema of the non-atomic stage 'Work preparation' is composed with features to come up with the complete 'Work preparation' stage specified for the N-Project. The 'Work preparation' stage of the N-Project consists of one complete feature, the base GSM schema 'Work preparation', and two partial features related to the variations defined earlier in this section. The feature composition chain that represents the 'Work preparation' stage of the N-Project is as follows, where 'WPN' is the abbreviation of the 'Work preparation' stage of the N-Project:

$$\Gamma^{WPN} = \Gamma^{Documents} \bullet \Gamma^{Transfer} \bullet \Gamma^{WP\ Base}$$

The payment of the grid operator is always when the project is delivered. Therefore, there is no payment stage available in the 'Work preparation' stage of the N-Project. The payment terms need to be filled even if the payment is 100% afterwards, otherwise the invoice could not be created in the ERP system.

F.2.2 Execution

The non-atomic stage 'Execution' is the second main stage of the GSM project architecture. This stage contains a base model GSM schema and additional features that differs between projects. Schema fragments are added to the base schema, which all together form the final GSM model of the stage 'Execution' for that particular project type. The base schema for the 'Execution' stage is presented in Figure 35.

This execution stage opens if the 'Work preparation' stage is finished. The base GSM schema of the 'Execution' stage consists of five non-atomic stages: Resources, subcontractor, own resources, more/less work, and project transfer. The resource chosen in the 'Work preparation' stage opens or skips the non-atomic stages 'subcontractor' and/or 'own resources'. When the project is executed by a subcontractor, the first atomic stage is to receive PVs from the subcontractor. Thereafter, the PVs are approved or rejected by the executor. When the PVs are approved, the finance department creates IOR and ION numbers for the PVs. Otherwise if the PVs are rejected, the subcontractor needs to change the PVs. IOR stands for 'inkooporder', which is Dutch for purchase order and the ION stands for 'inkoopontvangst', which is the translation for purchase receipt. In this case, both are created at the same time because the subcontractor describes the activities in the PVs and we immediately receive these activities. When the work is performed by own personnel, the work is executed by the mechanic and checked by the executor. If the work is approved, the 'Resources' stage is finished, otherwise if the executor reject the work, the mechanic needs to perform some rework on the project.

During the lifecycle of the 'Resources' stage, the non-atomic stage 'More/less work' is also opened. There could occur more or less work during the execution of the project. The

situation could be different than drawn in the design of the project. For example, lampposts need to be placed on another location, do not have to be placed at all, or extras added to the project. This influences the costs of the project. First, the executor notifies the more/less work activities to the client and thereafter, the client approves or rejects this proposed more or less work. The lifecycle of the non-atomic stage 'More/less work' closes at the same time the non-atomic stage 'Resources' closes.

The 'Project transfer' stage is the last non-atomic stage in the 'Execution' stage. After all other processes are completed in the 'Execution' stage, the project is transferred to the administration department. When the project is transferred, the status of the project in the ERP system is changed from execution to technically ready.

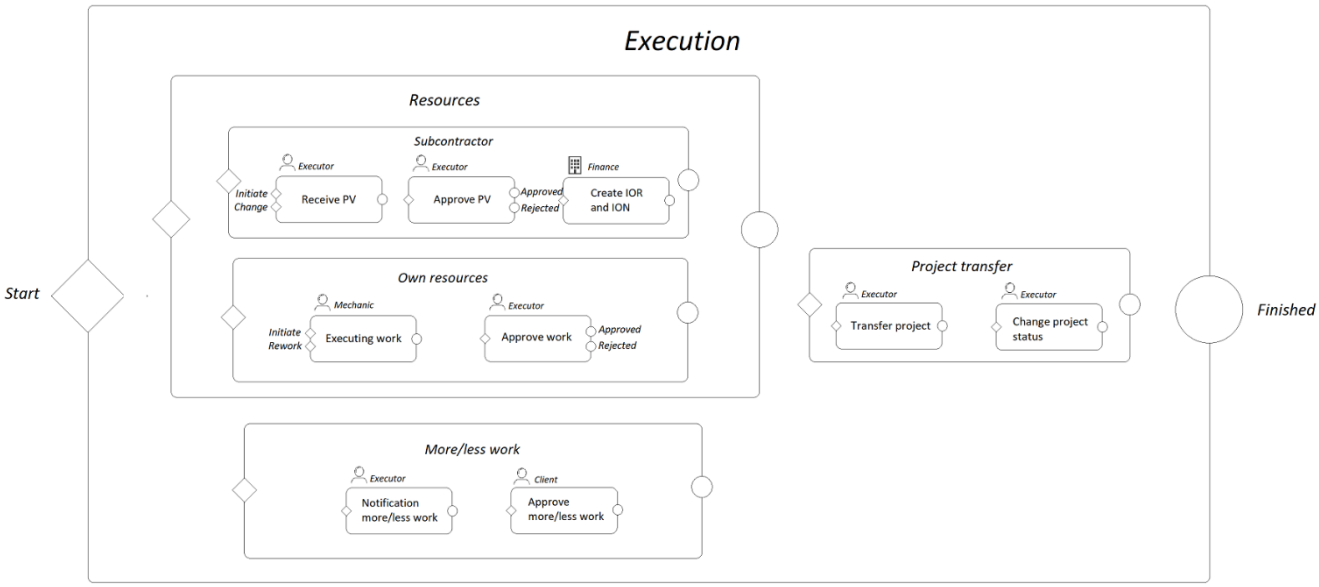

Figure 35: Base GSM schema 'Execution'

F.2.2.1 Features

This section creates features that are added to the base GSM schema of the 'Execution' stage. The combination of these features added to the base model, represent the complete GSM schema of the 'Execution' stage for each project type. First, the different features are described and thereafter the complete 'Execution' stage is created for the different project types by the composition of these features and the base model. The features represent a variation that is added to the base model.

The 'Execution' stage has the following variations depending on the project type:

- Materials are booked on the project as part of the 'Execution' stage.
- The mutation form is edit and approved as part of the 'Execution' stage.
- The amount for the more or less work is processed in the ERP system as part of the 'More/less work' stage.
- The second invoice to the client is sent as part of the 'Execution' stage.
- The revision is received and approved as part of the 'Execution' stage.
- The WON-form is created as part of the 'Execution' stage.
- The project is delivered to the client as part of the 'Execution' stage.

In this section features are created that represent these variations. The combinations of these features and the base model form the complete GSM schema for the 'Execution' stage of a particular project type.

F.2.2.1.1 Materials ($\Gamma^{EX\ Materials}$)

The first feature that could be part of the 'Execution' stage, adds the non-atomic stage 'Materials' with one atomic stage in it. This atomic stage is called 'Booking materials on project'. When the project is executed, the materials requested for this project are booked and released on the project by the warehouse worker. The subcontractor or own personnel takes these materials to the place where the project needs to be executed. The GSM schema of this feature is presented in Figure 36. The 'Materials' stage in the execution phase has the same dependency as the 'Materials' stage in the work preparation stage. This means that this stage one occurs ones in a main project. If a M-Project is present in the main project, the 'Materials' stage is only available in the M-Project and is skipped in the P-Project. Otherwise, the 'Materials' stage is present in the P-Project.

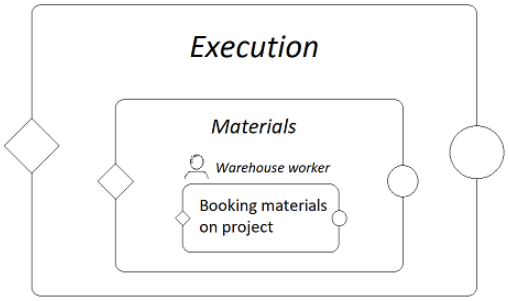

Figure 36: GSM schema for partial feature 'Materials' in 'Execution'

F.2.2.1.2 Mutation form ($\Gamma^{EX\ Mutation\ form}$)

The second feature that could be part of the 'Execution' stage has a non-atomic stage called 'Mutation form' and two atomic stages called 'Edit mutation form' and 'Approve mutation form'. The mutation form is edited by the subcontractor or by own personnel. They change the mutation form if needed to the real situation outside and provide an installation date. This mutation form is approved or rejected by the executor. When the mutation form is approved, the 'Mutation form' stage is closed. If the executor reject the mutation form, the subcontractor or the own mechanic needs to change the mutation form. The non-atomic 'Mutation form' stage in the execution stage has the same principles as the 'Mutation form' stage in the work preparation stage. This means that if a M-Project is present in the main

project, this stage will be part of the M-Project. Otherwise, this stage is part of the P-Project. The GSM schema of this feature is present in Figure 37.

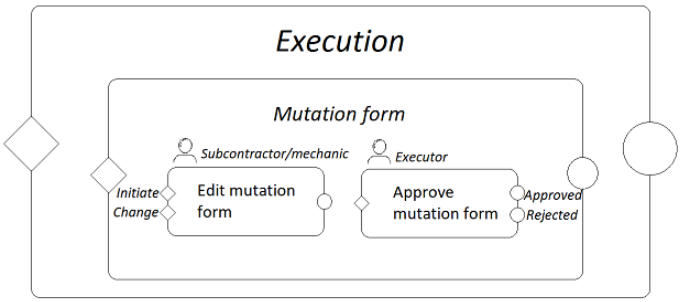

Figure 37: GSM schema for partial feature 'Mutation form' in 'Execution'

F.2.2.1.3 More/less work ($\Gamma^{More/less\ work}$)

The third feature in the 'Execution' stage adds an atomic stage to the non-atomic stage 'More/less work'. This atomic stage is added after the already existing stages in the base model of the 'Execution' stage. This new stage is called 'Processing more/less work', which is performed by the executor in the ERP system. The price of the more or less work needs to be added in the system for the payment by the client or grid operator. This amount is added to the already existing contract price and is part of the final invoice. The amount can only be justified if the client or grid operator approves the extra activities, which is part of the base 'Execution' model. The more or less work does not have to be processed in the M-Project because these costs are part of the lease construction. The more/less work schema is presented in Figure 38.

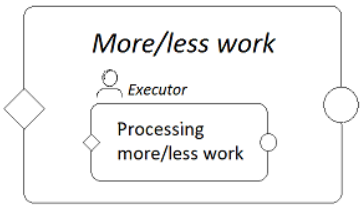

Figure 38: GSM schema for partial feature 'More/less work' in 'Execution'

F.2.2.1.4 Client payment ($\Gamma^{EX\ Client\ payment}$)

The next feature in the 'Execution' stage adds a new atomic stage within a new non-atomic stage. The new non-atomic stage 'Client payment' is the continuation of the 'Client payment' stage in the 'Work preparation' stage. The second part of the agreed upon payment term is invoiced during the execution of the project. This is most of the time 40% of the contract price, but could be different depending on the payment terms. The GSM schema of this feature is presented in Figure 39.

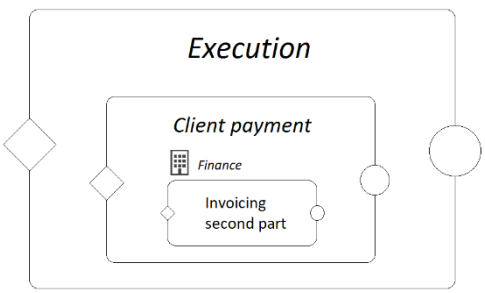

Figure 39: GSM schema for partial feature 'Client payment' in 'Execution'

F.2.2.1.5 Revision ($\Gamma^{Revision}$)

This feature is only part of the N-Project and consists of a new non-atomic stage and two atomic stages within this non-atomic stage. The two atomic stages in the non-atomic 'Revision' stage are the stage 'Receive revision' and 'Approve revision'. The subcontractor or provides the revision to the executor. If the project is executed by own mechanics, the revision is provided by them. The executor checks the correctness of the revision by approving or rejection the revision. If the revision is rejected, the creator of the revision needs to change the revision to the correct state. When the revision is accepted, the revision stage is completed and the non-atomic stage is closed. The GSM schema of this stage is presented in Figure 40.

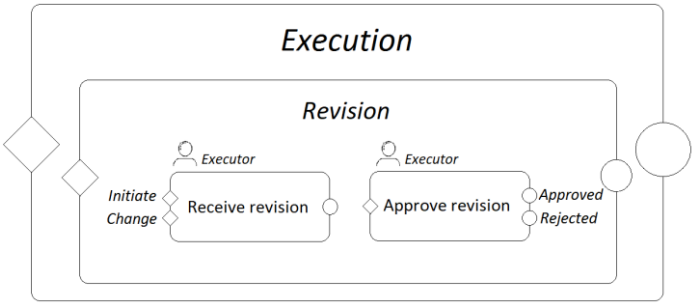

Figure 40: GSM schema for partial feature 'Revision' in 'Execution'

F.2.2.1.6 WON-form ($\Gamma^{WON-form}$)

This feature adds the atomic stage 'Create WON-form' within the non-atomic stage 'WON-form'. The WON-form is only part of the N-Project and is created to initiated the activities performed in this project. These activities consists of the activities originally in the assignment and the activities performed as more or less work. The executor created this form, which the supply chain manager uses in the 'Administration' stage as input to create the PVs and TMs for the grid operator. The GSM schema of the 'WON-form' feature is presented in Figure 41.

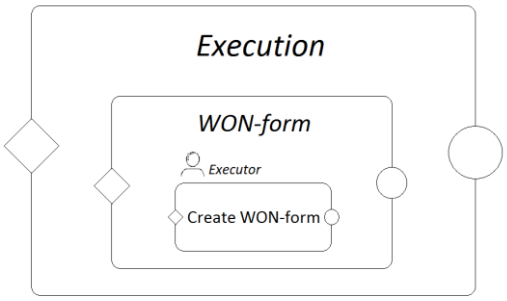

Figure 41: GSM schema for partial feature 'WON-form' in 'Execution'

F.2.2.1.7 Project delivery ($\Gamma^{EX\ Project\ delivery}$)

The 'Project delivery' feature is part of the 'Execution' stage in the P-Project or the M-Project. The project is also delivered in the N-Project but then this non-atomic stage is part of the 'Administration' stage and is delivered to the grid operator instead of the client. The 'Project delivery' stage in the 'Execution' stage is part of the M-Project if a M-Project exist within the main project. This non-atomic stage is then skipped in the P-Project. Only if there is not a M-Project present in the main project, the project delivery to the client is performed in the P-Project. This follows the same principles as the 'Mutation form' stage and the

'Materials' stage, which also means that the sentries for the P-Project differs from the sentries for the M-Project. The two atomic stages in the non-atomic 'Project delivery' stage are the stages 'Make appointment' and 'Approve PVO'. First, an appointment is made with the client on the spot where the project is executed. On that date, the executor brings all required documents of the project and an official report of delivery is signed. The Dutch abbreviation for this official report of delivery is PVO. When the client rejects the PVO, the executor needs to sort out the required documents and makes a new appointment for the project delivery. The GSM schema of the 'Project delivery' feature is presented in Figure 42.

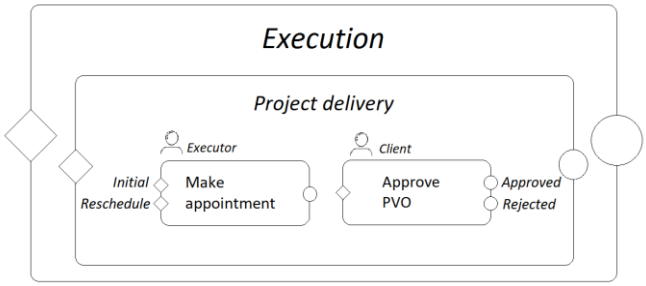

Figure 42: GSM schema for partial feature 'Project delivery' in 'Execution'

F.2.2.2 P-Project

The 'Execution' stage of the P-Project is the continuation of the 'Work preparation' stage of the P-Project. Both related to the client side of the main project. This project type consists of the following variations compared to the base model 'Execution':

- Materials are booked on the project as part of the 'Execution' stage.
- The mutation form is edit and approved as part of the 'Execution' stage.
- The amount for the more or less work is processed in the ERP system as part of the 'More/less work' stage.
- The second invoice to the client is sent as part of the 'Execution' stage.
- The project is delivered to the client as part of the 'Execution' stage.

The complete 'Execution' stage specified for the P-Project is established by adding these variations to the base model. Features are created in the previous section based on these variations. These features are also defined in GSM schemas. The composition of the features and the base 'Execution' model is the same as the composition of the 'Work preparation' stage. The 'Execution' stage of the P-Project consists of five partial features based on the variations defined, and one complete feature, which is the base model. The five features and the base model are composed to create one complete 'Execution' stage specified for the P-Project.

As discussed before, the order of the features in the composition chain influence the outcome. The feature composition chain that represents the 'Execution' stage of the P-Project is as follows, where 'EXP' is the abbreviation of the 'Execution' stage of the P-Project:

$$\Gamma^{EXP} = \Gamma^{EX\ Project\ delivery} \bullet \Gamma^{EX\ Client\ payment} \bullet \Gamma^{EX\ Mutation\ form} \bullet \Gamma^{More/less\ work} \bullet \Gamma^{EX\ Materials} \bullet \Gamma^{EX\ Base}$$

The sentries of the ‘Materials’, ‘Mutation form’, and ‘Project delivery’ stages in the P-Project differs from the sentries of these stages in the M-Project. These stages are only performed in the P-Project if there is no M-Project in the main project.

F.2.2.3 M-Project

The ‘Execution’ stage of the M-Project is the continuation of the ‘Work preparation’ stage of the M-Project. The M-Project is only created when the project is performed for a lease client. All activities that are executed in the ‘Execution’ stage are part of the lease construction. Only activities that are not part of the ‘Execution’ stage are the activities related to the underground infrastructure which are part of the N-Project, and the activities related to moving lampposts from one location to another location. An example of such situation is that new parking spots are created on the location of the lampposts. The lampposts need to move a few meter to the side to make place for these parking spots. These costs are not covered in the lease construction because streetlights are provided on that location, but the client changes the architecture of the location while the materials are not amortized. The client pays for these activities, so these activities are part of the P-Project.

The M-Project consists of the following variations compared to the base model ‘Execution’:

- Materials are booked on the project as part of the ‘Execution’ stage.
- The mutation form is edit and approved as part of the ‘Execution’ stage.
- The project is delivered to the client as part of the ‘Execution’ stage.

These features of these variations are described earlier in the previous section. The ‘Execution’ stage is composed with these features to provide a complete ‘Execution’ stage of the M-Project. The ‘Execution’ stage of the M-Project consists of one complete feature, the base model, and three partial features related to the variations defined earlier in this section. The feature composition chain that represents the ‘Execution’ stage of the M-Project is as follows, where ‘EXM’ is the abbreviation of the ‘Execution’ stage of the M-Project:

$$\Gamma^{EXM} = \Gamma^{EX\ Project\ delivery} \bullet \Gamma^{EX\ Mutation\ form} \bullet \Gamma^{EX\ Materials} \bullet \Gamma^{EX\ Base}$$

The sentries of the ‘Materials’, ‘Mutation form’, and ‘Project delivery’ are different than the sentries of these stage for the P-Project. The M-Project is the superior project, which means that if a M-Project exists in the main project, these stages are part of the M-Project and are skipped in the P-Project.

F.2.2.4 N-Project

The ‘Execution’ stage of the N-Project is the continuation of the ‘Work preparation’ stage of the N-Project. This N-Project is the project type that handles the grid operator side of the main project. The activities performed in the ‘Execution’ stage of the N-Project are all related to the electronic underground infrastructure of the grid operator. The grid operator provides an assignment which is executed in this stage including the more or less work related to that particular assignment. If the assignment is an individual project, the project is

planned on the request of the grid operator. Otherwise, the planning of the N-Project is equal to the planning of the P-Project and/or M-Project.

The N-Project consists of the following variations compared to the base model 'Execution':

- The amount for the more or less work is processed in the ERP system as part of the 'More/less work' stage.
- The revision is received and approved as part of the 'Execution' stage.
- The WON-form is created as part of the 'Execution' stage.

The base GSM schema of the 'Execution' stage is composed with features related to these variations to provide the complete 'Execution' stage specified for the N-Project. The N-Project consists of three partial features defining the variations, and one complete feature, the base GSM schema 'Execution'. The feature composition chain that represents the 'Execution' stage of the N-Project is as follows, where 'EXN' is the abbreviation of the 'Execution' stage of the N-Project:

$$\Gamma^{EXN} = \Gamma^{WON-form} \bullet \Gamma^{Revision} \bullet \Gamma^{More/less\ work} \bullet \Gamma^{EX\ Base}$$

The WON-form and the revision are both output documents created in this 'Execution' stage, which are input for the supply chain manager in the 'Administration' stage. The more and less work amount is added in the ERP system for increasing or decreasing the amount in the invoice.

F.2.3 Administration

The non-atomic stage 'Administration' is the third and last main stage of the GSM project architecture. A base model for the 'Administration' stage is created and features are added to this model to specify the project type. These features composed with the base model form the final GSM model of the stage 'Administration' for that particular project type. The base schema for the 'Administration stage' is presented in …

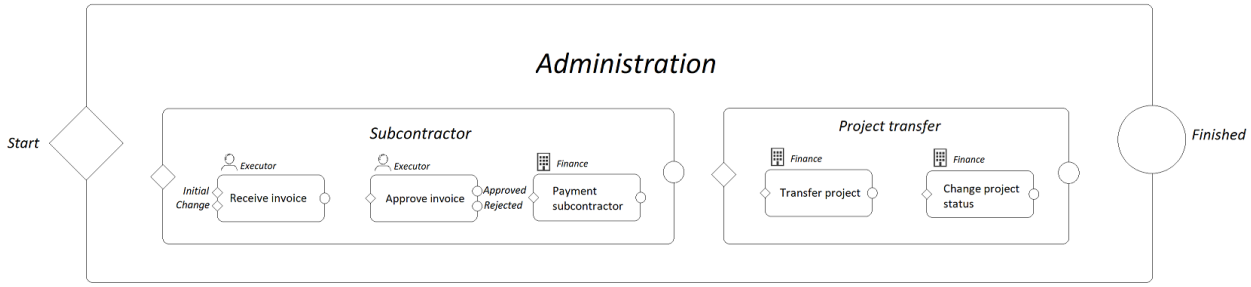

Figure 43: Base GSM schema 'Administration'

The 'Administration' stage starts when the execution stage is finished. This triggers the non-atomic stage 'Subcontractor' in the 'Administration' stage. This non-atomic stage consists of three atomic stages. First, the invoice of the subcontractor is received. This could also be multiple invoices. These correspond to the IOR and the ION number created in the 'Execution' stage of the project for the subcontractor. The executor approves or rejects the received invoice. If the invoice is approved, the finance department pays the amount on the invoice to the subcontractor. When the invoice is rejected, the subcontractor is notified and

changes the specifications in the invoice which were wrong. After all processes in the 'Administration' stage are performed, the project is transferred to the project controller who performs a final check on the correctness of the project. The project status is also changed from technically ready to administratively ready.

F.2.3.1 Features

This section describes the features that could be added to the base GSM schema of the 'Administration' to specify this stage for a particular project type. After the features are described, a combination of the features are composed with the base model. This creates the complete GSM schema of the 'Administration' stage for that particular project type. The features added to the base model represent a variation of the base model.

The 'Administration' stage has the following variations depending on the project type:

- The invoice of the grid operator is handled as part of the 'Administration' stage.
- The mutation form is processed in the ERP system as part of the 'Administration' stage.
- Activate all costs booked in the project as asset in the ERP system as part of the 'Administration' stage.
- The final invoice to the client is sent as part of the 'Administration' stage.
- The invoice to the grid operator is sent as part of the 'Administration' stage.
- The project is delivered to the grid operator as part of the 'Administration' stage.

This section creates features that represent these six variations. These features are created in a GSM schema. The complete GSM schema specialized for a particular project type, is a combination of these features and the base model of the 'Administration' stage.

F.2.3.1.1 Power connection ($\Gamma^{Power\ connection}$)

The power connection feature adds the non-atomic stage 'Power connection' with three atomic stages to the base model of the 'Administration' stage. The stages in the non-atomic stage handle the invoice of the grid operator. The invoice of the grid operator is received by the finance department. The invoice is put in the ERP system and the executor approves the invoice. When the invoice of the grid operator is approved, the costs are booked on the project and the invoice is paid by the finance department. If the invoice is rejected, the grid operator provides a new revised version of the invoice. The invoice of the grid operator

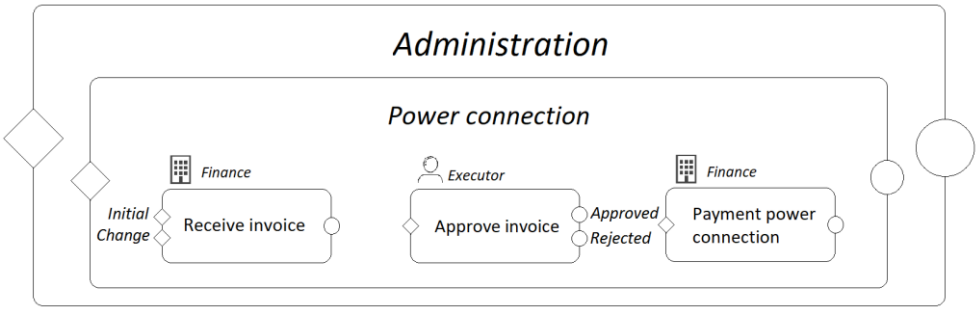

Figure 44: GSM schema for partial feature 'Power connection' in 'Administration'

could be part of the P-Project, but also of the M-Project. The GSM schema of the 'Power connection' stage in the 'Administration' stage is presented in Figure 44.

F.2.3.1.2 Mutation form ($\Gamma^{AD\ Mutation\ form}$)

This feature adds a new non-atomic stage which is also part of the 'Work preparation' and 'Execution' stage. This time, the non-atomic stage 'Mutation form' consists of only one atomic stage. This atomic stage called 'Processing mutation form' is performed by the asset management department. This department process the mutation form in the ERP system. The objects and materials used are added to the database. This data consists of specifications about all installations in the management of CityTec. On the basis of this information, failures to these installations are solved. It is especially important that the mutation form of a M-Project is processed because the monthly collection to the client is also based on this asset data. All materials provided in the M-Project have a code which represents a yearly fee. If this mutation form is not processed, the lampposts are not included in the lease construction.

The stage 'Mutation form' in the 'Administration' stage is like the other 'Mutation form' stages mutually exclusive between the M-Project and P-Project. The M-Project is the superior project, which means that if a M-Project is present in the Main project, this feature is added to the base model of the M-Project. Otherwise, the feature is added to the P-Project.

The GSM schema of the 'Mutation form' stage that could be added in the 'Administration' stage is present in Figure 45.

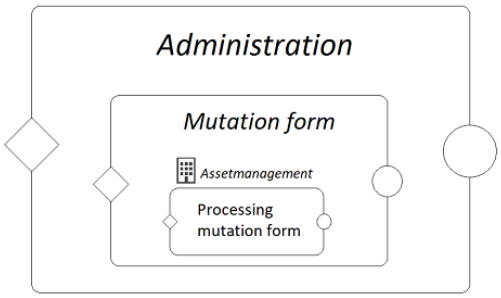

Figure 45: GSM schema for partial feature 'Mutation form' in 'Administration'

F.2.3.1.3 Lease (Γ^{Lease})

This feature is only part of the M-Project. This feature is added for activating the costs as assets by adding a new atomic stage within a new non-atomic stage. The ownership of the installations provided in the M-Project, is CityTec. The client pays a yearly fee for the services CityTec provides. This means that the installations are part of the assets of CityTec and need to be added to the balance sheet. Otherwise, the financial status of CityTec may be endangered. The GSM schema of the 'Lease' stage is presented in Figure 46.

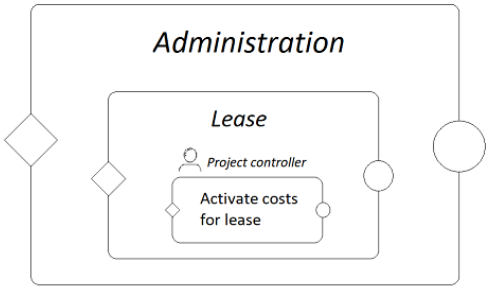

Figure 46: GSM schema for partial feature 'Lease' in 'Administration'

F.2.3.1.4 Client payment ($\Gamma^{AD\ Client\ payment}$)

The 'Client payment' feature is also part of the 'Work preparation' and 'Execution' stage. The administration stage has on the other hand two atomic stages instead of one atomic stage. The non-atomic 'Client payment' stage consists in the 'Administration' stage of the atomic stages 'Invoicing final part' and 'Payment'. The final invoice consists of the last payment term and the price of the more or less work. The payment of all invoices combined is checked in the second atomic stage of the non-atomic stage 'Client payment'. The client has 30 days for paying the invoice. The stage only closes if 100% including the more or less work is paid. The GSM schema of this feature is presented in Figure 47.

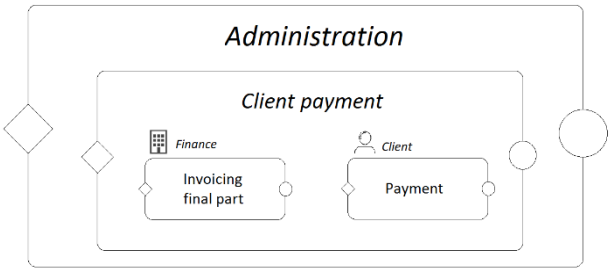

Figure 47: GSM schema for partial feature 'Client payment' in 'Administration'

F.2.3.1.5 Grid operator payment ($\Gamma^{Grid\ operator\ payment}$)

This feature is only applies on the 'Administration' stage of the N-Project. The principle is the same as the client payment, but the grid operator payment is not divided into payment terms. The grid operator pays for the project afterwards, so the final part of the invoice is the full contract price. Therefore, the non-atomic stage 'Grid operator payment' is added to the N-project. Two atomic stages are located within this non-atomic stage. First, the finance department send the invoice to the grid operator. The next stage is the payment by the grid operator. The grid operator has 30 days to pay the invoice. These process together form the GSM schema for the 'Grid operator payment' stage presented in Figure 48.

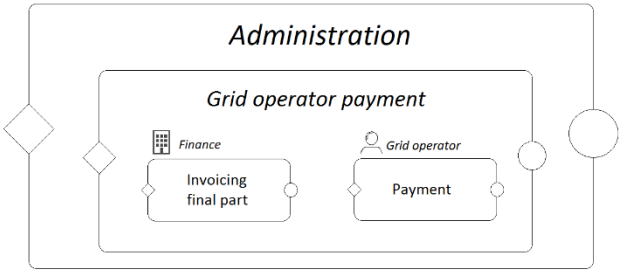

Figure 48: GSM schema for partial feature 'Grid operator payment' in 'Administration'

F.2.3.1.6 Project delivery ($\Gamma^{AD\ Project\ delivery}$)

This feature adds a new non-atomic stage to the 'Administration' stage. The new non-atomic stage consists of six atomic stages and is only used in the N-Project. The first atomic stage creates a PV. The activities performed are present in the WON-form. The PV is created by the supply chain manager, which lists the activities and their responding prices. This PV is almost the same as the PV of the subcontractor, but other specifications are used. The next stage of the non-atomic stage 'Project delivery' in the 'Administration' stage, is 'Create TM'. The TM is almost the same as the PVO from the client side. The TM is form that sums all work carried out and the required documents. This is only needed under circumstances were the number of activities are above the standard of the grid operator. If the number of activities exceed this standard, an appointment is made with the grid operator to deliver the project. The grid operator approves the TM with this approval, the project is technically approved. The grid operator can also reject the TM and triggers the executor to sort out all documents. Thereafter, a new appointment is made for the technical approval. If the amount of activities are below the standard or the TM is approved, the supply chain manager provides the PV and the revision in the portal of the grid operator. This is the administrative part of the approval. When the grid operator approves the PV and revision, the project is administratively approved by the grid operator. The GSM schema of these processes performed in this feature are presented in Figure 49.

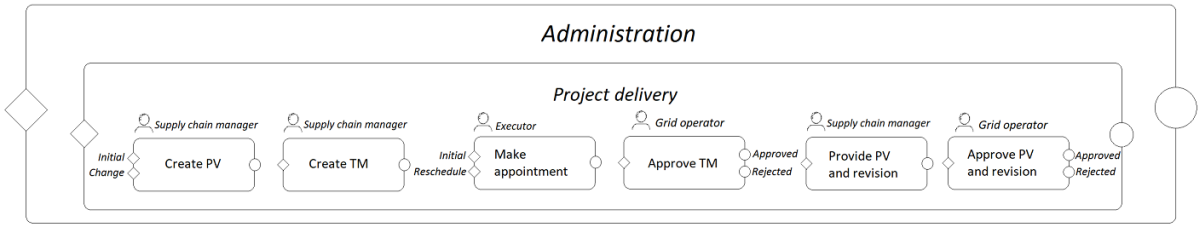

Figure 49: GSM schema for partial feature 'Project delivery' in 'Administration'

F.2.3.2 P-Project

The 'Administration' stage of the P-Project is the continuation of the 'Execution' stage of the P-Project. The 'Administration' stage of the P-Project is also client oriented. This project type consists of the following variations compared to the base model 'Administration':

- The invoice of the grid operator is handled as part of the 'Administration' stage.
- The mutation form is processed in the ERP system as part of the 'Administration' stage.
- The final invoice to the client is sent as part of the 'Administration' stage.

These variations are transformed to GSM schemas in the previous section. These GSM schemas composed with the base model of the 'Administration' stage present the complete 'Administration' stage for the P-Project. There are three variations relevant for this complete GSM schema, which means that there are also three partial features relevant for this project type. There is also one complete feature, which is the base model. The combination of the complete feature and the partial features form the 'Administration' stage for the P-Project.

The feature composition chain that represents the 'Administration' stage of the P-Project is as follows, where 'ADP' is the abbreviation of the 'Administration' stage of the P-Project:

$$\Gamma^{ADP} = \Gamma^{AD\ Client\ payment} \bullet \Gamma^{AD\ Mutation\ form} \bullet \Gamma^{Power\ connection} \bullet \Gamma^{AD\ Base}$$

The sentries of the 'Mutation form' stage in the P-Project differs from the sentries of this stage in the M-Project. This stage is only performed in the P-Project if there is no M-Project in the main project.

F.2.3.3 M-Project

The 'Administration' stage of the M-Project is the continuation of the 'Execution' stage of the M-Project. All processes related to a lease construction are part of the M-Project. Not only the materials are part of the lease construction, but also all direct costs related to the placement of these materials, for example labor. The lease construction of CityTec is a pretty complex process. The materials are always part of the M-Project if the project is performed for a lease client. The costs for the subcontractor and internal hours are not always part of the M-Project. If the activity contains a movement of an installation, the costs are booked on the P-Project. All other activities like placing or replacing installations, are part of the M-project. The costs for the grid operator can also be for both projects. The direct disconnecting and connecting activity is part of the exchange of materials, so is part of the M-Project. But all other activities are part of the P-Project and the client has to pay for these activities directly.

The M-Project consists of the following variations compared to the base model 'Administration':

- The invoice of the grid operator is handled as part of the 'Administration' stage.
- The mutation form is processed in the ERP system as part of the 'Administration' stage.
- Activate all costs booked in the project as asset in the ERP system as part of the 'Administration' stage.

The GSM schemas of these variations are created in the previous section. The three variations suggested for the M-Project, represent also three GSM schemas. The composition of these GSM schemas of these features and the base model of the 'Administration' stage present the complete 'Administration' stage of the M-Project. The feature composition chain that represents the 'Administration' stage of the M-Project is as follows, where 'ADM' is the abbreviation of the 'Administration' stage of the M-Project:

$$\Gamma^{ADM} = \Gamma^{Lease} \bullet \Gamma^{AD\ Mutation\ form} \bullet \Gamma^{Power\ connection} \bullet \Gamma^{AD\ Base}$$

It is important that the 'Lease' stage is executed as last. Otherwise are not all costs activated. In addition the sentries of the 'Mutation form' is different than the sentries of these stage for the P-Project. The M-Project is the superior project, which means that if a M-Project exists in the main project, these stages are part of the M-Project and are skipped in the P-Project.

F.2.3.4 N-Project

The 'Administration' stage of the N-Project is the continuation of the 'Execution' stage of the N-Project. The N-Project is the project from the grid operator side of the main project. The 'Administration' stage is therefore quite different in comparison to the P-Project and M-Project. The project delivery in the N-Project is in the 'Administration' stage, while the project delivery in the M-Project and P-Project is performed in the 'Execution' stage. The project delivery of the N-Project requires more administrative work compared to the other two project types. The project delivery of the two other project types is just a paper that needs to be signed, but the project delivery of the N-Project requires more documentation.

The N-Project consists of the following variations compared to the base model 'Administration':

- The invoice to the grid operator is sent as part of the 'Administration' stage.
- The project is delivered to the grid operator as part of the 'Administration' stage.

The GSM schemas of these variations are composed with the base model of the 'Administration' stage to provide the complete 'Administration' stage specified for the N-Project. Two partial features which are defining the variations, and one complete feature which is the base GSM schema of the 'Administration' stage, are composed into one complete GSM schema. The feature composition chain that represents the 'Administration' stage of the N-Project is as follows, where 'ADN' is the abbreviation of the 'Administration' stage of the N-Project:

$$\Gamma^{ADN} = \Gamma^{Grid\ operator\ payment} \bullet \Gamma^{AD\ Project\ delivery} \bullet \Gamma^{AD\ Base}$$

The 'Project delivery' feature is executed before the 'Grid operator payment' feature, because the grid operator first needs to approve that the project execution and the corresponding costs are correct before the invoice is sent to the grid operator.

Appendix G

G.1 SO-DOP-P

Table 8: Opening and terminating sentries of stages in the SO-DOP-P GSM model

Stages	Guards (opening sentries)	Terminating sentries
SO-DOP-P	*r1:* **on** E:RequestClient	*r2:* **on** +SO-DOP-PFinished
		r3: **on** +RequestClientCancelled
Preparation	*r4:* **on** +SO-DOP-P	*r5:* **on** +PreparationFinished
Define needs with intake form	*r6:* **on** +Preparation	*r7:* **on** +IntakeformFilledIn
Check items needed	*r8:* **on** +IntakeformFilledIn	*r9:* **on** +ItemsNeededChecked
Define planning	*r10:* **on** +IntakeformFilledIn	*r11:* **on** +PlanningDefined
Create project folder	*r12:* **on** +Preparation	*r13:* **on** +ProjectFolderCreated
Credit check client	*r14:* **on** +Preparation	*r15:* **on** +CreditChecked
Offer	*r14:* **on** +PreparationFinished	*r15:* **on** +OfferAccepted
Create light calculation	*r16:* **on** +Offer **if** CheckItemsNeeded(LightCalculation)=true	*r18:* **on** +LightCalculationCreated
	r17: **on** +LightCalculationRejected	*r19:* **on** +LightCalculationCreated
Send light calculation	*r20:* **on** +LightCalculationCreated	*r21:* **on** +LightCalculationSend
Approve light calculation	*r22:* **on** +LightCalculationSend	*r23:* **on** +LightCalculationApproved
		r24: **on** +LightCalculationDisapproved
Create design	*r25:* **on** +Offer **if** Check items needed(design)=true	*r26:* **on** +DesignCreated
	r27: **on** +DesignRejected	*r28:* **on** +DesignCreated
Send design	*r29:* **on** +DesignCreated	*r30:* **on** +DesignSend
Approve design	*r31:* **on** +DesignSend	*r32:* **on** +DesignApproved
		r33: **on** +DesignDisapproved
Set budget	*r34:* **on** +Offer **if** CheckItemsNeeded(LightCalculation)=false ∧ CheckItemsNeeded(Design)=false ∨ +LightCalculationApproved ∧ CheckItemsNeeded(Design)=false ∨ CheckItemsNeeded(LightCalculation)=false ∧ +DesignApproved ∨ +LightCalculationApproved ∧ +DesignApproved	*r36:* **on** +BudgetSet
	r35: **on** +OfferDisapproved ∨ +QuotationRejected	*r37:* **on** +BudgetSet
Create quotation	*r38:* **on** +Offer **if** CheckItemsNeeded(LightCalculation)=false ∧ CheckItemsNeeded(Design)=false ∨ +LightCalculationApproved ∧ CheckItemsNeeded(Design)=false ∨ CheckItemsNeeded(LightCalculation)=false ∧ +DesignApproved ∨ +LightCalculationApproved ∧ +DesignApproved	*r39:* **on** +QuotationCreated

	r40: **on** +OfferDisapproved ∨ +QuotationRejected	*r41:* **on** +QuotationCreated
Approve offer	*r42:* **on** +QuotationCreated ∧ +BudgetSet	*r43:* **on** +OfferApproved
		r44: **on** +OfferDisapproved
Send quotation	*r45:* **on** +OfferApproved	*r46:* **on** +QuotationSend
Accept quotation	*r47:* **on** +QuotationSend	*r48:* **on** +QuotationAccepted
		r49: **on** +QuotationRejected
Power connection	*r50:* **on** +OfferAccepted ∧ CheckItemsNeeded(PowerConnection)=true	*r51:* **on** +PowerConnectionRequestCompleted
Request power connection	*r52:* **on** +PowerConnection	*r53:* **on** +PowerConnectionRequested
Confirm power connection	*r54:* **on** +PowerConnectionRequested	*r55:* **on** +PowerConnectionRequestConfirmed
Project transfer	*r56:* **on** +PowerConnectionRequestCompleted ∧ +OfferAccepted **if** CheckItemsNeeded(PowerConnection)=false	*r57:* **on** +ProjectTransferSO-DOP-PCompleted
Transfer project	*r58:* **on** +ProjectTransfer	*r59:* **on** +AcceptanceWorkPreparator
Change project status	*r60:* **on** +AcceptanceWorkPreparator	*r61:* **on** +StatusChanged

Table 9: Achieving and invalidating sentries of milestones in the SO-DOP-P GSM model

Milestone	Achieving sentries	Invalidating sentries
SO-DOP-PFinished	*r62:* **on** + ProjectTransferSO-DOP-PCompleted	*r63:* **on** +RequestClientCancelled
		r64: **on** +SO-DOP-P
RequestClientCancelled	*r65:* **on** E:ClientCancelled	*r66:* **on** +SO-DOP-PFinished
		r67: **on** +SO-DOP-P
PreparationFinished	*r68:* **on** +IntakeformFilledIn ∧ +ItemsNeededChecked ∧ +PlanningDefined ∧ +ProjectFolderCreated ∧ +CreditChecked	*r68:* **on** +Preparation
IntakeformFilledIn	*r69:* **on** C:DefineNeedsWithIntakeform	*r70:* **on** +DefineNeedsWithIntakeform
ItemsNeededChecked	*r71:* **on** C:CheckItemsNeeded	*r72* **on** +CheckItemsNeeded
PlanningDefined	*r71:* **on** C:DefinePlanning	*r71:* **on** +DefinePlanning
ProjectFolderCreated	*r73:* **on** C:CreateProjectFolder	*r74:* **on** +CreateProjectFolder
CreditChecked	*r75:* **on** C:CreditCheckClient	*r76:* **on** +CreditCheckClient
OfferAccepted	*r77:* **on** +LightCalculationApproved ∧ +DesignApproved ∧ +QuotationAccepted **if** CheckItemsNeeded(LightCalculation)=true ∧ CheckItemsNeeded(Design)=true	*r81:* **on** +Offer
	r78: **on** +LightCalculationApproved ∧ +QuotationAccepted **if** CheckItemsNeeded(LightCalculation)=true ∧ CheckItemsNeeded(Design)=false	
	r79: **on** +DesignApproved ∧ +QuotationAccepted **if**	

	CheckItemsNeeded(LightCalculation)=false ∧ CheckItemsNeeded(Design)=true	
	r80: **on** +QuotationAccepted **if** CheckItemsNeeded(LightCalculation)=false ∧ CheckItemsNeeded(Design)=false	
LightCalculationCreated	*r82:* **on** C:CreateLightCalculation	*r83:* **on** +CreateLightCalculation
		r84: **on** +RedefineOffer
		r85: **on** +LightCalculationDisapproved
LightCalculationSend	*r86:* **on** C:SendLightCalculation	*r87:* **on** +CreateLightCalculation **if** RedefineOffer
		r88: **on** +SendLightCalculation
		r89: **on** +LightCalculationDisapproved
LightCalculationApproved	*r88:* **on** E:LightCalculationApproved	*r89:* **on** +CreateLightCalculation **if** RedefineOffer
		r90: **on** +ApproveLightCalculation
		r91: **on** +LightCalculationDisapproved
LightCalculationDisapproved	*r92:* **on** E:LightCalculationDisapproved	*r93:* **on** +CreateLightCalculation **if** RedefineOffer
		r94: **on** +ApproveLightCalculation
		r95: **on** +LightCalculationApproved
DesignCreated	*r96:* **on** C:DesignCreated	*r97:* **on** +CreateDesign
		r98: **on** +RedefineOffer
		r99: **on** +DesignDisapproved
DesignSend	*r100:* **on** C:SendDesign	*r101:* **on** +CreateLightCalculation **if** RedefineOffer
		r102: **on** +SendDesign
		r103: **on** +DesignDisapproved
DesignApproved	*r104:* **on** E:DesignApproved	*r105:* **on** +CreateDesign **if** RedefineOffer
		r106: **on** +ApproveDesign
		r107: **on** +DesignDisapproved
DesignDisapproved	*r108:* **on** E:DesignDisapproved	*r109:* **on** +CreateDesign **if** RedefineOffer
		r110: **on** +ApproveDesign
		r111: **on** +DesignApproved
BudgetSet	*r112:* **on** C:SetBudget	*r113:* **on** +SetBudget
		r114: **on** +RedefineOffer
		r115: **on** +OfferDisapproved
QuotationCreated	*r116:* **on** C:CreateQuotation	*r117:* **on** +CreateQuotation

		r118: **on** +RedefineOffer
		r119: **on** +OfferDisapproved
OfferApproved	*r120:* **on** E:OfferApproved	*r121:* **on** +CreateQuotation **if** RedefineOffer
		r122: **on** +SetBudget **if** RedefineOffer
		r123: **on** +ApproveOffer
		r124: **on** +OfferDisapproved
OfferDisapproved	*r125:* **on** E:OfferDisapproved	*r126:* **on** +CreateQuotation **if** RedefineOffer
		r127: **on** +SetBudget **if** RedefineOffer
		r128: **on** +ApproveOffer
		r129: **on** +OfferApproved
QuotationSend	*r130:* **on** C:SendQuotation	*r131:* **on** +CreateQuotation **if** RedefineOffer
		r132: **on** +SendQuotation
QuotationAccepted	*r133:* **on** E:QuotationAccepted	*r134:* **on** +AcceptQuotation
		r135: **on** +QuotationRejected
QuotationRejected	*r136:* **on** E:QuotationRejected	*r137:* **on** +CreateQuotation **if** RedefineOffer
		r138: **on** +AcceptQuotation
		r139: **on** +QuotationAccepted
RedefineOffer	*r140:* **on** +QuotationRejected	*r141:* **on** +BudgetSet ∧ +QuotationCreated
PowerConnectionRequestCompleted	*r142:* **on** +PowerConnectionRequestConfirmed	*r143:* **on** +PowerConnection
PowerConnectionRequested	*r144:* **on** C:RequestPowerConnection	*r145:* **on** +RequestPowerConnection
PowerConnectionRequestConfirmed	*r146:* **on** C:ConfirmPowerConnection	*r147:* **on** +ConfirmPowerConnection
AcceptanceWorkPlanner	*r148:* **on** +StatusChanged ∧ +ProjectTransferred	*r149:* **on** +ProjectTransfer
ProjectTransferred	*r150:* **on** C:TransferProject	*r151:* **on** +TransferProject
StatusChanged	*r152:* **on** C:ChangeProjectStatus	*r153:* **on** +ChangeProjectStatus

G.2 SO-DOP-N

Table 10: Opening and terminating sentries of stages in the SO-DOP-N GSM model

Stages	Guards (opening sentries)	Terminating sentries
SO-DOP-N	*r1:* **on** E:ReceiveAssignment	*r2:* **on** +SO-DOP-NFinished
Define planning	*r3:* **on** +SO-DOP-N	*r4:* **on** +PlanningDefined
Set budget	*r5:* **on** +SO-DOP-N	*r6:* **on** +BudgetSet
Import unit prices	*r7:* **on** +SO-DOP-N	*r8:* **on** +UnitPricesImported
Change project status	*r9:* **on** +PlanningDefined ∧ +BudgetSet ∧ +UnitPricesImported	*r10:* **on** +StatusChanged

Table 11: Achieving and invalidating sentries of milestones in the SO-DOP-N GSM model

Milestone	Achieving sentries	Invalidating sentries
SO-DOP-NFinished	*r11:* **on** +StatusChanged	*r12:* **on** +SO-DOP-N
PlanningDefined	*r13:* **on** C:DefinePlanning	*r14:* **on** +DefinePlanning
BudgetSet	*r15:* **on** C:SetBudget	*r16:* **on** +SetBudget
UnitPricesImported	*r17:* **on** C:ImportUnitPrices	*r18:* **on** +ImportUnitPrices
StatusChanged	*r19:* **on** C:ChangeProjectStatus	*r20:* **on** +ChangeProjectStatus

G.3 P-/M-/N-Project

Table 12: Opening and terminating sentries of stages in the P-/M-/N-Project GSM models

Stages	Guards (opening sentries)	Terminating sentries
P-/M-/N-Project	*r1:* **on** E:ProjectCreation	*r2:* **on** +P-/M-/N-ProjectFinished
Work preparation	*r3:* **on** +P-/M-/N-Project	*r4:* **on** +WorkPreparationFinished
Execution	*r5:* **on** +WorkPreparationFinished	*r6:* **on** +ExecutionFinished
Administration	*r7:* **on** +ExecutionFinished	*r8:* **on** +AdministrationFinished

Table 13: Achieving and invalidating sentries of milestones in the P-/M-/N-Project GSM models

Milestone	Achieving sentries	Invalidating sentries
P-/M-/N-ProjectFinished	*r9:* **on** WorkPreparationFinished ∧ ExecutionFinished ∧ AdministrationFinished	*r10:* **on** +P-/M-/N-Project
WorkPreparationFinished	*r11:* **on** +ProjectTransferred [Work preparation]	*r12:* **on** +WorkPreparation
ExecutionFinished	*r13:* **on** +ProjectTransferred [Execution]	*r14:* **on** +Execution
AdministrationFinished	*r15:* **on** +ProjectTransferred [Administration]	*r16:* **on** +Administration

G.3.1 Work preparation

Table 14: Opening and terminating sentries of stages in the base 'Work preparation' GSM schema

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** +P-/M-/N-Project [P-/M-/N-Project]	*r2:* **on** +WorkPreparationFinished
Transfer	*r3:* **on** +WorkPreparation	*r4:* **on** +TranferFinished
Transfer budget to project	*r5:* **on** +Transfer	*r6:* **on** +BudgetTransferred
Transfer costs to project	*r7:* **on** +Transfer	*r8:* **on** +CostsTransferred
Transfer planning to project	*r9:* **on** +Transfer	*r10:* **on** +PlanningTransferred
Resources	*r11:* **on** +TransferFinished	*r12:* **on** +ResourcesFinished
Choose resources	*r13:* **on** +Resources	*r14:* **on** +ResourceChosen
Subcontractor	*r15:* **on** +ResourceChosen **if** ChooseResource = “Subcontractor” ∨ ChooseResource = “Both”	*r16:* **on** +SubcontractorFinished
Send tender	*r17:* **on** +Subcontractor **if** subcontractor amount >= €25.000,-	*r18:* **on** +TenderSent
Choose subcontractor	*r19:* **on** +Subcontractor **if** subcontractor amount < €25.000,- ∨ +TenderSent	*r20:* **on** +SubcontractorChosen
Edit budget	*r21:* **on** +SubcontractorChosen	*r22:* **on** +BudgetEdited
Own Resources	*r23:* **on** +ResourceChosen **if** ChooseResource = “Own Resources” ∨ ChooseResource = “Both”	*r24:* **on** +OwnResourcesFinished
RequestKlic	*r25:* **on** +OwnResources	*r26:* **on** +KlicRequested
		r27: **on** +KlicNA
ReceiveKlic	*r28:* **on** +KlicRequested	*r29:* **on** +KlicReceived
CreateWorkorder	*r30:* **on** +KlicReceived ∨ +KlicNA	*r31:* **on** +WorkorderCreated
Project Transfer	*r32:* **on** +ResourcesFinished	*r33:* **on** +ProjectTransferred
Transfer project	*r34:* **on** +ProjectTransfer	*r35:* **on** +AcceptanceExecutor
Change project status	*r36:* **on** +AcceptanceExecutor	*r37:* **on** +StatusChanged

Table 15: Achieving and invalidating sentries of milestones in the 'Work preparation' GSM schema

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r38:* **on** +ProjectTransferred	*r39:* **on** +WorkPreparation
TransferFinished	*r40:* **on** BudgetTransferred ∧ CostsTransferred ∧ Planning Transferred	*r41:* **on** +Transfer
BudgetTransferred	*r42:* **on** C:BudgetTransfer	*r43:* **on** +TransferBudgetToProject
CostsTransferred	*r44:* **on** C:CostsTransfer	*r45:* **on** +TransferCostsToProject
PlanningTransferred	*r46:* **on** C:PlanningTransfer	*r47:* **on** +TransferPlaninngToProject
ResourcesFinished	*r48:* **on** +SubcontractorFinished **if** ChooseResource = “Subcontractor”	*r51:* **on** +Resources
	r49: **on** +OwnResourcesFinished **if** ChooseResource = “OwnResources”	*r52:* **on** +Resources

	r50: **on** SubcontractorFinished ∧ OwnResourcesFinished	*r53:* **on** +Resources
ResourceChosen	*r54:* **if** ChooseResource = "Subcontractor" ∨ ChooseResource = "Own Resources" ∨ ChooseResource = "Both"	*r55:* **on** +ResourceChosen
SubcontractorFinished	*r56:* **on** TenderSent ∧ SubcontractorChosen ∧ BudgetEdited **if** subcontractor amount >= €25.000,-	*r58:* **on** +Subcontractor
	r57: **on** SubcontractorChosen ∧ BudgetEdited **if** subcontractor amount < €25.000,-	*r59:* **on** +Subcontractor
TenderSent	*r60:* **if** SendTender(Sent) = true	*r61:* **on** +SendTender
SubcontractorChosen	*r62:* **if** ChooseSubcontractor(Chosen) = true	*r63:* **on** +ChooseSubcontractor
BudgetEdited	*r64:* **if** EditBudget(Edited) = true	*r65:* **on** +EditBudget
OwnResourcesFinished	*r66:* **on** KlicRequisted ∧ KlicReceived ∧ WorkorderCreated	*r68:* **on** +OwnResources
	r67: **on** KlicNA ∧ WorkorderCreated	*r69:* **on** +OwnResources
KlicRequested	*r70:* **if** RequestKlic(Requested) = true	*r71:* **on** +RequestKlic
		r72: **on** +KlicNA
KlicNA	*r73:* **if** RequestKlic(NA) = true	*r74:* **on** +RequestKlic
		r75: **on** +KlicRequested
KlicReceived	*r76:* **if** ReceiveKlic(Received) = true	*r77:* **on** +ReceiveKlic
WorkorderCreated	*r78:* **on** C:CreateWorkorder	*r79:* **on** +CreateWorkorder
ProjectTransferred	*r80:* **on** AcceptanceExecutor ∧ StatusChanged	*r81:* **on** +ProjectTransfer
AcceptanceExecutor	*r82:* **if** TransferProject(Transferred) = true	*r83:* **on** +TransferProject
StatusChanged	*r84:* **if** Project status = "Uitvoering"	*r85:* **on** +ChangeProjectStatus

Table 16: Opening and terminating sentries of stages in the feature 'Transfer' in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Transfer	*r1:* **on** *orig*	*r2:* **on** *orig*
Transfer contract price to project	*r3:* **on** +Transfer	*r4:* **on** +ContractPriceTransferred
Set payment terms	*r5:* **on** +Transfer	*r6:* **on** +PaymentTermsSet

Table 17: Achieving and invalidating sentries of milestones in the feature 'Transfer' in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
TransferFinished	*r7:* **on** *orig* ∧ ContractPriceTransferred ∧ PaymentTermsSet	*r8:* **on** *orig*
ContractPriceTransferred	*r9:* **on** C:ContractPriceTransfer	*r10:* **on** +TransferContractPriceToProject
PaymentTermsSet	*r11:* **on** C:SetPaymentsTerms	*r12:* **on** +SetPaymentTerms

Table 18: Opening and terminating sentries of stages in the feature 'Mutation form' of the M-Project in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormGenerated	*r4:* **on** *orig*
Mutation form	*r5:* **on** +WorkPreparation	*r6:* **on** +MutationFormGenerated
Create mutation form	*r7:* **on** +MutationForm	*r8:* **on** +MutationFormCreated

Table 19: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the M-Project in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
MutationFormGenerated	*r13:* **on** +MutationFormCreated	*r14:* **on** +MutationForm
MutationFormCreated	*r15:* **if** CreateMutationForm(Created) = true	*r16:* **on** +CreateMutationForm

Table 20: Opening and terminating sentries of stages in the feature 'Mutation form' of the P-Project in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormGenerated **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Mutation form	*r7:* **on** +WorkPreparation **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +MutationFormGenerated
		r9: **on** +M-Project [M-Project]
Create mutation form	*r10:* **on** +MutationForm	*r11:* **on** +MutationFormCreated
		r12: **on** +M-Project [M-Project]

Table 21: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the P-Project in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r13:* **on** *orig*	*r14:* **on** *orig*
ProjectTransferred	*r15:* **on** *orig*	*r16:* **on** *orig*
MutationFormGenerated	*r17:* **on** +MutationFormCreated	*r18:* **on** +MutationForm
		r19: **on** +M-Project [M-Project]
MutationFormCreated	*r20:* **if** CreateMutationForm(Created) = true	*r21:* **on** +CreateMutationForm
		r22: **on** +M-Project [M-Project]

Table 22: Opening and terminating sentries of stages in the feature 'Materials' of the M-Project in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MaterialsFinished	*r4:* **on** *orig*
Materials	*r5:* **on** +WorkPreparation	*r6:* **on** +MaterialsFinished
Request materials	*r7:* **on** +Materials	*r8:* **on** +MaterialsRequested
Check availability materials	*r9:* **on** +MaterialsRequested	*r10:* **on** +AllMaterialsAvailable

Table 23: Achieving and invalidating sentries of milestones in the feature 'Materials' of the M-Project in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r11:* **on** *orig*	*r12:* **on** *orig*
ProjectTransferred	*r13:* **on** *orig*	*r14:* **on** *orig*
MaterialsFinished	*r15:* **on** +AllMaterialsAvailable	*r16:* **on** +Materials
MaterialsRequested	*r17:* **on** C:RequestMaterials	*r18:* **on** +RequestMaterials
AllMaterialsAvailable	r19: **on** +AvailabilityEnough [Materials]	*r18:* **on** +CheckAvailableMaterials

Table 24: Opening and terminating sentries of stages in the feature 'Materials' of the P-Project in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MaterialsFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Materials	*r7:* **on** +WorkPreparation **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +MaterialsFinished
		r9: **on** +M-Project [M-Project]
Request materials	*r10:* **on** +Materials	*r11:* **on** +MaterialsRequested
		r12: **on** +M-Project [M-Project]
Check availability materials	*r13:* **on** +MaterialsRequested	*r14:* **on** +AllMaterialsAvailable
		r15: **on** +M-Project [M-Project]

Table 25: Achieving and invalidating sentries of milestones in the feature 'Materials' of the P-Project in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r16:* **on** *orig*	*r17:* **on** *orig*
ProjectTransferred	*r18:* **on** *orig*	*r19:* **on** *orig*
MaterialsFinished	*r20:* **on** +AllMaterialsAvailable	*r21:* **on** +Materials
		r22: **on** +M-Project [M-Project]
MaterialsRequested	*r23:* **on** C:RequestMaterials	*r24:* **on** + RequestMaterials
		r25: **on** +M-Project [M-Project]
AllMaterialsAvailable	*r26:* **on** +AvailabilityEnough [Materials]	*r27:* **on** +CheckAvailableMaterials
		r28: **on** +M-Project [M-Project]

Table 26: Opening and terminating sentries of stages in the feature 'Client payment' in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ClientPaymentFinished	*r4:* **on** *orig*
Client payment	*r5:* **on** +WorkPreparation	*r6:* **on** +ClientPaymentFinished
Invoicing first part	*r7:* **on** +ClientPayment	*r8:* **on** +InvoicedAmountChecked

Table 27: Achieving and invalidating sentries of milestones in the feature 'Client payment' in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
ClientPaymentFinished	*r13:* **on** +InvoicedAmountChecked	*r14:* **on** +ClientPayment
InvoiceAmountChecked	*r15:* **if** InvoicingFirstPart(Correct) = true	*r16:* **on** +InvoicingFirstPart

Table 28: Opening and terminating sentries of stages in the feature 'Documents' in 'Work preparation'

Stages	Guards (opening sentries)	Terminating sentries
Work preparation	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ DocumentsFinished	*r4:* **on** *orig*
Documents	*r5:* **on** +WorkPreparation	*r6:* **on** +DocumentsFinished
Check presence of documents	*r7:* **on** +Documents	*r8:* **on** +PresenceDocumentsChecked
Check consequences	*r9:* **on** +PresenceDocumentsChecked	*r10:* **on** +ConsequencesChecked
Handling consequences	*r11:* **if** CheckConsequences(Poluted soil) = true ∨ CheckConsequences(V&G plan needed) = true ∨ CheckConsequences(Traffic barriers) = true	*r12:* **on** +ConsequencesHandled

Table 29: Achieving and invalidating sentries of milestones in the feature 'Documents' in 'Work preparation'

Milestone	Achieving sentries	Invalidating sentries
WorkPreparationFinished	*r13:* **on** *orig*	*r14:* **on** *orig*
ProjectTransferred	*r15:* **on** *orig*	*r16:* **on** *orig*
DocumentsFinished	*r17:* **on** +ConsequencesHandled	*r18:* **on** +Documents
	r19: **on** + ConsequencesChecked **if** CheckConsequences(Poluted soil) = false ∧ CheckConsequences(V&G plan needed) = false ∧ CheckConsequences(Traffic barriers) = false	*r20:* **on** +Documents ∨ CheckConsequences(Poluted soil) = true ∨ CheckConsequences(V&G plan needed) = true ∨ CheckConsequences(Traffic barriers) = true
ConsequencesHandled	*r21:* **if** Handling consequences(Handled) = true	*r22:* **on** +HandlingConsequences
ConsequencesChecked	*r23:* **on** C:CheckConsequences	*r24:* **on** +CheckConsequences
PresenceDocumentsChecked	*r25:* **on** C:PresenceDocumentsChecked	*r24:* **on** +CheckPresenceOfDocuments

G.3.2 Execution

Table 30: Opening and terminating sentries of stages in the base 'Execution' GSM schema

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** +WorkPreparationFinished	*r2:* **on** +ExecutionFinished
Resources	*r3:* **on** +Execution	*r4:* **on** +ResourcesFinished
Subcontractor	*r5:* **on** +Resources **if** ChooseResource [Work perparation] = "Subcontractor" ∨ ChooseResource [Work preparation] = "Both"	*r6:* **on** +SubcontractorFinished
Receive PV	*r7:* **on** +Subcontractor	*r9:* **on** +AllPVReceived
	r8: **on** +PVRejected	*r10:* **on** +AllPVReceived
Approve PV	*r11:* **if** number of PVs received > (number of PVs approved + number of PVs rejected)	*r12:* **on** +AllPVApproved
		r13: **on** +PVRejected
Create IOR and ION	*r14:* **if** number of PVs approved > number of IOR numbers ∨ number of PVs approved > number of ION numbers	*r15:* **on** +AllIORandIONCreated
Own Resources	*r16:* **on** +Resources **if** ChooseResource [Work perparation] = "Own Resources" ∨ ChooseResource [Work perparation] = "Both"	*r17:* **on** +OwnResourcesFinished
Executing work	*r18:* **on** +OwnResources	*r19:* **on** +WorkExecuted
	r20: **on** +WorkRejected	*r21:* **on** +WorkExecuted
Approve work	*r22:* **on** +WorkExecuted	*r23:* **on** +WorkApproved
		r24: **on** +WorkRejected
More/less work	*r25:* **on** +Resources	*r26:* **on** +MoreLessWorkFinished
Notification more/less work	*r27:* **on** +More/less work	*r28:* **on** +MoreLessWorkFinished
Approve more/less work	*r29:* **if** number of more/less work notifications > (number of more/less work approved + number of more/less work rejected)	*r30:* **on** + MoreLessWorkApprovementFinished
Project Transfer	*r31:* **on** ResourcesFinished ∧ MoreLessWorkFinished	*r32:* **on** +ProjectTransferred
Transfer project	*r33:* **on** +ProjectTransfer	*r34:* **on** +AcceptanceAdministration
Change project status	*r35:* **on** +AcceptanceAdministration	*r36:* **on** +StatusChanged

Table 31: Achieving and invalidating sentries of milestones in the 'Execution' GSM schema

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r37:* **on** +ProjectTransferred	*r38:* **on** +Execution
ResourcesFinished	*r39:* **on** +SubcontractorFinished **if** ChooseResource [Work preparation] = "Subcontractor"	*r42:* **on** +Resources
	r40: **on** +OwnResourcesFinished **if** ChooseResource [Work preparation] = "OwnResources"	*r43:* **on** +Resources
	r41: **on** SubcontractorFinished ∧ OwnResourcesFinished	*r44:* **on** +Resources

SubcontractorFinished	*r45:* **on** AllPVReceived ∧ AllPVApproved ∧ AllIORandIONCreated	*r46:* **on** +Subcontractor
AllPVReceived	*r47:* **if** ReceivePV(AllReceived) = true	*r48:* **on** +ReceivePV
AllPVApproved	*r49:* **if** number of PVs received = (number of PVs approved + number of PVs rejected)	*r50:* **on** +ApprovePV *r51:* **on** +PVRejected
PVRejected	*r52:* **on** +ReceivePV **if** number of PVs rejected > 0	*r53:* **on** +ApprovePV *r54:* **on** +AllPVApproved
AllIORandIONCreated	*r55:* **if** number of PVs approved = number of IOR numbers ∧ number of PVs approved = number of ION numbers	*r56:* **on** +CreateIORandION
OwnResourcesFinished	*r57:* **on** WorkExecuted ∧ WorkApproved	*r58:* **on** +OwnResources
WorkExecuted	*r59:* **if** ExecutingWork(AllExecuted) = true	*r60:* **on** +ExecutingWork
WorkApproved	*r61:* **if** AprroveWork(Approved) = true	*r62:* **on** +ApproveWork *r63:* **on** +WorkRejected
WorkRejected	*r64:* **if** AprroveWork(Rejected) = true	*r65:* **on** +ApproveWork *r66:* **on** +WorkApproved
MoreLessWorkFinished	*r67:* **on** +ResourcesFinished ∧ -ApproveMoreLessWork	*r68:* **on** +MoreLessWork
MoreLessWorkNotified	*r69:* **on** +ResourcesFinished	*r70:* **on** +NotificationMoreLessWork
MoreLessWorkApprovementFinished	*r71:* **if** number of more/less work notifications = (number of more/less work approved + number of more/less work rejected)	*r72:* **on** +ApproveMoreLessWork
ProjectTransferred	*r73:* **on** AcceptanceAdministration ∧ StatusChanged	*r74:* **on** +ProjectTransfer
AcceptanceAdministration	*r75:* **if** TransferProject(Transferred) = true	*r76:* **on** +TransferProject
StatusChanged	*r77:* **if** Project status = “Technisch gereed”	*r78:* **on** +ChangeProjectStatus

Table 32: Opening and terminating sentries of stages in the feature 'Materials' of the M-Project in 'Execution'

Stages	**Guards (opening sentries)**	**Terminating sentries**
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MaterialsFinished	*r4:* **on** *orig*
Materials	*r5:* **on** +Execution	*r6:* **on** +MaterialsFinished
Booking materials on project	*r7:* **on** +Materials	*r8:* **on** +AllMaterialsBookedOnProject
Resources	*r9:* **if** Percentage materials booked on project > 0	*r10:* **on** *orig*

Table 33: Achieving and invalidating sentries of milestones in the feature 'Materials' of the M-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r11:* **on** *orig*	*r12:* **on** *orig*
ProjectTransferred	*r13:* **on** *orig*	*r14:* **on** *orig*
MaterialsFinished	*r15:* **on** +AllMaterialsBookedOnProject	*r16:* **on** +Materials
AllMaterialsBookedOnProject	*r17:* **if** Percentage materials booked on project = 100	*r18:* **on** +BookingMaterialsOnProject
ResourcesFinished	r19: **on** *orig*	*r20:* **on** *orig*

Table 34: Opening and terminating sentries of stages in the feature 'Materials' of the P-Project in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MaterialsFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Materials	*r7:* **on** +Execution **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +MaterialsFinished
		r9: **on** +M-Project [M-Project]
Booking materials on project	*r10:* **on** +Materials	*r11:* **on** +AllMaterialsBookedOnProject
		r12: **on** +M-Project [M-Project]
Resources	*r13:* **if** Percentage materials booked on project > 0 ∧ –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r15:* **on** *orig*
	r14: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r16:* **on** *orig*

Table 35: Achieving and invalidating sentries of milestones in the feature 'Materials' of the P-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r17:* **on** *orig*	*r18:* **on** *orig*
ProjectTransferred	*r19:* **on** *orig*	*r20:* **on** *orig*
MaterialsFinished	*r21:* **on** +AllMaterialsBookedOnProject	*r22:* **on** +Materials
		r23: **on** +M-Project [M-Project]
AllMaterialsBookedOnProject	*r24:* **if** Percentage materials booked on project = 100 ∧ –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r25:* **on** +BookingMaterialsOnProject
		r26: **on** +M-Project [M-Project]
ResourcesFinished	*r27:* **on** *orig*	*r28:* **on** *orig*

Table 36: Opening and terminating sentries of stages in the feature 'Mutation form' of the M-Project in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormFinished	*r4:* **on** *orig*
Mutation form	*r5:* **on** ResourcesFinished ∧ MoreLessWorkFinished	*r6:* **on** +MutationFormFinished
Edit mutation form	*r7:* **on** +MutationForm	*r9:* **on** +MutationFormEdited
	r8: **on** +MutationRejected	*r10:* **on** +MutationFormEdited
Approve mutation form	*r11:* **on** +MutationFormEdited	*r12:* **on** +MutationFormApproved
		r13: **on** +MutationFormRejected

Table 37: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the M-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r14:* **on** *orig*	*r15:* **on** *orig*
ProjectTransferred	*r16:* **on** *orig*	*r17:* **on** *orig*
MutationFormFinished	*r18:* **on** +MutationFormApproved	*r19:* **on** +MutationForm
MutationFormEdited	*r20:* **if** EditMutationForm(Edited) = true	*r21:* **on** +EditMutationForm
MutationFormApproved	*r22:* **if** ApproveMutationForm(Approved) = true	*r23:* **on** +ApproveMutationForm
		r24: **on** +MutationFormRejected
MutationFormRejected	*r25:* **if** ApproveMutationForm(Rejected) = true	*r26:* **on** +ApproveMutationForm
		r27: **on** +MutationFormApproved

Table 38: Opening and terminating sentries of stages in the feature 'Mutation form' of the P-Project in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Mutation form	*r7:* **on** ResourcesFinished ∧ MoreLessWorkFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +MutationFormFinished
		r9: **on** +M-Project [M-Project]
Edit mutation form	*r10:* **on** +MutationForm	*r12:* **on** +MutationFormEdited
		r13: **on** +M-Project [M-Project]
	r11: **on** +MutationFormRejected	*r14:* **on** +MutationFormEdited
		r15: **on** +M-Project [M-Project]
Approve mutation form	*r16:* **on** +MutationFormEdited	*r17:* **on** +MutationFormApproved
		r18: **on** +MutationFormRejected
		r19: **on** +M-Project [M-Project]

Table 39: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the P-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
Execution	*r20:* **on** *orig*	*r21:* **on** *orig*
ProjectTransferred	*r22:* **on** *orig*	*r23:* **on** *orig*
MutationFormFinished	*r24:* **on** +MutationFormApproved	*r25:* **on** +MutationForm
		r26: **on** +M-Project [M-Project]
MutationFormEdited	*r27:* **if** EditMutationForm(Edited) = true	*r28:* **on** +EditMutationForm
		r29: **on** +M-Project [M-Project]
MutationFormApproved	*r30:* **if** ApproveMutationForm(Approved) = true	*r31:* **on** +ApproveMutationForm
		r32: **on** +MutationFormRejected
		r33: **on** +M-Project [M-Project]
MutationFormRejected	*r34:* **if** ApproveMutationForm(Rejected) = true	*r35:* **on** +ApproveMutationForm
		r36: **on** +MutationFormApproved
		r37: **on** +M-Project [M-Project]

Table 40: Opening and terminating sentries of stages in the feature 'More/less work' in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
More/less work	*r1:* **on** *orig*	*r2:* **on** *orig*
Processing more/less work	*r3:* **on** +MoreLessWorkApprovementFinished	*r4:* **on** +MoreLessWorkProcessed

Table 41: Achieving and invalidating sentries of milestones in the feature 'More/less work' in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
MoreLessWorkFinished	*r5:* **on** *orig* ∧ -ProcessingMoreLessWork	*r6:* **on** *orig*
MoreLessWorkProcessed	*r7:* **if** ProcessingMoreLessWork(Processed) = true	*r8:* **on** +ProcessingMoreLessWork

Table 42: Opening and terminating sentries of stages in the feature 'Client payment' in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ClientPaymentFinished	*r4:* **on** *orig*
Client payment	*r5:* **on** +Execution	*r6:* **on** +ClientPaymentFinished
Invoicing second part	*r7:* **on** +ClientPayment	*r8:* **on** +InvoicedAmountChecked

Table 43: Achieving and invalidating sentries of milestones in the feature 'Client payment' in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
ClientPaymentFinished	*r13:* **on** +InvoicedAmountChecked	*r14:* **on** +ClientPayment
InvoiceAmountChecked	*r15:* **if** InvoicingSecondPart(Correct) = true	*r16:* **on** +InvoicingSecondPart

Table 44: Opening and terminating sentries of stages in the feature 'Revision' in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ RevisionFinished	*r4:* **on** *orig*
Revision	*r5:* **on** ResourcesFinished ∧ MoreLessWorkFinished	*r6:* **on** +RevisionFinished
Receive revision	*r7:* **on** +Revision	*r9:* **on** +RevisionReceived
	r8: **on** +RevisionRejected	*r10:* **on** +RevisionReceived
Approve revision	*r11:* **on** +RevisionReceived	*r12:* **on** +RevisionApproved
		r13: **on** +RevisionRejected

Table 45: Achieving and invalidating sentries of milestones in the feature 'Revision' in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r14:* **on** *orig*	*r15:* **on** *orig*
ProjectTransferred	*r16:* **on** *orig*	*r17:* **on** *orig*
RevisionFinished	*r18:* **on** +RevisionApproved	*r19:* **on** +Revision
RevisionReceived	*r20:* **if** ReceiveRevision(Received) = true	*r21:* **on** +ReceiveRevision
RevisionApproved	*r22:* **if** ApproveRevision(Approved) = true	*r23:* **on** +ApproveRevision
		r24: **on** +RevisionRejected
MutationFormRejected	*r25:* **if** ApproveRevision(Rejected) = true	*r26:* **on** +ApproveRevision
		r27: **on** +RevisionApproved

Table 46: Opening and terminating sentries of stages in the feature 'WON form' in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ WONFormFinished	*r4:* **on** *orig*
WON-form	*r5:* **on** +RevisionFinished	*r6:* **on** +WONFormFinished
Create WON-form	*r7:* **on** +WONForm	*r8:* **on** +WONFormCreated

Table 47: Achieving and invalidating sentries of milestones in the feature 'WON form' in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
WONFormFinished	*r13:* **on** +WONFormCreated	*r14:* **on** +WONForm
WONFormCreated	*r15:* **if** CreateWONForm(Created) = true	*r16:* **on** +CreateWONForm

Table 48: Opening and terminating sentries of stages in the feature 'Project delivery' of the M-Project in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ProjectDelivered	*r4:* **on** *orig*
Project delivery	*r5:* **on** ResourcesFinished ∧ MoreLessWorkFinished	*r6:* **on** +ProjectDelivered
Make appointment	*r7:* **on** +ProjectDelivery	*r9:* **on** +AppointmentMade
	r8: **on** +PVORejected	*r10:* **on** +AppointmentMade
Approve PVO	*r11:* **on** +AppointmentMade	*r12:* **on** +PVOApproved
		r13: **on** +PVORejected

Table 49: Achieving and invalidating sentries of milestones in the feature 'Project delivery' of the M-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
ExecutionFinished	*r14:* **on** *orig*	*r15:* **on** *orig*
ProjectTransferred	*r16:* **on** *orig*	*r17:* **on** *orig*
ProjectDelivered	*r18:* **on** +PVOApproved	*r19:* **on** +ProjectDelivery
AppointmentMade	*r20:* **if** MakeAppointment(Made) = true	*r21:* **on** +MakeAppointment
PVOApproved	*r22:* **if** ApprovePVO(Approved) = true	*r23:* **on** +ApprovePVO
		r24: **on** +PVORejected
PVORejected	*r25:* **if** ApproveMutationForm(Rejected) = true	*r26:* **on** +ApprovePVO
		r27: **on** +PVOApproved

Table 50: Opening and terminating sentries of stages in the feature 'Project delivery' of the P-Project in 'Execution'

Stages	Guards (opening sentries)	Terminating sentries
Execution	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ProjectDelivered **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Project delivery	*r7:* **on** ResourcesFinished ∧ MoreLessWorkFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +ProjectDelivered
		r9: **on** +M-Project [M-Project]
Make appointment	*r10:* **on** +ProjectDelivery	*r12:* **on** +AppointmentMade
		r13: **on** +M-Project [M-Project]
	r11: **on** +PVORejected	*r14:* **on** +AppointmentMade
		r15: **on** +M-Project [M-Project]
Approve PVO	*r16:* **on** +AppointmentMade	*r17:* **on** +PVOApproved
		r18: **on** +PVORejected
		r19: **on** +M-Project [M-Project]

Table 51: Achieving and invalidating sentries of milestones in the feature 'Project delivery' of the P-Project in 'Execution'

Milestone	Achieving sentries	Invalidating sentries
Execution	*r20:* **on** *orig*	*r21:* **on** *orig*
ProjectTransferred	*r22:* **on** *orig*	*r23:* **on** *orig*
ProjectDelivered	*r24:* **on** +PVOApproved	*r25:* **on** +ProjectDelivery
		r26: **on** +M-Project [M-Project]
AppointmentMade	*r27:* **if** MakeAppointment(Made) = true	*r28:* **on** +MakeAppointment
		r29: **on** +M-Project [M-Project]
PVOApproved	*r30:* **if** ApprovePVO(Approved) = true	*r31:* **on** +ApprovePVO
		r32: **on** +PVORejected
		r33: **on** +M-Project [M-Project]
PVORejected	*r34:* **if** ApprovePVO(Rejected) = true	*r35:* **on** +ApprovePVO
		r36: **on** +PVOApproved
		r37: **on** +M-Project [M-Project]

G.3.3 Administration

Table 52: Opening and terminating sentries of stages in the base 'Administration' GSM schema

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** +ExecutionFinished [Execution]	*r2:* **on** +AdministrationFinished
Subcontractor	*r3:* **on** +Administration	*r4:* **on** +SubcontractorFinished
Receive invoice	*r5:* **on** +Subcontractor	*r7:* **on** +AllInvoicesReceived
	r6: **on** +InvoiceRejected	*r8:* **on** +AllInvoicesReceived
Approve invoice	*r9:* **if** amount invoices received > (amount invoices approved + amount invoices rejected)	*r10:* **on** +AllInvoicesApproved
		r11: **on** +InvoiceRejected
Payment subcontractor	*r12:* **if** amount invoices approved > (amount invoices approved + amount invoices rejected)	*r13:* **on** +AllInvoicesPaid
Project Transfer	*r14:* **on** SubcontractorFinished	*r15:* **on** +ProjectTransferred
Transfer project	*r16:* **on** +ProjectTransfer	*r17:* **on** +AcceptanceProjectController
Change project status	*r18:* +AcceptanceProjectController	*r19:* **on** +StatusChanged

Table 53: Achieving and invalidating sentries of milestones in the 'Administration' GSM schema

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r20:* **on** +ProjectTransferred	*r21:* **on** +Administration
SubcontractorFinished	*r22:* **on** AllInvoicesReceived ∧ AllInvoicesApproved ∧ AllInvoicesPaid	*r23:* **on** +Subcontractor
AllInvoicesReceived	*r24:* **if** Amount invoices received = amount IOR created	*r25:* **on** +ReceiveInvoice
AllInvoicesApproved	*r26:* **if** Amount invoices received = (amount invoices approved + amount invoices rejected)	*r27:* **on** +ApproveInvoice *r28:* **on** +InvoiceRejected
AllInvoicesPaid	*r29:* **if** Amount invoices approved = amount invoices paid	*r30:* **on** +PaymentSubcontractor
ProjectTransferred	*r31:* **on** AcceptanceProjectController ∧ StatusChanged	*r32:* **on** +ProjectTransfer
AcceptanceProjectController	*r33:* **if** TransferProject(Transferred) = true	*r34:* **on** +TransferProject
StatusChanged	*r35:* **if** Project status = “Administratief gereed”	*r36:* **on** +ChangeProjectStatus

Table 54: Opening and terminating sentries of stages in the feature 'Power connection' in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ PowerConnectionFinished	*r4:* **on** *orig*
Power connection	*r5:* **on** +Administration	*r6:* **on** +PowerConnectionFinished
Receive invoice	*r7:* **on** +PowerConnection	*r8:* **on** +AllInvoicesReceived
	r9: **on** +InvoiceRejected	*r10:* **on** +AllInvoicesReceived
Approve invoice	*r11:* **if** amount invoices received > (amount invoices approved + amount invoices rejected)	*r12:* **on** +AllInvoicesApproved *r13:* **on** +InvoiceRejected
Payment power connection	*r14:* **if** amount invoices approved > (amount invoices approved + amount invoices rejected)	*r15:* **on** +AllInvoicesPaid

Table 55: Achieving and invalidating sentries of milestones in the feature 'Power connection' in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r16:* **on** *orig*	*r17:* **on** *orig*
ProjectTransferred	*r18:* **on** *orig*	*r19:* **on** *orig*
PowerConnectionFinished	*r20:* **on** AllInvoicesReceived ∧ AllInvoicesApproved ∧ AllInvoicesPaid	*r21:* **on** +PowerConnection
AllInvoicesReceived	*r22:* **if** ReceiveInvoice(AllReceived) = true	*r23:* **on** +ReceiveInvoice
AllInvoicesApproved	*r24:* **if** Amount invoices received = (amount invoices approved + amount invoices rejected)	*r25:* **on** +ApproveInvoice *r26:* **on** +InvoiceRejected
AllInvoicesPaid	*r27:* **if** Amount invoices approved = amount invoices paid	*r28:* **on** +PaymentPowerConnection

Table 56: Opening and terminating sentries of stages in the feature 'Mutation form' of the M-Project in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormFinished	*r4:* **on** *orig*
Mutation form	*r5:* **on** +Administration	*r6:* **on** +MutationFormFinished
Processing mutation form	*r7:* **on** +MutationForm	*r8:* **on** +MutationFormProcessed

Table 57: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the M-Project in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
MutationFormFinished	*r13:* **on** +MutationFormProcessed	*r14:* **on** +MutationForm
MutationFormProcessed	*r15:* **if** ProcessingMutationForm(Processed) = true	*r16:* **on** +ProcessingMutationForm

Table 58: Opening and terminating sentries of stages in the feature 'Mutation form' of the P-Project in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ MutationFormFinished **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r5:* **on** *orig*
	r4: **on** *orig* **if** +M-Project [M-Project] ∨ +M-ProjectFinished [M-Project]	*r6:* **on** *orig*
Mutation form	*r7:* **on** +Adminstration **if** –M-Project [M-Project] ∧ –M-ProjectFinished [M-Project]	*r8:* **on** +MutationFormFinished
		r9: **on** +M-Project [M-Project]
Processing mutation form	*r10:* **on** +MutationForm	*r11:* **on** +MutationFormProcessed
		r12: **on** +M-Project [M-Project]

Table 59: Achieving and invalidating sentries of milestones in the feature 'Mutation form' of the P-Project in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r13:* **on** *orig*	*r14:* **on** *orig*
ProjectTransferred	*r15:* **on** *orig*	*r16:* **on** *orig*
MutationFormFinished	*r17:* **on** +MutationFormProcessed	*r18:* **on** +MutationForm
		r19: **on** +M-Project [M-Project]
MutationFormProcessed	*r20:* **if** ProcessingMutationForm(Processed) = true	*r21:* **on** +ProcessingMutationForm
		r22: **on** +M-Project [M-Project]

Table 60: Opening and terminating sentries of stages in the feature 'Lease' in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ LeaseFinished	*r4:* **on** *orig*
Lease	*r5:* **on** +Administration	*r6:* **on** +LeaseFinished
Activate costs for lease	*r7:* **on** +Lease	*r8:* **on** +AllCostsActivated

Table 61: Achieving and invalidating sentries of milestones in the feature 'Lease' in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r9:* **on** *orig*	*r10:* **on** *orig*
ProjectTransferred	*r11:* **on** *orig*	*r12:* **on** *orig*
LeaseFinished	*r13:* **on** +AllCostsActivated	*r14:* **on** +Lease
AllCostsActivated	*r15:* **if** costs on Project = 0	*r16:* **on** +ActivateCostsForLease

Table 62: Opening and terminating sentries of stages in the feature 'Client payment' in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ClientPaymentFinished	*r4:* **on** *orig*
Client payment	*r5:* **on** +Administration	*r6:* **on** +ClientPaymentFinished
Invoicing final part	*r7:* **on** +ClientPayment	*r8:* **on** +InvoicedAmountChecked
Payment	*r9:* **on** +InvoicedAmountChecked	*r10:* **on** +ClientPaid

Table 63: Achieving and invalidating sentries of milestones in the feature 'Client payment' in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r11:* **on** *orig*	*r12:* **on** *orig*
ProjectTransferred	*r13:* **on** *orig*	*r14:* **on** *orig*
ClientPaymentFinished	*r15:* **on** InvoicedAmountChecked ∧ ClientPaid	*r16:* **on** +ClientPayment
InvoiceAmountChecked	*r17:* **if** amount invoiced = (contract price + amount more/less work)	*r18:* **on** +InvoicingFinalPart
ClientPaid	*r19:* **if** amount paid = amount invoiced	*r20:* **on** +Payment

Table 64: Opening and terminating sentries of stages in the feature 'Grid operator payment' in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ GridOperatorPaymentFinished	*r4:* **on** *orig*
Grid operator payment	*r5:* **on** +Administration	*r6:* **on** +GridOperatorPaymentFinished
Invoicing final part	*r7:* **on** +GridOperatorPayment	*r8:* **on** +InvoicedAmountChecked
Payment	*r9:* **on** +InvoicedAmountChecked	*r10:* **on** +GridOperatorPaid

Table 65: Achieving and invalidating sentries of milestones in the feature 'Grid operator payment' in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r11:* **on** *orig*	*r12:* **on** *orig*
ProjectTransferred	*r13:* **on** *orig*	*r14:* **on** *orig*
GridOperatorPaymentFinished	*r15:* **on** InvoicedAmountChecked ∧ GridOperatorPaid	*r16:* **on** +GridOperatorPayment
InvoiceAmountChecked	*r17:* **if** amount invoiced = (contract price + amount more/less work)	*r18:* **on** +InvoicingFinalPart
GridOperatorPaid	*r19:* **if** amount paid = amount invoiced	*r20:* **on** +Payment

Table 66: Opening and terminating sentries of stages in the feature 'Project delivery' in 'Administration'

Stages	Guards (opening sentries)	Terminating sentries
Administration	*r1:* **on** *orig*	*r2:* **on** *orig*
Project Transfer	*r3:* **on** *orig* ∧ ProjectDelivered	*r4:* **on** *orig*
Project delivery	*r5:* **on** +Administration	*r6:* **on** +ProjectDelivered
Create PV	*r7:* **on** +ProjectDelivery	*r9:* **on** +PVCreated
	r8: **on** +PVandRevisionRejected	*r10:* **on** +PVCreated
Create TM	*r11:* **on** +PVCreated	*r12:* **on** +TMCreated
Make appointment	*r13:* **on** +TMCreated ∧ CreateTM(Created) = true	*r14:* **on** +AppointmentMade
	r15: **on** +TMRejected	*r16:* **on** +AppointmentMade
Approve TM	*r17:* **on** +AppointmentMade	*r18:* **on** +TMApproved
		r19: **on** +TMRejected
Provide PV and revision	*r20:* **on** +TMApproved	*r22:* **on** +PVandRevisionProvided
	r21: **if** CreateTM(N.A.) = true	*r23:* **on** +PVandRevisionProvided
Approve PV and revision	*r24:* **on** +PVandRevisionProvided	*r25:* **on** +PVandRevisionApproved
		r26: **on** +PVandRevisionRejected

Table 67: Achieving and invalidating sentries of milestones in the feature 'Project delivery' in 'Administration'

Milestone	Achieving sentries	Invalidating sentries
AdministrationFinished	*r27:* **on** *orig*	*r28:* **on** *orig*
ProjectTransferred	*r29:* **on** *orig*	*r30:* **on** *orig*
ProjectDelivered	*r31:* **on** +PVandRevisionApproved	*r32:* **on** +ProjectDelivery
PVCreated	*r33:* **if** CreatePV(Created) = true	*r34:* **on** +CreatePV
		r35: **on** +PVandRevisionRejected
TMCreated	*r36:* **if** CreateTM(Created) = true	*r37:* **on** +CreateTM
		r38: **on** +PVandRevisionRejected
AppointmentMade	*r39:* **if** MakeAppointment(Made) = true	*r40:* **on** +MakeAppointment
		r41: **on** +TMRejected
		r42: **on** +PVandRevisionRejected
TMApproved	*r43:* **if** ApproveTM(Approved) = true	*r44:* **on** +ApproveTM
		r45: **on** +TMRejected
		r46: **on** +PVandRevisionRejected
TMRejected	*r47:* **if** ApproveTM(Rejected) = true	*r48:* **on** +ApproveTM
		r49: **on** +TMApproved
		r50: **on** +PVandRevisionRejected
PVandRevisionProvided		*r52:* **on** +ProvidePVandRevision

	r51: **if** ProvidePVandRevision(Provided) = true	*r53:* **on** +PVandRevisionRejected
PVandRevisionApproved	*r54:* **if** ApprovePVandRevision(Approved) = true	*r55:* **on** +ProvidePVandRevision
		r56: **on** +PVandRevisionRejected
PVandRevisionApproved	*r57:* **if** ApprovePVandRevision(Rejected) = true	*r58:* **on** +ProvidePVandRevision
		r59: **on** +PVandRevisionApproved

G.4 Materials

Table 68: Opening and terminating sentries of stages in the Materials GSM model

Stages	Guards (opening sentries)	Terminating sentries
Materials	*r1:* **on** +MaterialsRequested [P-/M-Project]	*r2:* **on** +MaterialsFinished
Check availability materials	*r3:* **on** +Materials	*r4:* **on** +AvailablityEnough
		r5: **on** +AvailabilityNotEnough
Order materials	*r6:* **on** +AvailabilityNotEnough	*r7:* **on** +MaterialsOrdered
		r8: **on** +MaterialsEnough
Confirm order	*r9:* **if** OrderMaterials(IOR nr) > 0	*r10:* **on** +OrdersConfirmed
		r11: **on** +MaterialsEnough
Set delivery date	*r12:* **if** OrderMaterials(IOR nr) > 0	*r13:* **on** +DeliveryDatesSet
		r14: **on** +MaterialsEnough
Delivering materials	*r15:* **if** OrderMaterials(IOR nr) > 0	*r16:* **on** +MaterialsDelivered
		r17: **on** +MaterialsEnough

Table 69: Achieving and invalidating sentries of milestones in the Materials GSM model

Milestone	Achieving sentries	Invalidating sentries
MaterialsFinished	*r18:* **on** +MaterialsEnough	*r19:* **on** +Materials
AvailablityEnough	*r20:* **if** amount available >= amount requested	*r21:* **on** +CheckAvailabilityMaterials
		r22: **on** +AvailabilityNotEnough
AvailablityNotEnough	*r23:* **if** amount available < amount requested	*r24:* **on** +CheckAvailabilityMaterials
		r25: **on** +AvailabilityEnough
OrdersConfirmed	*r26:* **if** all E:Confirmations are true	*r27:* **on** +ConfirmOrders
DeliveryDatesSet	*r28:* **if** all delivery dates are not empty	*r29:* **on** +SetDeliveryDate
MaterialsDelivered	*r30:* **on** +AvailabilityEnough	*r29:* **on** +Delivering materials

G.5 Main project

Table 70: Opening and terminating sentries of stages in the Main Project GSM model

Stages	Guards (opening sentries)	Terminating sentries
Main project	*r1:* **on** E:ProjectCreation	*r2:* **on** +MainProjectFinished
P-Project	*r3:* **on** +P-Project [P-Project]	*r4:* **on** +P-ProjectFinished [P-Project]
Work preparation (P-Project)	*r5:* **on** +WorkPreparation [P-Project]	*r6:* **on** +WorkPreparationFinished [P-Project]
Execution (P-Project)	*r7:* **on** +Execution [P-Project]	*r8:* **on** +ExecutionFinished [P-Project]
Administration (P-Project)	*r9:* **on** +Administration [P-Project]	*r10:* **on** +AdministrationFinished [P-Project]
M-Project	*r11:* **on** +M-Project [M-Project]	*r12:* **on** +M-ProjectFinished [M-Project]
Work preparation (M-Project)	*r13:* **on** +WorkPreparation [M-Project]	*r14:* **on** +WorkPreparationFinished [M-Project]
Execution (M-Project)	*r15:* **on** +Execution [M-Project]	*r16:* **on** +ExecutionFinished [M-Project]
Administration (M-Project)	*r17:* **on** +Administration [M-Project]	*r18:* **on** +AdministrationFinished [M-Project]
N-Project	*r19:* **on** +P-Project [N-Project]	*r20:* **on** +N-ProjectFinished [N-Project]
Work preparation (N-Project)	*r21:* **on** +WorkPreparation [N-Project]	*r22:* **on** +WorkPreparationFinished [N-Project]
Execution (N-Project)	*r23:* **on** +Execution [N-Project]	*r24:* **on** +ExecutionFinished [N-Project]
Administration (N-Project)	*r25:* **on** +Administration [N-Project]	*r26:* **on** +AdministrationFinished [N-Project]
Materials	*r27:* **on** +Materials [Materials]	*r28:* **on** +MaterialsFinished [Materials]
Evaluating	*r29:* **on** MaterialsFinished ∧ N-ProjectFinished ∧ M-ProjectFinished ∧ P-ProjectFinished	*r30:* **on** +Evaluated

Table 71: Achieving and invalidating sentries of milestones in the Main Project GSM model

Milestone	Achieving sentries	Invalidating sentries
MainProjectFinished	*r31:* **on** +Evaluated	*r32:* **on** +Mainproject
P-ProjectFinished	*r33:* **on** +P-ProjectFinished [P-Project]	*r34:* **on** +P-Project [P-Project]
M-ProjectFinished	*r35:* **on** +M-ProjectFinished [M-Project]	*r36:* **on** +M-Project [M-Project]
N-ProjectFinished	*r37:* **on** +N-ProjectFinished [N-Project]	*r38:* **on** +N-Project [N-Project]
WorkPreparationFinished (P-Project)	*r39:* **on** +WorkPreparationFinished [P-Project]	*r40:* **on** +WorkPreparation [P-Project]
ExecutionFinished (P-Project)	*r41:* **on** + ExecutionFinished [P-Project]	*r42:* **on** +Execution [P-Project]
AdministrationFinished (P-Project)	*r43:* **on** + AdministrationFinished [P-Project]	*r44:* **on** +Administration [P-Project]
WorkPreparationFinished (M-Project)	*r45:* **on** +WorkPreparationFinished [M-Project]	*r46:* **on** +WorkPreparation [M-Project]

ExecutionFinished (M-Project)	*r47:* **on** +ExecutionFinished [M-Project]	*r48:* **on** +Execution [M-Project]
AdministrationFinished (M-Project)	*r49:* **on** +AdministrationFinished [M-Project]	*r50:* **on** +Administration [M-Project]
WorkPreparationFinished (N-Project)	*r51:* **on** +WorkPreparationFinished [N-Project]	*r52:* **on** +WorkPreparation [N-Project]
ExecutionFinished (N-Project)	*r53:* **on** +ExecutionFinished [N-Project]	*r54:* **on** +Execution [N-Project]
AdministrationFinished (N-Project)	*r55:* **on** +AdministrationFinished [N-Project]	*r56:* **on** +Administration [N-Project]
MaterialsFinished	*r57:* **on** +MaterialsFinished [Materials]	*r58:* **on** +Materials [Materials]
Evaluated	*r59:* **on** Evaluating(Evaluated) = true	*r60:* **on** +Evaluating

Appendix H

H.1 Risk management in SO-DOP-P

This section assigns risks to stages of the SO-DOP-P GSM model. The SO-DOP-P GSM model consists of 20 atomic stages distributed over 4 non-atomic stages. The SO-DOP-P certainly contains risk due to the fact that in this phase the client has not agreed on anything yet, so the client can cancel the project anytime he/she wants. Mitigate these risks is most of the time the best optional as we can see in this section.

H.1.1 Define needs with intake form

The risk in the stage *Define needs with intake form* is that the engineer does not fill the intake form with the client, which results in not having a physical indication of the needs of the client. Money could be wasted by performing unnecessary tasks and the quality of the project could be damaged by not knowing the exact needs of the client. This risk has a very high probability and a medium impact. The risk response defined for this risk, is to add this risk to a checklist to decrease the probability. Therefore, the checkbox *Defined* is implemented in the tool within this stage. The sensor is triggered when the checkbox *Defined* is not checked, while the milestones *ItemsNeededChecked* or *PlanningDefined* are already reached. The engineer is responsible for controlling this risk.

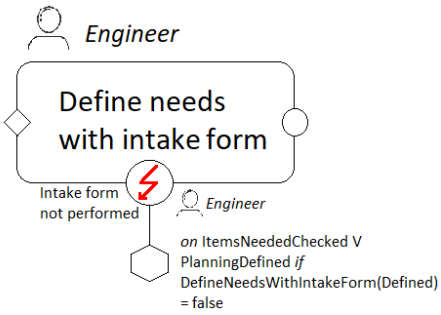

Figure 50: Risk integrated in stage 'Define needs with intake form' within 'SO-DOP-P'

H.1.2 Create project folder

There is a risk that the project folder is forgotten by the engineer to create. This has a high impact on the quality of the project. Data objects will not be in the shared environment and stakeholders in the project all have a piece of information about the project, but when this information is not shared, the quality of the project suffers. The probability is almost zero, due to the fast notability of not having a project folder. The corresponding risk response is risk mitigation by adding this risk to a checklist to decrease the probability, even though the probability is already is almost zero, but the impact is not changeable. The checkbox *Created* is implemented within this stage to make sure the project folder is created by the engineer. The sensor of this risk is triggered when the *Offer* stage is already open or the milestone *OfferAccepted* is already reached, while the checkbox *Created* in the *Create project folder* stage is not checked.

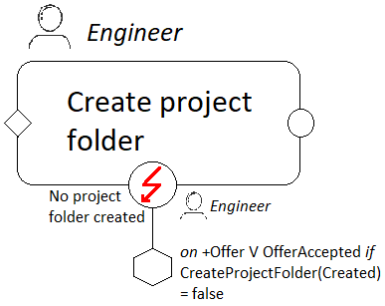

Figure 51: Risk integrated in stage 'Create project folder' within 'SO-DOP-P'

H.1.3 Credit check client

The credit check is added in the model as avoid strategy for the risk that the client will not pay the invoice. The risk is brought forward to the process for earlier risk response when needed. Sooner or later, the client needs to pay the invoice, but the postponement by the client of paying invoices has a negative impact on the cashflow of the organization of CityTec. The probability of this risk is low. Only 11% of the invoices are paid after the due

date. The impact is also low, because it only influence the cashflow of the organizition. The risk response to avoid this risk, is to perform a credit check. The outstanding amount of the client to CityTec is added to the tool to make the engineers aware of the trustability of a client. Two checkboxes are added in this stage. One to indicate that the client is trustable and one to indicate that the client is not trustable. When the debit amount is too high according to the engineer, the checkbox *Not trusted* is checked. This triggers the finance department to collect the open invoices before the new project continues. Even though the engineer performs the *Credit check client* stage, the finance department is the risk owner for the risk that the client does not pay the invoice. The finance department is responsible for the payment by the client. The sensor is triggered when the *Offer* stage is already open or the milestone *OfferAccepted* is already reached, while the checkbox *Trusted* in the *Credit check client* stage is not checked. The risk corresponding to this sensor does not immediately occur, but the risk is increased when the *Credit check client* stage is not performed.

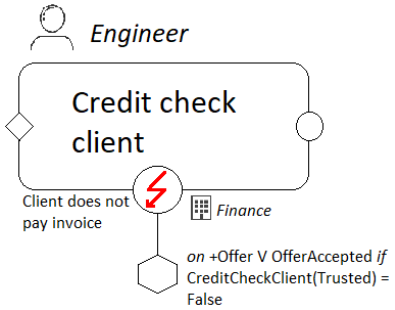

Figure 52: Risk integrated in stage 'Credit check client' within 'SO-DOP-P'

H.1.4 Approve light calculation

There are two risks in the *Approve light calculation* stage. Only the risk that the client forgets to approve the light calculation is implemented in the R-GSM model. The risk that the light calculation is not approved, has a acceptance strategy. The disapprovement is indicated via the *Disapproved* milestone, but no actions could be taken to avoid or mitigate this risk. When the light calculation is disapproved due to a change by the client in the project plan, the futile hours could be charged. This is not part of the current contract and requires an escalation strategy. Therefore, this risk is not part of the R-GSM model.

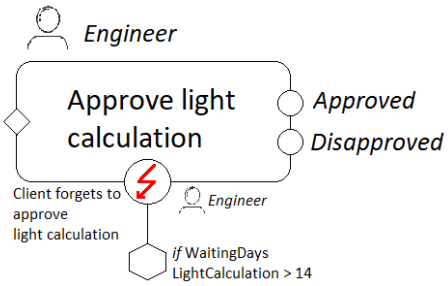

Figure 53: Risk integrated in stage 'Approve light calculation' within 'SO-DOP-P'

The risk that the client forgets to approve the light calculation has a medium probability and a low impact. The risk response is to mitigate this risk by adding a trigger to contact the client after 2 weeks. Therefore, the sensor of this risk is triggered after 14 days. When the client has not responsed after 14 days, the risk becomes active. The engineer is the risk owner of this risk, so when this risk becomes active, the engineer is responsible to contact the client for a quick response.

H.1.5 Approve design

The risks in the stage *Approve design* are the same as in the stage *Approve light calculation* except that the client forgets to approve or disapproves the design instead of the light calculation. The risk that the design is not approved, has the same strategy as in the *Approve light calculation* stage. The risk that the client forgets to approve the design has a medium probability and a low impact. The client has 2 weeks to respond to the proposed design. After these 2 weeks, the sensor is triggered and the risk becomes active. The engineer is again responsible to contact the client for a response when the risk becomes active.

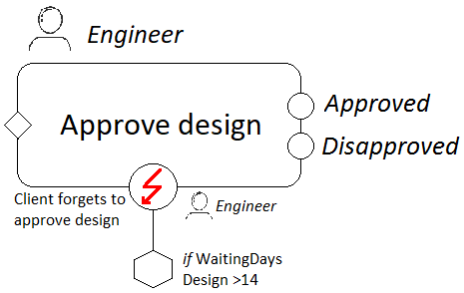

Figure 54: Risk integrated in stage 'Approve design' within 'SO-DOP-P'

H.1.6 Approve offer

There are several risks within the stage *Approve offer*. The two risks with respect to the budget are the risk that not all materials are included in the budget and the risk that not all labor is included in the budget. The risk that not materials are included has a medium probability with a very high impact, while the risk that not all labor is included in the budget has a low probability with a low impact. The same risks correspond to the quotation. The probability of the risk that materials are not included in the quotation and the risk that labor is not included in the quotation, are the same as the risks in the budget. The impact for the risks in the quotation are a little bit higher than the impact for the risks in the budget, due to the fact that the price in the quotation is higher than the price for the same thing in the budget. All these risks are combined into one risk because these risks are triggered by the same sensor condition. The sensor is triggered when the quotation is sent to the client while the offer is not approved by the region manager. The region manager is responsible for this risk. The region manager needs to check if everything is included in the budget and quotation which are compiled by the engineer. This four-eyes principle reduces the probability that mistakes are made in the budget and quotation.

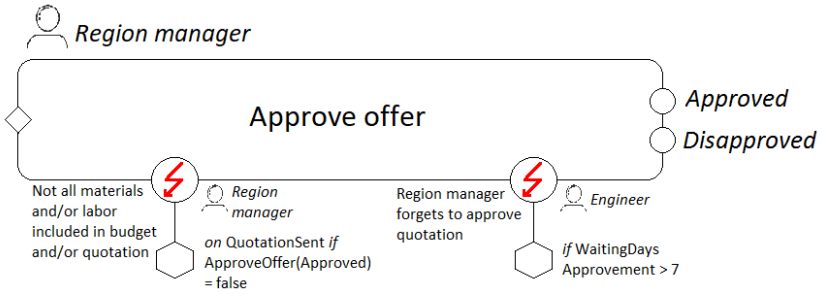

Figure 55: Risk integrated in stage 'Approve offer' within 'SO-DOP-P'

Another risk in the *Approve offer* stage is the risk that the region manager forgets to approve the quotation. The region manager checks the budget and quotation and when everything is correct, the region manager signs the quotation for approval. Unnecessary time is lost when the region manager forgets to approve the offer. The probability of this risk is very low and the impact is also very low. The region manager has 7 days to approve the offer before the sensor is triggered. When the sensor is triggered, the risk becomes active. The engineer is responsible for solving this risk by contact the region manager for a quick response.

H.1.7 Approve quotation

The stage *Approve quotation* has the risk that the client does not respond within the validity of the quotation. The client has 30 days to accept the quotation. The probability of this risk low and the impact is high. The impact is high because price changes by the subcontractor, supplier and grid operator that are not take into account in the quotation, have a high impact on the profit margin of a project. Most of the time, the client response within the 30 days, but when the client does not respond within these 30 days, the sensor of this risk is triggered and the risk becomes active. The risk owner of this risk is the engineer. The engineer creates a new version of the quotation where all prices are updated. The old version is not valid anymore and the engineer contacts the client with the new version as final attempt to accept the project.

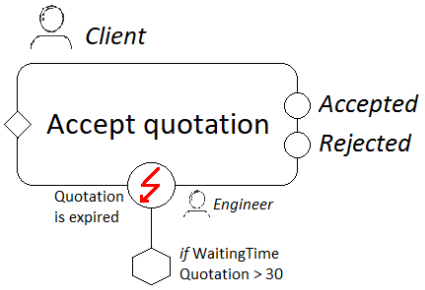

Figure 56: Risk integrated in stage 'Approve quotation' within 'SO-DOP-P'

H.1.8 Request power connection

In the stage *Request power connection* is the risk present that the engineer forgets to request the power connection. This risk has a very low probability and a low impact on the schedule of the project. The sensor of this risk is triggered when the *Requested* checkbox is not checked and a power connection request is needed according to the *Check items needed* stage, while the *Project transfer* stage is open or the *ProjectTransferred* milestone is reached. The sensor activates the risk and the engineer is the risk owner of this risk. The engineer is responsible for the mitigation of this risk.

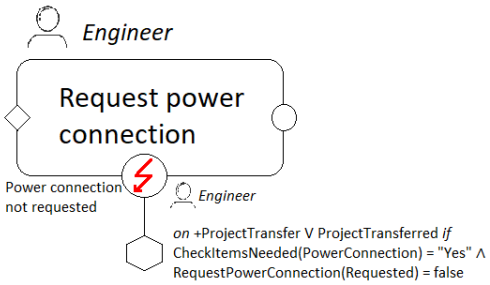

Figure 57: Risk integrated in stage 'Request power connection' within 'SO-DOP-P'

H.1.9 Change project status

The risk in the stage *Change project status* is not analyzed during the process of identifying risks. This is due to the fact that this risk is not a direct risk for the project itself, but a risk for the pollution of the ERP system. When the SO-DOP-P is not closed in the ERP system, the data about the open SO-DOP-Ps gets polluted. The managing board forecasts future financial flows according to this data. These forecasts are not correct if these SO-DOP-Ps are not closed. Therefore, the risk is implemented in the *Change project status* stage. The sensor is triggered when a P-Project or M-Project is created, while the status of the related SO-DOP-P is still open. The project controller is responsible for the status of the projects and SO-DOPs.

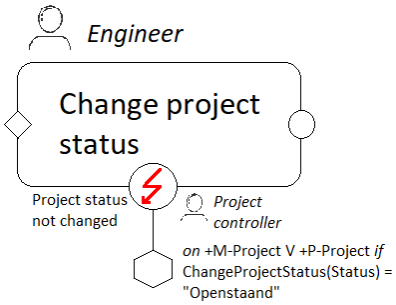

Figure 58: Risk integrated in stage 'Change project status' within 'SO-DOP-P'

H.2 Risk management in SO-DOP-N

There are no risks identified with regards to the SO-DOP-N. The SO-DOP-N is only created for importing the unit prices provided by the grid operator, the underlying budget which is already predefined for each activity, and importing the planning. After this data is imported in the ERP system, a N-Project is created and the SO-DOP-N is closed. The only risk in the SO-DOP-N is in the *Change project status* stage.

H.2.1 Change project status

The stage *Change project status* has the only risk of the SO-DOP-N. This risk is not a direct risk for the project itself, but for the pollution of the ERP system. The need for this risk integration, is the same as risk in the *Change project status* of the SO-DOP-P. The differences are the actor of the stage and the condition of the sensor. The actor of this stage is the work preparator and sensor is triggered by the creation of the N-Project.

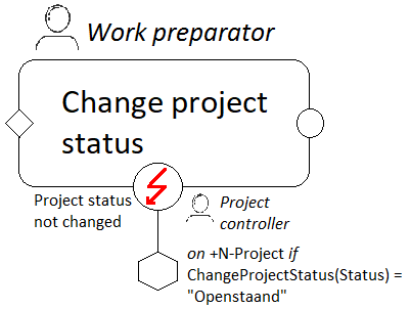

Figure 59: Risk integrated in stage 'Change project status' within 'SO-DOP-N'

H.3 Risk management in P-/M-/N-Project

The risks in the projects of CityTec are separated in the risks in the *Work preparation* stage, *Execution* stage and *Administration* stage. Risk will be managed in both the base model of these stages as the corresponding features of these stages.

H.3.1 Work preparation

The *Work preparation* stage is part of the P-Project, M-Project and N-Project. The work preparation consists of a base model and additional features. The base model has 3 non-atomic stages and is expanded with the additional features depending on the project type. The risk within the base model of the work preparation and the related features are integrated in this section.

H.3.1.1 Transfer budget to project

The risk in the *Transfer budget to project* stage is that the budget is incorrect transferred from the SO-DOP. This means that the established budget in the SO-DOP is not transferred in the correct way to the project. This budget is established in the SO-DOP and should be the same as the budget provided in the project. Otherwise, the predefined profit margin is affected by the change in the budget. In the old situation, this risk was not insight because the transition from the SO-DOP to the project was only insightful for the project controller. In the R-GSM model, the risk that the budget is incorrect transferred is controlled. The sensor is triggered when the budget of the project does not correspond with the related SO-DOP. When the sensor is triggered, the risk becomes active. The work preparator is the risk owner of this risk. The work preparator is responsible for the detection and the solution of this risk.

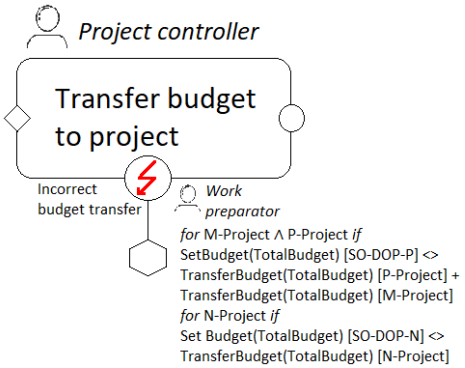

Figure 60: Risk integrated in stage 'Transfer budget to project' within 'Work preparation'

H.3.1.2 Transfer costs to project

The risk in the *Transfer costs to project* stage is the same risk as the risk in the *Transfer budget to project* stage. The project controller needs to transfer the costs made in the SO-DOP to the project. This risk was also not insight in the old situation. The R-GSM integrates this risk in the *Transfer costs to project* stage to make the work preparator aware of this risk. The sensor of this risk is triggered when there are still costs booked on the SO-DOP, while the SO-DOP is connected to a project. The sensor activates the risk and the work preparator is responsible for the detection and solution of this risk.

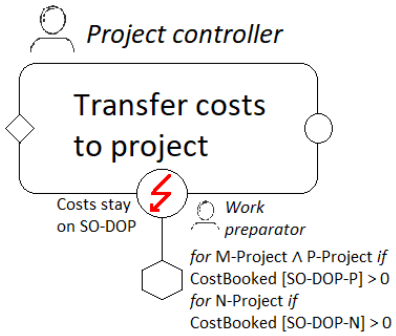

Figure 61: Risk integrated in stage 'Transfer costs to project' within 'Work preparation'

H.3.1.3 Transfer planning to project

The planning could be changed during the project. Therefore, the transfer of the planning is not a risk on its own, but the risk in the *Transfer planning to project* stage is that the planning of the projects differs from each other. All project types within a main project are executed at the same time. Risk in the project schedule is triggered when the planning of the projects are not the same. The planner is responsible for the synchronization of the planning between different project types.

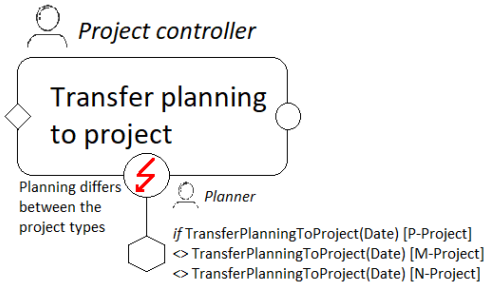

Figure 62: Risk integrated in stage 'Transfer planning to project' within 'Work preparation'

H.3.1.4 Edit budget

The *Edit budget* stage contains the risk of not editing the budget based on the subcontractor's specific prices. This risk has a very high probability and a low impact. The prices difference between the subcontractors is on average 4.7%. Therefore, it is important to edit the budget with the specific prices of the chosen subcontractor to have a better prediction of the budget. The sensor of this risk is triggered when the subcontractor is chosen for the execution for this project and the checkbox *Edited* in the stage *Edit budget* is not checked, while the *Project transfer* stage is opened or even when the *ProjectTransferred* is already reached. The work preparator is the risk owner of this risk. The work preparator is responsible for the correct execution of this stage.

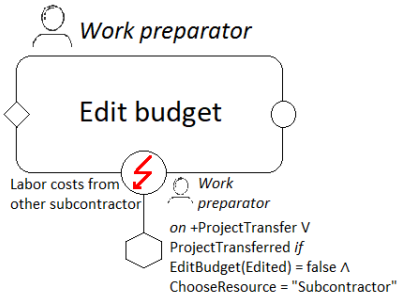

Figure 63: Risk integrated in stage 'Edit budget' within 'Work preparation'

H.3.1.5 Create work order

The stage *Create work order* has the risk that work orders are generated, while the project is executed by the subcontractor. The mechanic should not be scheduled for a project that is executed by the subcontractor only. This causes too many internal hours of the mechanic on the project because these hours are booked on the project, but are not included in the budget. In the stage *Create work order* is only the risk of too many internal hours by the mechanic applicable, which is only a part of main risk. The main risk has a very high probability and a high impact. The internal hours are not monitored in the old situation and often causes the budget to be exceeded. This risk is integrated in the stage *Create work order* in the R-GSM model. The sensor of this risk is triggered when the subcontractor is chosen in the *Choose resource* stage and the number of work orders are higher than zero. This means that a mechanic is scheduled, while the subcontractor is responsible for the execution of the project. The region manager is responsible for the risk, even though the work preparator performs this stage. The region manager is responsible for all internal hours booked on the project.

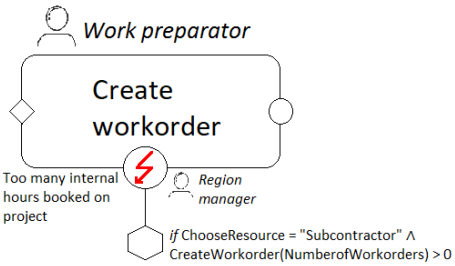

Figure 64: Risk integrated in stage 'Create work order' within 'Work preparation'

H.3.1.6 Transfer contract price to project

The risk in the stage *Transfer contract price to project* is the incorrect transfer of the contract price. Like the other transfer stages, the risk is a system risk. The project controller transfers the contract price from the SO-DOP to the project. In the old situation, the project controller was the only actor who has this stage insight. In the R-GSM model, the risk of an incorrect transfer of the contract price is added to the stage. The work preparator is the risk owner of this risk. The sensor is triggered when the price in the project not respond with the price in the SO-DOP. If the sensor condition holds, the risk becomes active. The work preparator is responsible for this risk and needs to take action to solve this risk.

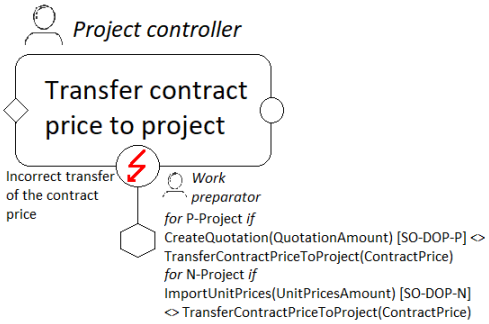

Figure 65: Risk integrated in stage 'Transfer contract price to project' within 'Work preparation'

H.3.1.7 Create mutation form

Risk in the *Create mutation form* is the risk that no mutation form is created. The probability of this risk is low and the impact high. The mutation form can be created in the M-Project and P-Project. The impact of this risk is higher on the M-Project than the P-Project, because the objects in the M-Project are leased and if there is no mutation created about these object, the objects cannot be processed in the system. The sensor condition of this risk is when the checkbox *Created* in the stage *Create mutation form* is not checked, while the

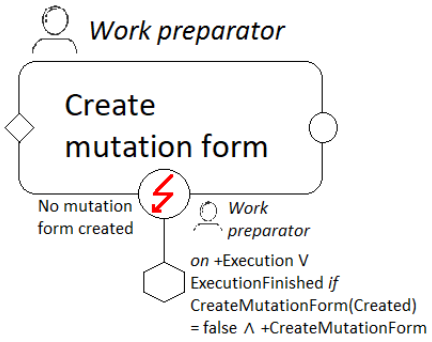

Figure 66: Risk integrated in stage 'Create mutation form' within 'Work preparation'

Execution stage is opened or the milestone *ExecutionFinished* is already reached. The condition that the stage *Create mutation form* needs to be opened is added to ensure that the risk is only triggered when the mutation form is part of the project type.

H.3.1.8 Request materials

The risk of requesting too much or too less material is part of the *Request materials* stage in the R-GSM model. This risk has a medium probability and a medium impact on the project objectives. The materials are requested by the work preparator, but when too less materials are requested, the remaining materials need to be requested in a later state of the project. This affect the schedule of the project. Vice versa when too much materials are requested, the cost objective of the project is affected. The sensor of this risk is triggered when the sum of the quantity materials requested is not equal to the sum of the quantity materials in the budget. The risk is activated when the sensor condition holds. The work preparator is the risk owner who is responsible for this risk. The work preparator changes this request or the budget when this risk occurs.

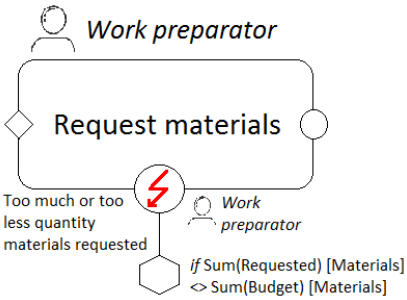

Figure 67: Risk integrated in stage 'Request materials' within 'Work preparation'

H.3.1.9 Invoicing first part

The stage *Invoicing first part* consists of the risk that the finance department forgets to invoice the client during the project. The first invoice is most of the time the highest percentage of the contract price. This risk has a high probability and a medium impact. CityTec has some cash flow problems, so the impact of this risk is not only lost interest and investment opportunities, but also the payment of the creditors. When the suppliers are not paid, the supplier could stop delivering products to CityTec, which influence other projects.

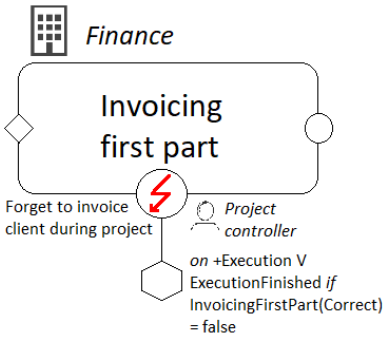

Figure 68: Risk integrated in stage 'Invoicing first part' within 'Work preparation'

The risk response for this risk is to add a checkbox. Therefore, the checkbox *Correct* is added to the *Invoicing first part* stage. The sensor of this risk is triggered when the checkbox *Correct* is not checked, while the *Execution* stage is open or the milestone *ExecutionFinished* is even been reached. The project controller is responsible for this risk. The project controller is triggered by this risk to contact the finance department for the first invoice.

H.3.1.10 Check presence of documents

The risk that not all documents are provided by the grid operator occurs in the *Check presence of documents* which is only part of the N-Project. The grid operator needs to provide a design, permit and soil investigation when these apply. This stage is part of to the R-GSM model to let the work preparator check if the required documents are provided. The probability of this risk is low and the impact is very low. The work preparator contacts the grid operator if not all documents are available that are needed in the project. The sensor of this risk is triggered when the *Execution* stage is open or when the milestone *ExecutionFinished* is reached, while the milestone *PresenceDocumentsChecked* is not reached yet. The work preparator makes sure that this check is performed because the work preparator is responsible for this risk.

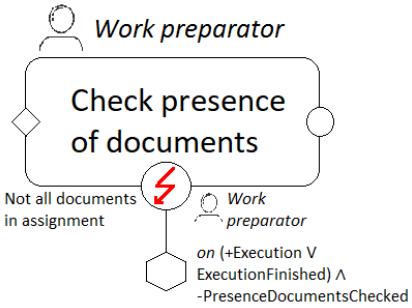

Figure 69: Risk integrated in stage 'Check presence of documents' within 'Work preparation'

H.3.1.11 Handling consequences

The stage *Handling consequences* consists of two risks. One of these risks is that the soil is contaminated. This entails extra costs for the execution of the project. The risk strategy for this risk is to transfer these costs to the client. The probability of this risk is almost nil, but the impact is in the category very high. The sensor of this risk is triggered when the soil is contaminated and the checkbox *Handled* is not checked in the stage *Handling consequences*.

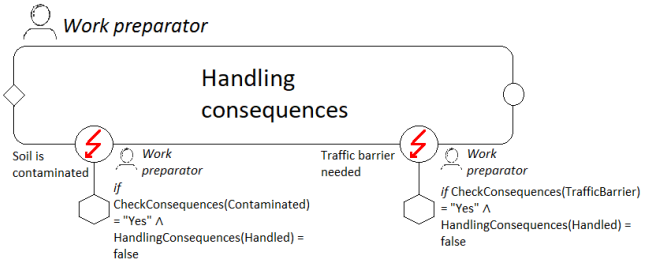

Figure 70: Risk integrated in stage 'Handling consequences' within 'Work preparation'

The other risk in this stage is that traffic barriers are needed. This also entails extra costs for the execution of the project. The risk strategy is also to transfer these costs to the client. The probability of this risk is low and the impact of this is risk is medium. The sensor of this risks is triggered when traffic barriers are needed and the checkbox *Handled* is not checked in the stage *Handling consequences*. The work preparator is the risk owner for both risks and ensures that the extra costs are presented as more work.

H.3.2 Execution

The execution is part of the P-Project, M-Project and N-Project. The execution is constructed of a base model and additional features. The base model consists of three non-atomic stages. Features are added to this model to compose the complete GSM model. The risks in this phase are risks that occur during the execution of the project. This section integrates these risk in the GSM schemas to come up with the R-GSM model for the execution stage.

H.3.2.1 Create IOR and ION

The stage *Create IOR and ION* is intended to visualize the number of the IOR and ION numbers created. These IOR and ION numbers corresponds to the number of PVs approved in the previous stage. The risk exists that the PV is not booked on the right project. The *Create IOR and ION* stage is present in the R-GSM to make sure that the PVs received for a project, are also booked on the right project. The risk has a medium probability and a low impact. The sensor of this risk is triggered when the number of approved PVs becomes lower than the number of IOR numbers created. When this condition holds, the risk that a PV is not booked on the right project, becomes active. The risk owner of this risk is the executor. The executor is responsible for the next steps. The executor contacts the project controller, who can transfer the costs of the subcontractor to the right project.

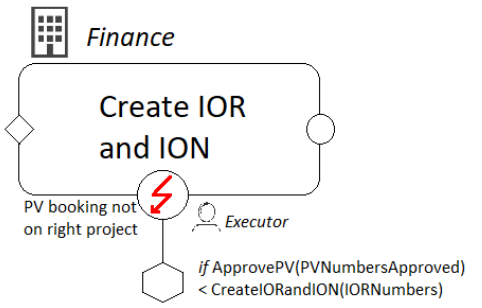

Figure 71: Risk integrated in stage 'Create IOR and ION' within 'Execution'

H.3.2.2 Approve more/less work

The risk in the *Approve more/less work* is that work is executed without the approval of the client or grid operator. The client or grid operator needs to approve the more or less w ork before the realization. They could also disapprove the more or less work and the costs made or time lost are the consequences for CityTec. Therefore, the approval is needed before the more or less work is performed. The probability of this risk medium and the impact is high. The risk response for this risk is to add this risk to the checklist. Hence, the stage *Approve more/less work* is part of the R-GSM and provides the number of approvals for more/less work to make sure that the more or less work is only performed when the approval is available. The sensor of this risk is triggered when the *Resource* stage is finished and the more or less work is not approved. If the condition holds, the risk becomes active and the executor contacts the client for fast response.

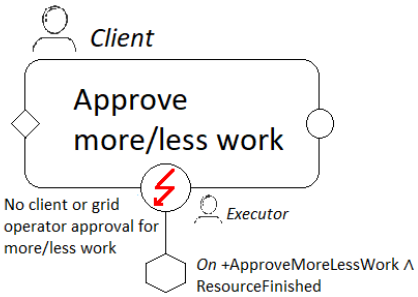

Figure 72: Risk integrated in stage 'Approve more/less work' within 'Execution'

H.3.2.3 Booking materials on project

The risk in the *Booking materials on project* stage is that materials are booked on the project while these materials are not intended for this project. The percentage booked is calculated by dividing the sum of the quantity materials requested by the sum of the quantity materials booked on the project. The sensor of this risk is triggered when this percentage is above the 100%. This means that there are more materials booked on the project than materials requested. The warehouse worker has booked the materials to the wrong project for which these materials where intended. The executor is

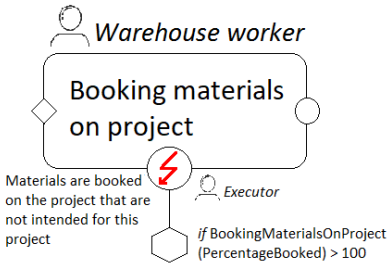

Figure 73: Risk integrated in stage 'Booking materials on project' within 'Execution'

responsible for detection and solving this risk by contacting the project controller, who transfers the materials in the system to the right project.

H.3.2.4 Approve mutation form

The stage *Approve mutation form* contains the risk of having the wrong data in the mutation form. This stage is part of the R-GSM model to let the executor check the mutation form before the mutation form is processed. The sensor of this risk is triggered when the project is transferred to the administration, while the checkbox *Approved* in the stage *Approve mutation form* is not checked yet. This data is especially important when the mutation form is part of the M-Project, because this data is used for the lease. The mutation form needs to be check by the executor to mitigate this risk. The risk owner is also the executor. The executor is responsible for the risk if this risk occurs and needs to take action to solve this risk.

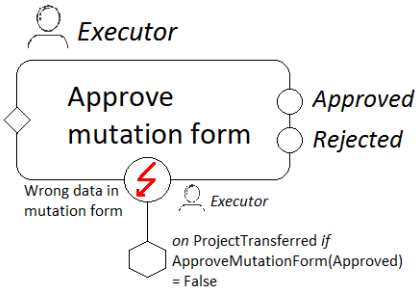

Figure 74: Risk integrated in stage 'Approve mutation form' within 'Execution'

H.3.2.5 Processing more/less work

More or less work is notified and accepted by the client or grid operator in the stages before the *Processing more/less work* stage. These stage are not part of the old situation, but are part of the model for earlier detection of more or less work. The *Processing more/less work* stage contains the risk that the more or less work is not booked on the project in the ERP system. This has as consequence that the last invoice does not include these costs. This risk is only part of the P-Project and the N-Project, because the more or less work on the M-Project is not invoiced but is part of the lease construction. The impact of this risk is high and the probability is very high. Therefore, it is important that this stage is completed before the project is transferred to the administration. The risk sensor is triggered when the project is transferred, while the checkbox *All processed* is not checked and the number of more or less work approved by the client or grid operator is more than zero. The executor needs to solve this risk by ensuring that all more or less work is processed in the system.

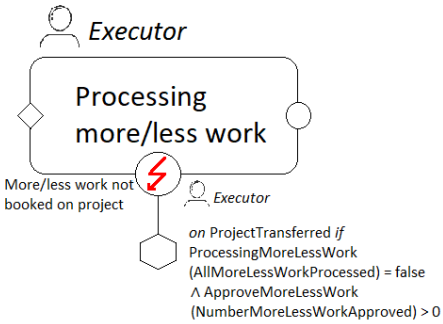

Figure 75: Risk integrated in stage 'Processing more/less work' within 'Execution'

H.3.2.6 Invoicing second part

The stage *Invoicing second part* contains the risk that the finance department forgets to invoice during the project. This is the same risk as in the work preparation, but now for the second invoice. The second invoice is most of the time lower than the first invoice or even skipped. Due to the cash flow problems of CityTec, this risk is becoming an important risk to mitigate. The probability of this risk decreases by letting this stage be a part of the R-GSM model. Therefore,

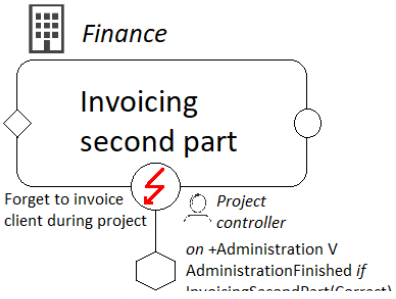

Figure 76: Risk integrated in stage 'Invoicing second part' within 'Execution'

the checkbox *Correct* and the invoiced percentage are added to this stage to make the actors aware of invoice status of the project. The sensor of this risk is triggered when the checkbox *Correct* is not checked, while the *Administration* stage is open or the milestone *AdministrationFinished* is even been reached. The project controller is the risk owner of this risk. The project controller is triggered by this risk to contact the finance department for the second invoice.

H.3.2.7 Approve PVO

The project needs to be approved and delivered to the client. The stage *Approve PVO* is part of the R-GSM to ensure that the project is approved and transmitted to the client. The risk in this stage is that the project is not delivered to the client. The consequence is that the last invoice including the more or less work, cannot be send. Therefore, the risk is marked as having a high impact and a low probability. The risk is triggered when the project is transferred, while the checkbox *Approved* in the stage *Approve PVO* is not checked. The risk owner of this risk is the executor. The executor is responsible for the project delivery and needs to take action when this risk occurs.

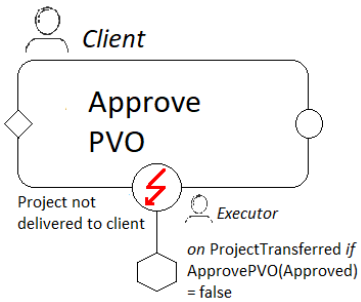

Figure 77: Risk integrated in stage 'Approve PVO' within 'Execution'

H.3.2.8 Create WON form

The WON form is created by the executor to visualize the performed activities to the project controller. The risk in the stage *Create WON form* is that the WON form could contain wrong activities. This stage is therefore part of the R-GSM model to make sure that the WON form is created. This risk has a medium probability and impact. The risk strategy for this risk is to mitigate this risk. This is performed by ensuring that the WON form is created and make it easier accessible for the project controller to control the activities. The sensor of this risk is triggered when the project is transferred, while the checkbox *Created* is not check in the stage *Create WON form.* The risk owner of this risk is the project controller. The project controller address the risk to the executor if this risk occurs.

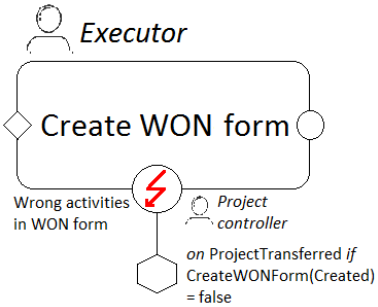

Figure 78: Risk integrated in stage 'Create WON form' within 'Execution'

H.3.3 Administration

After the execution comes the administration. The administration is part of the P-Project, M-Project and N-Project. The administration consists of a base model with additional features. The base model of the administration phase consists of two non-atomic models. Six features are established that could be added to the base model to make the complete model depending on the project type. This section provides the integrated risks in the administration phase.

H.3.3.1 Approve invoice subcontractor

The stage *Approve invoice* in the non-atomic stage *Subcontractor* contains two risks. One of these risk is that the price is changed by the subcontractor, which means that the costs booked on the project by the subcontractor are higher than the costs predicted in the budget. The subcontractor have his prices indexed ones a year. The average indexing is 2.93% over the past ten years, which has a low impact on the project objectives. The average project duration between the project creation until the project is executed is 174 days, which corresponds to a high probability.

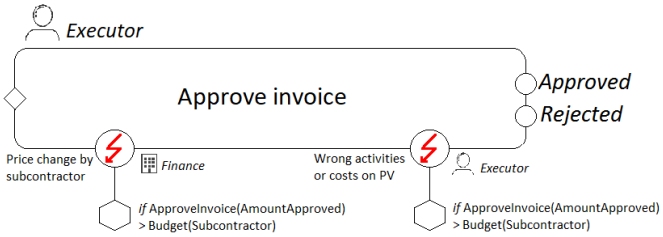

Figure 79: Risk integrated in stage 'Approve invoice' of subcontractor within 'Administration'

The other risk in the stage *Approve invoice* in the non-atomic stage *Subcontractor* is the risk that the wrong activities or costs are booked on the PV. The prices of the subcontractor booked on the project do not correspond with the prices of the subcontractor in the budget. This risk has a medium probability and a very low impact on the project objectives.

The sensor of these risks are the same. Both risk are triggered when the costs of the subcontractor exceeds the budget for the subcontractor in the budget. The risk owner for the risk that the prices of the subcontractor are changed, is the finance department. The finance department is responsible for the correct prices in the ERP system. The risk owner of the risk that wrong activities are booked on the PV is the executor. The executor is responsible for the activities that the subcontractor books on the project and needs to take action if these activities are not the same as the activities in the budget.

H.3.3.2 Payment subcontractor

After the *Approve invoice* stage of the subcontractor, the invoices are paid. The risk in the *Payment subcontractor* stage is that the project is closed without having all invoices paid. The invoices of the subcontractor cannot be booked on the project after the project is closed. The invoice ends as a write-off for the organization. The trigger of this risk is when the project is transferred to the project controller, while the amount paid to the subcontractor is lower than the amount in the IOR orders created for the subcontractor in this project. The IOR orders are created in the execution phase of the project and this amount should correspond to the amount accepted as invoice and paid to the subcontractor. The risk owner of this risk is the project controller. The project controller is responsible for the project transfer and needs to check all payments are made to the subcontractor.

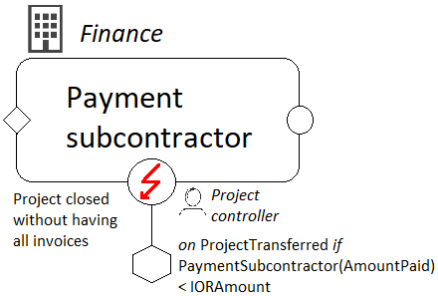

Figure 80: Risk integrated in stage 'Payment subcontractor' within 'Administration'

H.3.3.3 Approve invoice power connection

The invoice of the power connection requested in the SO-DOP-P is approved in the stage *Approve invoice power connection*. The executor approves this invoice in this stage. This stage contains the risk that the grid operator has increase the price of the power connections. The grid operator changes their price ones every year. The price increase is on average 10% every year, which has a high impact on the project objectives. The duration between the quotation to the client and the offer for the project connection request, is on average 2 months. Therefore, the risk has a medium probability. The sensor of the risk is triggered when the amount in the invoice is greater than the amount in the budget. The risk owner is the finance department, who is responsible for the prices in the ERP system.

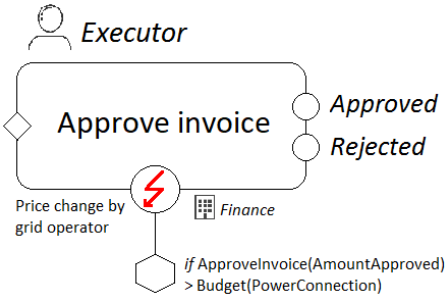

Figure 81: Risk integrated in stage 'Approve invoice' of power connection within 'Administration'

H.3.3.4 Payment power connection

The invoice for the power connection is paid after the invoice is approved in the previous stage. The risk in the stage *Payment power connection* is the same as the risk in the stage *Payment subcontractor.* In this stage is also the risk that the project is closed without having all invoices received and paid to the grid operator. The sensor of this risk differs from the subcontractor stage. There is no IOR order created for the invoice of the grid operator. Therefore, a checkbox *All received* is created in the *Receive invoice* stage of the power connection. The checkbox is added to ensure that all invoices are received for the project. The sensor of this risk is triggered when this checkbox is not checked and the project is transferred or when the amount approved is greater than the amount paid. The risk owner of this risk is the project controller. The project controller is responsible for the transfer of the project and needs to check if this risk has occured.

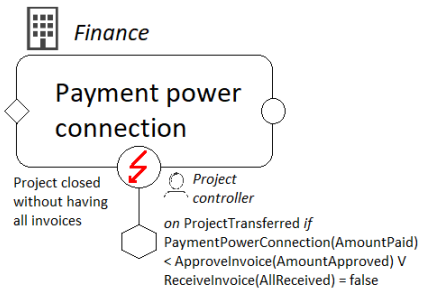

Figure 82: Risk integrated in stage 'Payment power connection' within 'Administration'

H.3.3.5 Processing mutation form

The mutation form created in the work preparation phase and edited in the execution phase, is processed in the ERP system in the stage *Processing mutation form.* The risk in this stage is that the mutation form is not sent to the asset management department. Processing the mutation form in the system is especially important in the M-Project for the lease construction. Therefore, the impact of this risk is high, while the probability is very low. The risk is triggered when the project is transferred to the project controller, while the checkbox *Processed* in the stage *Processing mutation form* is not checked. The executor is the risk owner of this risk. The executor is responsible that the mutation form of his project is sent and processed in the system.

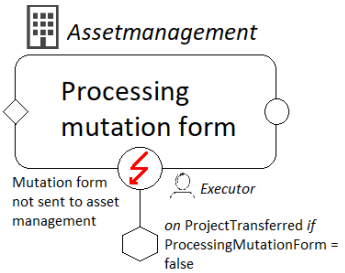

Figure 83: Risk integrated in stage 'Processing mutation form' within 'Administration'

H.3.3.6 Activate costs for lease

The stage *Activate costs for lease* contains the risk of not activating the costs. The consequence of this risk is that these costs are not part of the assets of the organization. These costs need to be added to the balance sheet, otherwise the financial status of CityTec may be endangered. The risk is triggered when there are still costs on the M-Project after the project is transferred to the project controller. The risk owner of this risk is the project controller. The project controller is responsible for the transfer of the project and needs to check if this risk has occurred.

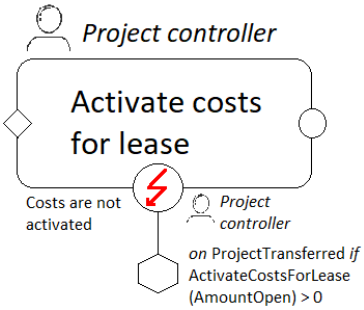

Figure 84: Risk integrated in stage 'Activate costs for lease' within 'Administration'

H.3.3.7 Invoicing final part to client

The *Invoicing final part* stage in the non-atomic stage *Client payment* is the last phase of the client payment. The last invoice to the client is sent in this stage. The risk within this stage is the risk of not including the more or less work in the last invoice. Revenue is lost when the last invoice is not performed correctly. This risk has a low probability but a high impact on the project objectives. In 6% of the projects in the past 2 years is the more or less work forgotten in the final invoice. The sensor of this risk gets triggered when the percentage invoiced is lower than 100%. The percentage invoiced is established by dividing the amount invoiced by the sum of the contract price and the amount of the more or less work. The risk owner of this risk is project controller, who needs to check if this risk has occurred when the project is transferred.

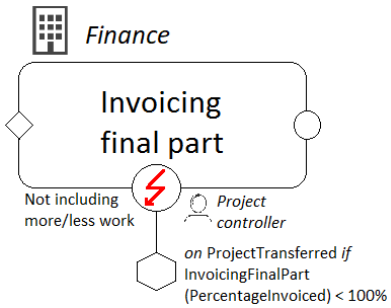

Figure 85: Risk integrated in stage 'Invoicing final part' of the client within 'Administration'

H.3.3.8 Payment client

The client needs to pay the invoice within 30 days after the invoice is sent. The risk in the *Payment* stage in the non-atomic stage *Client payment* is that the client does not pay the invoice within these 30 days. Only 11% of the invoices in the past 2 years are not paid within the 30 days, which corresponds to a low probability. The impact is low due to the fact that the impact has only effect on the cash flow of the organization. The *Credit check client* stage is already added to the R-GSM as avoid strategy to prevent that projects are performed for untrusted clients. The mitigate strategy for this risk in the *Payment* stage, is that a reminder is sent to the client. The sensor of this risk is triggered when the 30 days to pay the invoice have been exceeded. The risk owner of this risk is the finance department. The finance department is responsible for the payment by the client and needs the contract the client if the payment terms of 30 days have been exceeded.

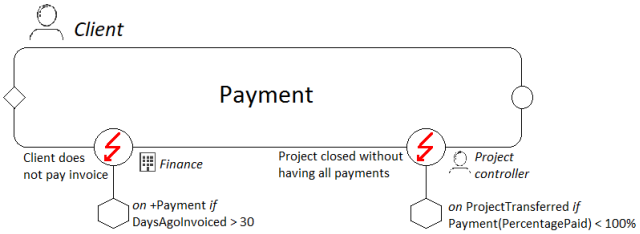

Figure 86: Risk integrated in stage 'Payment' of the client within 'Administration'

Another risk in this stage is the risk of closing the project without having all payments. When the project is closed without having all payments, the forgotten invoices are a lost in the project. Therefore, the impact of this risk is very high. Luckily, the probability of this risk is low. The sensor of this risk is triggered when the project is transferred, while the percentage paid of the contract price and the more or less work, is below 100%. The project controller is risk owner of this risk and is responsible for this risk if this risk occurs.

H.3.3.9 Invoicing final part to grid operator

The risk in the stage *Invoice final part* in the non-atomic stage *Grid operator payment*, is the same as the stage in the non-atomic stage *Client payment.* The grid operator is now the one where the invoice needs to be sent to. The grid operator is most of the time only invoices after the project is executed. The final part of the invoice is therefore the full invoice of the project including the more or less work. This stage is only part of the N-Project, which is the project for the change in the underground infrastructure. The sensor of this risk gets triggered when the percentage invoiced is lower than 100%. The percentage invoiced is established by dividing the amount invoiced by the sum of the contract price and the amount of the more or less work. The risk owner of this risk is project controller, who needs to check if this risk has occurred when the project is transferred.

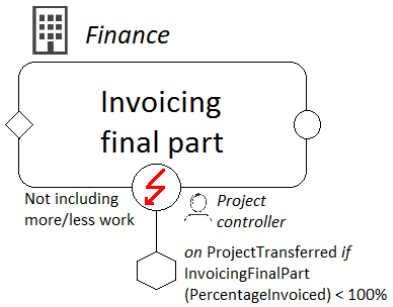

Figure 87: Risk integrated in stage 'Invoicing final part' of the grid operator within 'Administration'

H.3.3.10 Payment grid operator

The grid operator is only invoiced ones at the end of the project. This means that the payment is also at ones. The stage *Payment* in the non-atomic stage *Grid operator payment* contains two risks. The first risk is that the grid operator does not pay the invoice within the 30 days. This has only an impact on the cash flow of CityTec. The probability of this risk is low. The sensor of this risks gets triggered when the 30 days to pay the invoice have been exceeded. The risk owner is the finance department, who sends a reminder to the grid operator when this risk occurs.

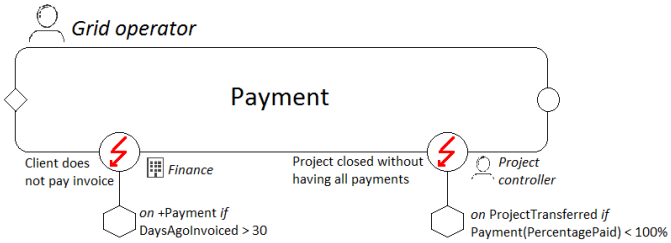

Figure 88: Risk integrated in stage 'Payment' of the grid operator within 'Administration'

The second risk in this *Payment* stage, is the risk of closing the project without having all payments. This is the same risk as the risk in the *Payment* stage of the non-atomic *Client payment* stage. The sensor is also triggered when the project is transferred, while the percentage paid of the contract price and the more or less work, is below 100%. The project controller is risk owner of this risk and is responsible for this risk if this risk occurs.

H.3.3.11 Approve TM

The grid operator needs to approve the TM when there are more than ten activities in the assignment. The TM is signed by the grid operator for the technical approval of the project. The risk in the stage *Approve TM* is that the project is not technically approved when needed. The probability of this stage is low and this risk has a medium impact if this risk occurs. The stage is part of the R-GSM to ensure that this stage is performed by the executor. The sensor is triggered when the TM is created and the TM is not approved by the grid operator, while the project is PV and revision is provided by the supply chain manager to the grid operator. The risk owner of this risk is the executor. The executor is responsible for this risk if this risk occurs.

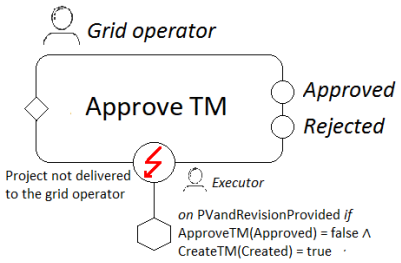

Figure 89: Risk integrated in stage 'Approve TM' within 'Administration'

H.3.3.12 Approve PV and revision

The stage *Approve PV and revision* is intended for the administrative approval of the grid operator. This stage is part of the R-GSM model to ensure that the grid operator approves the PV and revision before the project is closed. The risk in this stage is the same as the risk in the *Approve TM* only the project delivery is now the administrative approval instead of the technical approval. The sensor of this risk is triggered when the project is transferred to the project controller, while the checkbox *Approved* in the stage *Approve PV and revision* is not checked. The project controller is the risk owner because the project controller is responsible for the transfer of the project and needs to check if this risk has occurred.

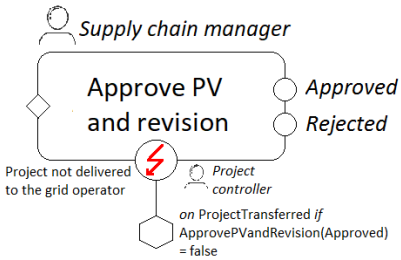

Figure 90: Risk integrated in stage 'Approve PV and revision' within 'Administration'

H.4 Risk management in Materials

The materials are separated from the projects because this process is centrally controlled, while the projects are regionally controlled. The materials phase consists of five atomic stages. In this section, risks are integrated in these atomic stages.

H.4.1 Order materials

The *Order materials* stage is performed by the purchase and logistics department. The risk in this stage is that the purchase and logistics department does not order the materials when needed. The work preparator creates a materials request and the purchase and logistics department needs to ordered the materials which are not enough in inventory in this stage. The probability of this risk is low but when this risk occurs has this risk a medium impact on the schedule of the project. The process of the purchase and logistics department are included in the R-GSM to make these process visible for all stakeholders in the project business process. The sensor of this risk is triggered when the materials are not ordered one and a

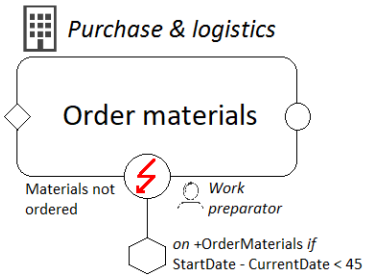

Figure 91: Risk integrated in stage 'Order materials'

half month before the start of the project. This condition activates the risk and the work preparator is assigned as risk owner for this risk. The work preparator is responsible for the materials during the project. The work preparator contacts the purchase and logistics department and mitigate this risk by a rush order, an alternative or a transfer from another warehouse.

H.4.2 Confirm order

After the materials are ordered, the supplier confirms the order and gives date for the delivery. The risk in the *Confirm order* stage is that the supplier does not confirm the order. This has a high probability but a low impact on the project objectives. The impact is low due to the fact that the ERP system automatically calculated the predicted delivery date based on the data of the supplier. The supplier gives only a more precise delivery date. The risk owner of this risk is the purchase and logistics department. This department is responsible for the confirmation of the supplier and needs to contact the supplier if the confirmation is not received within one week after the order is placed.

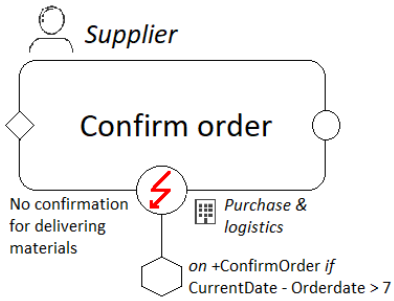

Figure 92: Risk integrated in stage 'Confirm order'

H.4.3 Delivering materials

In the stage *Delivering materials* the supplier delivers the materials to CityTec. The risk in this stage is that the supplier delivers the materials too late. The probability of this risk is high and the impact is low. The risk response is to fine the supplier for the goods that are delivered too late. This stage ensures that all materials are delivered before the start date. The sensor is triggered when the delivering dates provided by the supplier are after the start date of the project. When the risks becomes active, the purchase and logistics department becomes the risk owner. The purchase and logistics department is responsible for the mitigation of this risk.

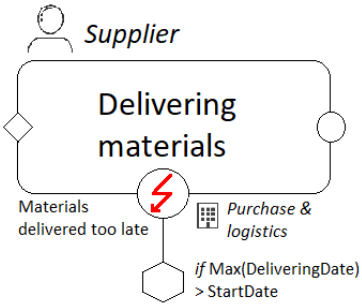

Figure 93: Risk integrated in stage 'Delivering materials'

Appendix I

The detailed results of the R-GSM tool are visualized in this appendix. The SO-DOPs and the work preparation stage of the P-Project and N-Project are related to the same project as the example project for the dashboard in chapter 6. The other results are from projects in other stages.

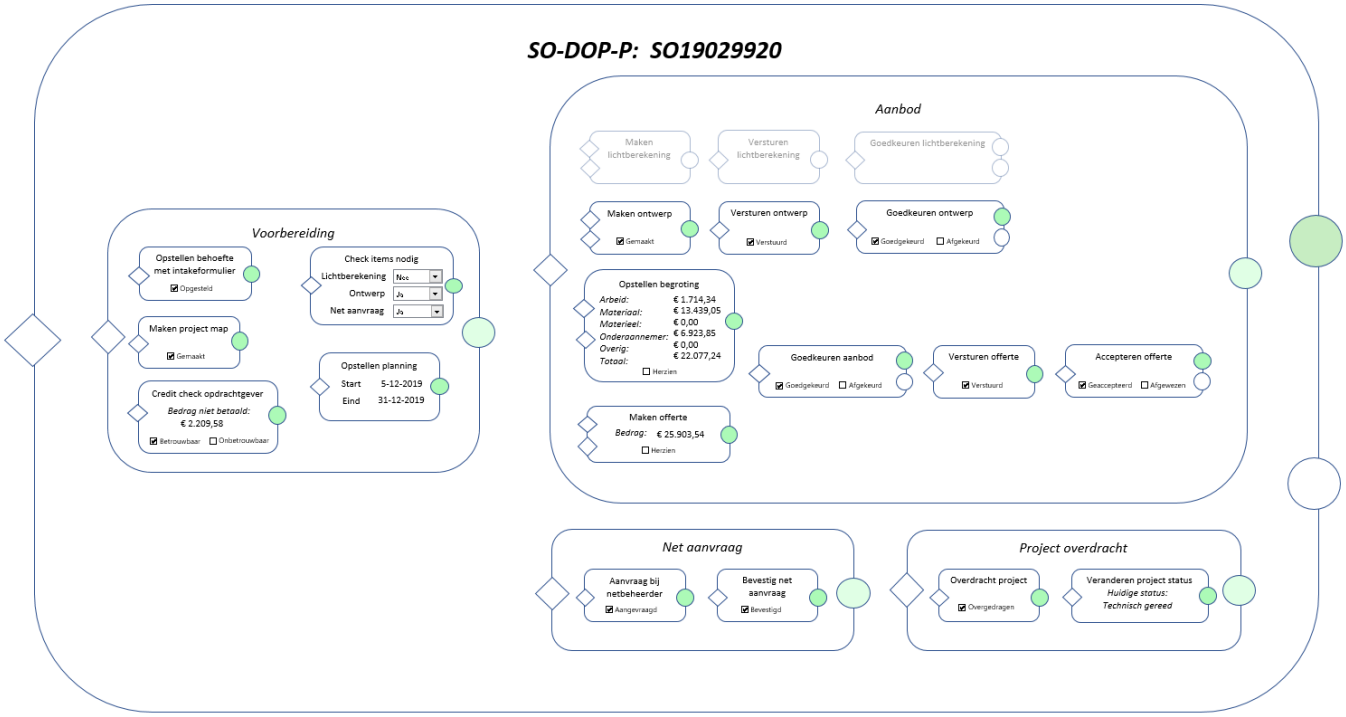

Figure 94: Example of the SO-DOP-P in the R-GSM tool

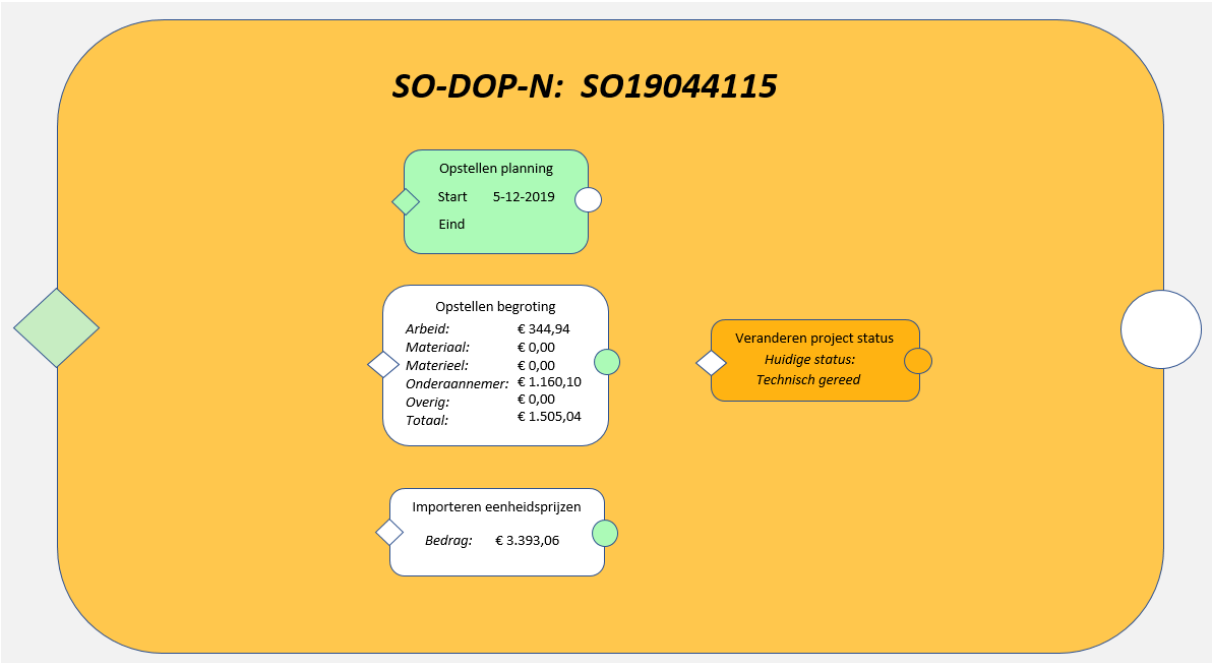

Figure 95: Example of the SO-DOP-N in the R-GSM tool

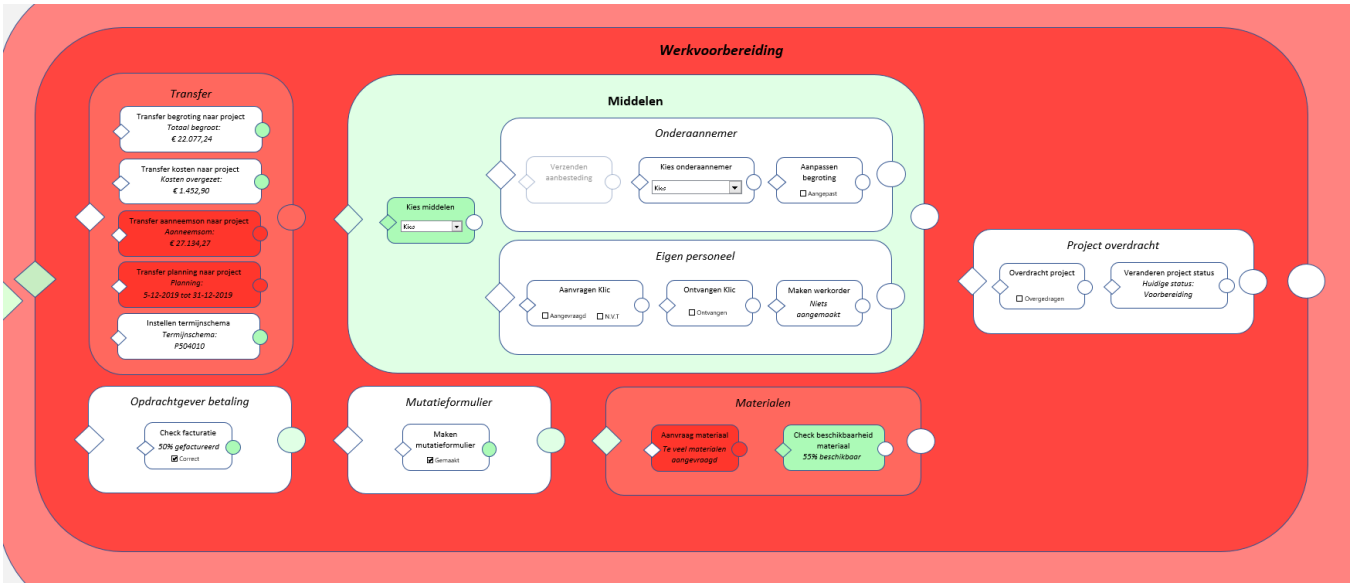

Figure 98: Example of the work preparation stage

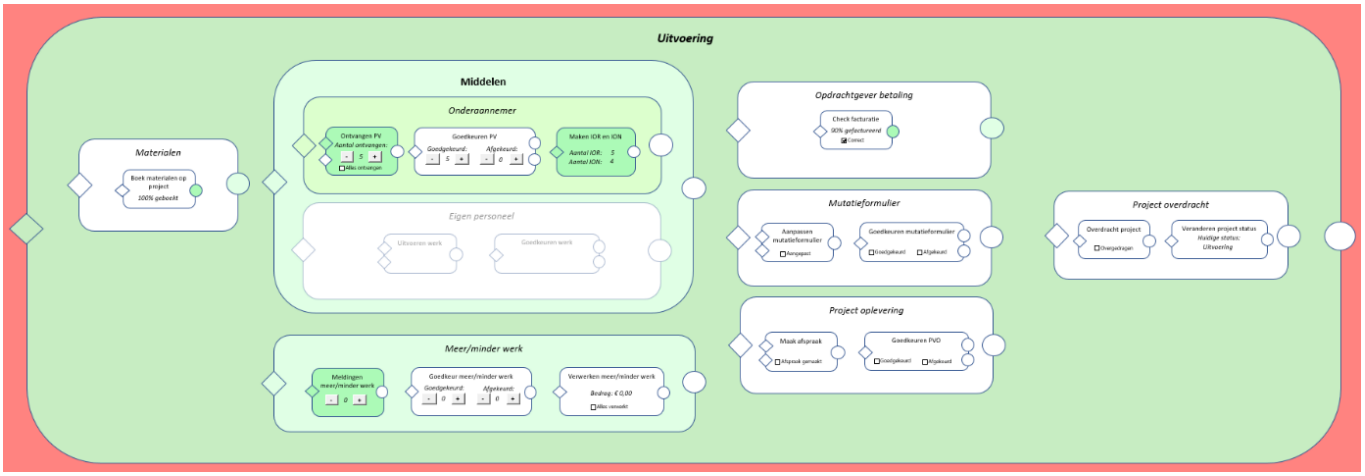

Figure 96: Example of the execution stage

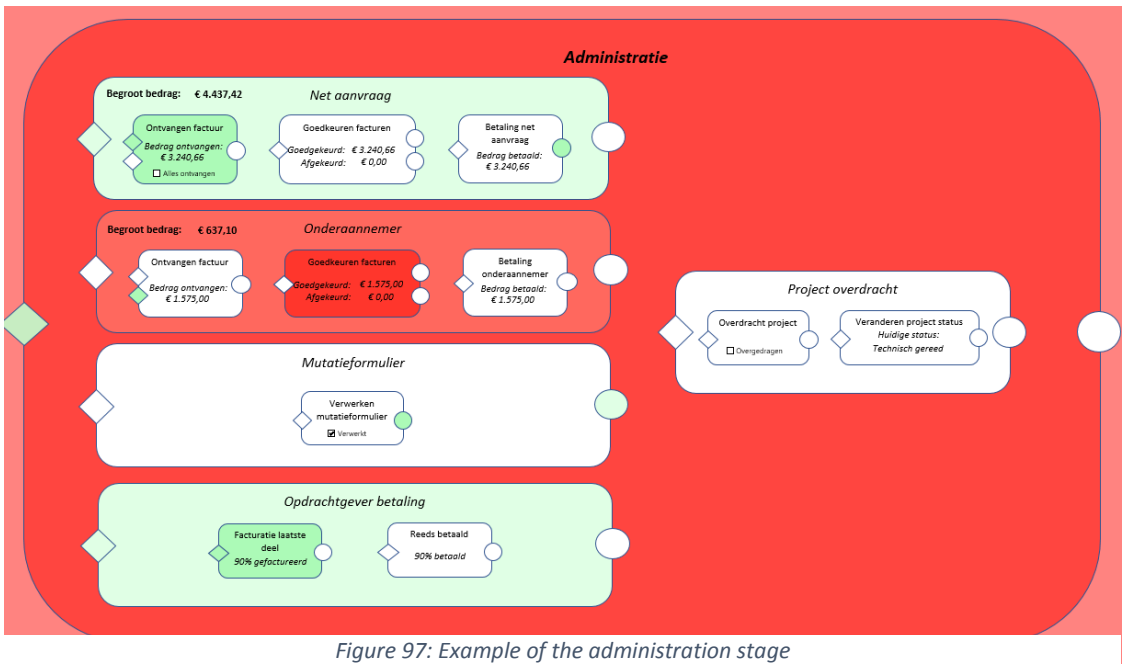

Figure 97: Example of the administration stage

Naam	ARM BRISA EL 7560L 3K LC-R OP	UITH VZ UE L1000 D60 5GR R600	MST 8M VZ VJ PT D51 R6005 100.N.175
Artikelnummer	5600664994	3355057043	3354593143
Voorraad	33	32	1
Adviesorder	25	20	20
Open aanvraag	25	20	20
Geboekt	0	0	0
IOR		IOR1906624	IOR1905590
Bevestigd		Ja	Ja
Ontvangst datum		12-12-2019	24-10-2019
Nodig andere projecten	0	22	0
In project begroting	23	19	19

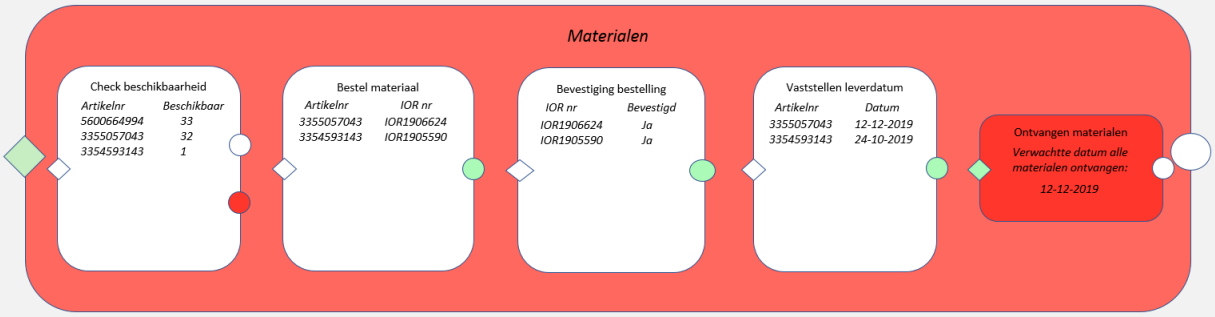

Figure 99: Example materials R-GSM model