Eindhoven University of Technology

Factors causing delays in the execution phase of Utility construction projects in the Netherlands

By using a Bayesian belief network

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Master Construction Management and Engineering

February 2018

Colophon

Title: Factors causing delays in the execution phase of Utility construction projects in the Netherlands

Subtitle: By using a Bayesian belief network

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Preface

This thesis is about quantifying the critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in the Netherlands by using a Bayesian Belief Network. This Master thesis has been developed in order to complete the Master Construction Management and Engineering at the University of Technology Eindhoven.

I would like to thank my graduation company Dura Vermeer Bouw Zuid West BV for the opportunity to carry out my graduation project within the company. In addition, I would like to thank in particular my supervisors for their support during the graduation process. Within Dura Vermeer Bouw Zuid West BV I would like to thank Remko Bentvelsen for his practical input and guidance during my graduation process. Within the university I would like to thank Qi Han and Astrid Kemperman for their scientific approach, they have been a valuable addition to the connection between theory and practice.

The results of this thesis could not have been produced without the help of the people who I have interviewed and who completed the questionnaires. I want to thank you all for your help!

Enjoy reading,

Jessy Boeters
Rotterdam, February 2018

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Summary

Utility construction projects (UCP) are one-off endeavours with many unique characteristics, such as long period, complicated processes, abominable environment, financial intensity and dynamic organisation structures. Within the utility discipline, it is challenging to quantify all potential and relevant uncertainties at an early stage, manage the valuable knowledge effectively and ensure that correct information can be extracted and communicated in time. Delays are common in the schedules of construction projects and cause significant losses to project parties. Therefore, it is important to quantify factors that cause delays and affect the execution phase of UCP in order to prevent potential delays and additional costs when managing the schedules.

The purpose of this thesis is to quantify the critical factors that cause delays and affect the execution phase of UCP in the Netherlands using a Bayesian belief network (BBN). In order to fulfil this purpose, this thesis focuses on selecting the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands, identifying the cause-effect relationships between the important critical factors and estimating the associated conditional probabilities. By capturing the cause-effect relationships and conditional probabilities a BBN can be developed.

In order to select the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands a literature review has been conducted. On the basis of this literature review, a total of one hundred and thirty-six (136) factors that influence construction projects have been collected. These one hundred and thirty-six (136) factors have been categorised into eleven groups, without repeating any factor. For example, the influencing factors “delay in progress payments by the client”, “ineffective planning and scheduling by the contractor” and “unfavourable weather conditions” are mentioned in several articles. To specify which of these influencing factors cause delays and affect the execution phase of UCP expert interviews have been held. With the expert interviews, the list of one hundred and thirty-six (136) factors that influence construction projects has been reduced to fifty-nine (59) critical factors that cause delays and affect the execution phase of UCP. The list of fifty-nine (59) critical factors compiled from the literature review and expert interviews has been assessed by a total of one hundred and thirty-eight (138) respondents in questionnaire (I). Results of questionnaire (I) have been analysed, using the Fuzzy Delphi method, in order to select important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. In total twenty critical factors that cause delays and affect the execution phase of UCP in the Netherlands have been selected using the Fuzzy Delphi Method. For example, the factors “Non-availability of drawing/design on time”, “Incompetent project team” and “Conflicts between the contractor and other parties” are selected.

To identify the cause-effect relationships between these important critical factors questionnaire (II) has been developed. In total two hundred and sixty-seven (267) possible relationships between the selected critical factors have been reviewed by forty respondents in the questionnaire (II). On the basis of the analysis, using nine Logical rules, a total of fifty-six (56) cause-effect relationships have been accepted. For example, the relationship from the factor “Late in revising and approving design documents” to “Non-availability of drawing/design on time” is accepted as cause-effect relationship.

In order to estimate the conditional probabilities between the important critical factors, a Directed graph (DG) has been developed on the basis of the cause-effect relationships and validated through Expert discussions. By means of the structure of the DG, the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands have been identified through questionnaire (III). On the basis of the results of ten respondents, the conditional probabilities have been determined.

After the conditional probabilities have been implemented in the DG, using the free academic computer program GeNIe (https://www.bayesfusion.com/), the DG will function as a BBN. The BBN, as shown in Figure 1, can be used to identify and evaluate the probabilities of a factors' condition on the basis of certain conditions of other factors.

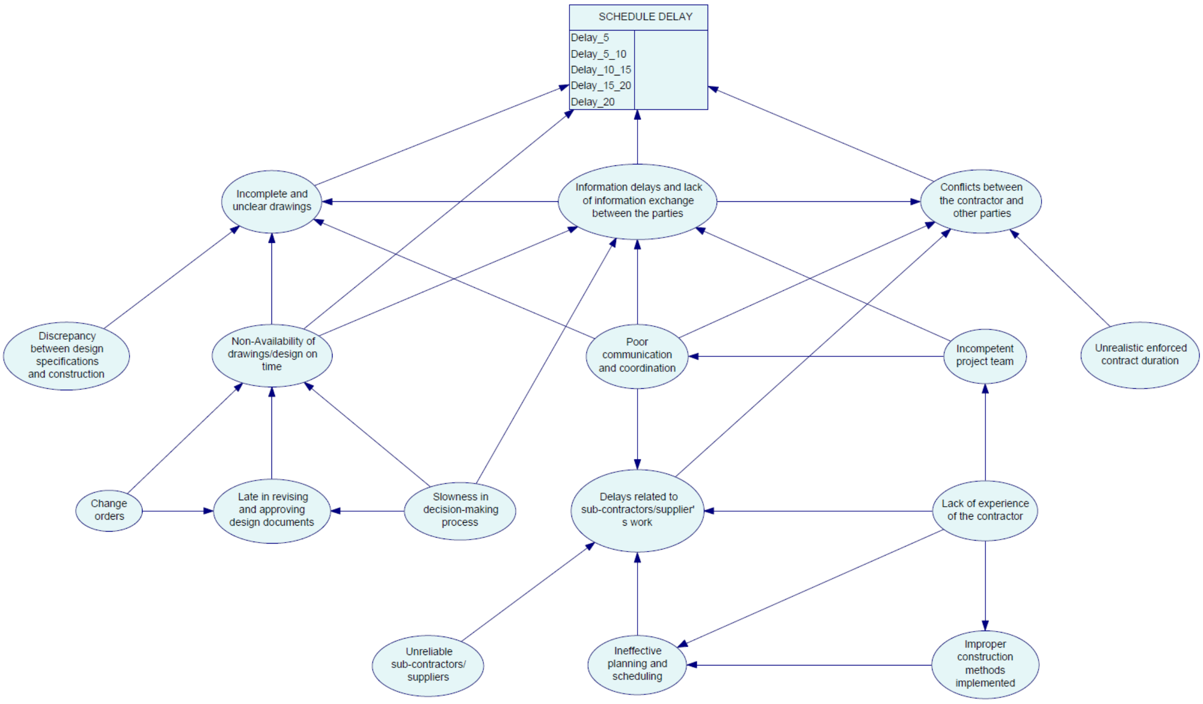


Figure 1: Final Bayesian belief network

As a result, the probabilities of the most influential critical factors that cause delays in the execution phase of UCP in the Netherlands can be determined by means of the BBN. The most influential critical factors "*Information delays and lack of information exchange between the parties*", "*Incomplete and unclear drawings*", "*Non-availability of drawing/design on time*" and "*Poor communication and coordination*" in the Netherlands, need to be controlled in all UCP in order to avoid schedule delays in advance. As shown in Table 1, it appears that these factors have a high chance of causing delays and affecting the execution phase of UCP in the Netherlands.

Table 1: Probabilities that the most influential critical factors cause delays

	Critical factors	Delay *
1	Information delays and lack of information exchange between the parties	*15 – > 20%*
2	Incomplete and unclear drawings	*5 – 20%*
3	Non-availability of drawing/design on time	*5 – 20%*
4	Poor communication and coordination	*5 – 20%*

* The delays are expressed in percentage (%) of the original project duration

Samenvatting

Utiliteitsbouw projecten (UCP) zijn eenmalige inspanningen met unieke kenmerken, zoals lange doorlooptijd, gecompliceerde processen, abominabele omgeving, financiële intensiteit en dynamische organisatiestructuren. Binnen de Utiliteitsbouw discipline is het een uitdaging om alle potentiële en relevante onzekerheden in een vroeg stadium te kwantificeren, de waardevolle kennis effectief te beheren en ervoor te zorgen dat de correcte informatie op tijd kan worden verkregen en gecommuniceerd. Vertragingen zijn gebruikelijk in de planningen van bouwprojecten en veroorzaken aanzienlijke verliezen voor partijen binnen het project. Daarom is het belangrijk om de factoren te kwantificeren die vertragingen veroorzaken en de uitvoeringsfase van UCP beïnvloeden, om daarmee mogelijke vertragingen en extra kosten te voorkomen tijdens het managen van de planningen.

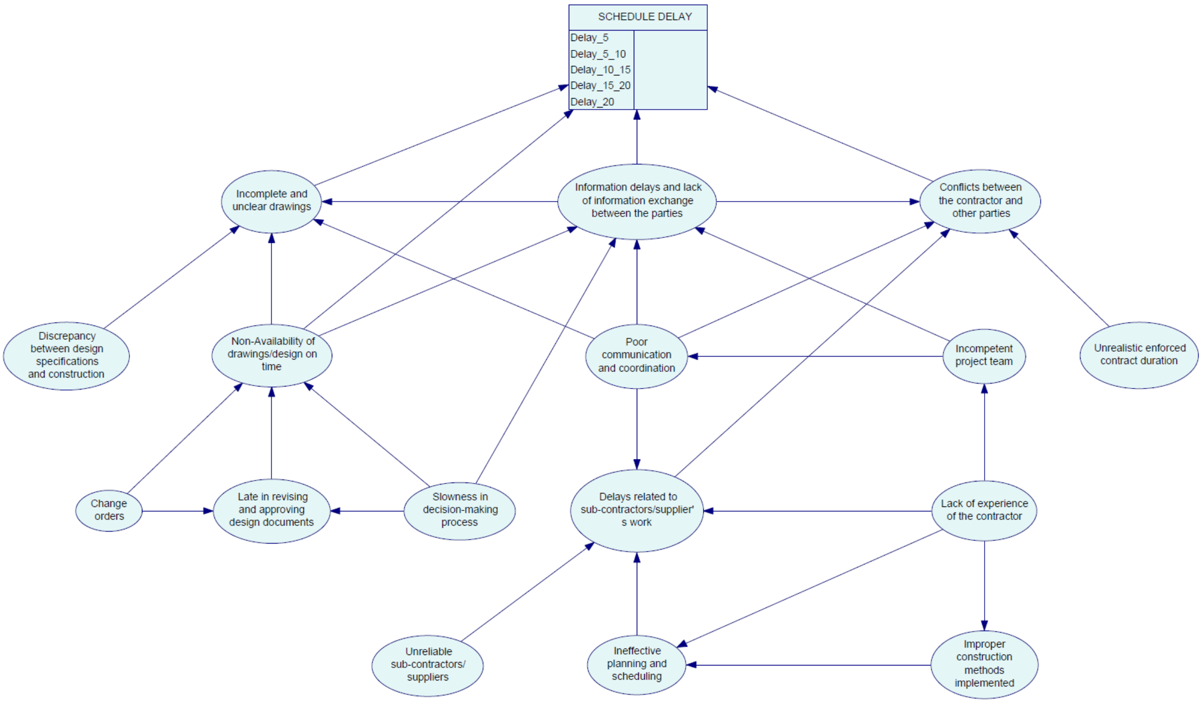
Het doel van deze thesis is om de kritieke factoren te kwantificeren die vertragingen veroorzaken en de uitvoeringsfase van UCP in Nederland beïnvloeden, met behulp van een Bayesian Belief Netwerk (BBN). Om dit doel te bereiken, richtte deze thesis zich op het selecteren van de belangrijkste kritieke factoren die vertragingen veroorzaken en de uitvoeringsfase van UCP in Nederland beïnvloeden, het identificeren van de oorzaak-gevolg relaties tussen deze factoren en het identificeren van de voorwaardelijke kansen van deze factoren. Door de oorzaak-gevolg relaties en de voorwaardelijke kansen kan een BBN ontwikkeld worden.

Om de belangrijkste kritieke factoren te selecteren die vertragingen veroorzaken en de uitvoeringsfase van UCP in Nederland beïnvloeden, is allereerst een literatuurstudie uitgevoerd. Op basis daarvan zijn in totaal honderdzesendertig (136) factoren die bouwprojecten beïnvloeden verzameld en onderverdeeld in elf groepen. Bijvoorbeeld de invloedrijke factoren “Vertraging in vooruitbetalingen door de opdrachtgever”, “Ineffectieve planning door de aannemer” en “Ongunstige weersomstandigheden” worden in meerdere artikelen genoemd. Om aan te geven welke van deze factoren vertragingen veroorzaken en de uitvoeringsfase van UCP beïnvloeden, zijn interviews met deskundigen afgenomen. Daardoor is de lijst van honderdvierenzestig (136) factoren teruggebracht tot negenenvijftig (59) kritieke factoren die vertragingen veroorzaken en de uitvoeringsfase van UCP beïnvloeden. Door middel van enquête (I) zijn de negenenvijftig (59) kritieke factoren beoordeeld door honderdachtendertig (138) respondenten. De resultaten van enquête (I) zijn geanalyseerd met behulp van de Fuzzy Delphi-methode. In totaal zijn twintig factoren geselecteerd die vertragingen veroorzaken en de uitvoeringsfase van UCP in Nederland beïnvloeden. Voorbeelden hiervan zijn “Niet beschikbaarheid van tekeningen of het ontwerp op tijd”, “Incompetent projectteam” en “Conflicten tussen aannemer en andere partijen”.

Om de oorzaak-gevolgrelaties tussen deze belangrijkste kritieke factoren te kunnen identificeren, is enquête (II) ontstaan. Via enquête (II) worden in totaal tweehonderdzevenenzestig (267) mogelijke relaties, tussen de geselecteerde kritieke factoren, beoordeeld door in totaal veertig respondenten. Op basis van de analyse, met behulp van de nine Logical rules, worden in totaal zesenvijftig (56) oorzaak-gevolg relaties geaccepteerd. Bijvoorbeeld de relatie tussen “Laat in het herzien en goedkeuren van ontwerpdocumenten” en “Niet beschikbaarheid van tekeningen of het ontwerp op tijd” is geaccepteerd als een oorzaak-gevolg relatie.

Om de voorwaardelijke kansen tussen de belangrijkste kritieke factoren te kunnen identificeren, is een Directed graph (DG) ontwikkeld op basis van de oorzaak-gevolg relaties en gevalideerd door middel van discussies met deskundigen. Aan de hand van de structuur van de DG, konden de voorwaardelijke kansen tussen de belangrijkste kritieke factoren via enquête (III) bepaald worden.

Nadat de voorwaardelijke kansen zijn geïmplementeerd in de DG, door gebruik te maken van het gratis academische computerprogramma GeNIe (https://www.bayesfusion.com/), zal de DG functioneren als een BBN. De BBN, zoals weergegeven in Figuur 2, kan worden gebruikt om de kansen van elke factor te identificeren en te evalueren op basis van bepaalde voorwaarden die gesteld zijn aan andere factoren.



Figuur 2: Definitieve Bayesian belief netwerk

Als resultaat kunnen de voorwaardelijke kansen van de meest invloedrijke kritieke factoren bepaald worden door middel van de BBN. De meest invloedrijke kritieke factoren "*Informatie vertragingen en gebrek aan informatie-uitwisseling tussen partijen*", "*Onvolledige en onduidelijke tekeningen*", "*Niet beschikbaarheid van tekeningen of het ontwerp op tijd*" en "*Slechte communicatie en coördinatie in het project*" in Nederland moeten gemanaged worden in elke UCP om vertragingen op voorhand te voorkomen. Zoals weergegeven in Tabel 2, blijkt dat deze factoren een grote invloed hebben in het veroorzaken van vertragingen in de uitvoeringsfase van UCP in Nederland.

Tabel 2: Kans dat de meest invloedrijke kritieke factoren vertragingen veroorzaken

	Kritieke factoren	Delay *
1	Informatie vertragingen en gebrek aan informatie-uitwisseling tussen partijen	*15 – > 20%*
2	Onvolledige en onduidelijke tekeningen	*5 – 20%*
3	Niet beschikbaarheid van tekeningen of het ontwerp op tijd	*5 – 20%*
4	Slechte communicatie en coördinatie in het project	*5 – 20%*

* De vertragingen zijn uitgedrukt in percentage (%) van de originele projectduur

Abstract

Utility construction projects (UCP) are one-off endeavours with many unique characteristics, such as long period, complicated processes, abominable environment, financial intensity and dynamic organisation structures. Delays are common in the schedules of construction projects and cause significant losses to project parties. Therefore, it is important to quantify factors that cause delays and affect the execution phase of UCP in order to prevent potential delays and additional costs when managing the schedules. The purpose of this thesis is to quantify the critical factors that cause delays and affect the execution phase of UCP in the Netherlands using a Bayesian belief network (BBN). To fulfil this purpose, this thesis focuses on selecting the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands, identifying the cause-effect relationships between the important critical factors and estimating the associated conditional probabilities. A total of 136 factors that influence construction projects have been collected through a literature review. With expert interviews, the factors that influence construction projects has been reduced to 59 critical factors that cause delays and affect the execution phase of UCP. These critical factors have been assessed by 138 respondents in questionnaire (I). In total twenty critical factors that cause delays and affect the execution phase of UCP in the Netherlands have been selected using the Fuzzy Delphi Method. Using nine Logical rules, a total of 56 cause-effect relationships between the selected critical factors have been accepted by forty respondents in questionnaire (II). Based on these cause-effect relationships a Directed graph (DG) has been developed. The knowledge and experience of ten experts have been used to create a BBN out of the DG by estimating the conditional probabilities in questionnaire (III). To identify and evaluate the probabilities of a factors' condition on the basis of certain conditions of other factors, the BBN can be used. The most influential critical factors "*Information delays and lack of information exchange between the parties*", "*Incomplete and unclear drawings*", "*Non-availability of drawing/design on time*" and "*Poor communication and coordination*" need to be controlled in every UCP to avoid schedule delays in advance.

Keywords: *Utility construction projects; Critical Factors; Scheduling; Delays; Execution phase; Fuzzy Delphi method; Logical rules; Directed graph; Bayesian Belief Networks; Netherlands*

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List of Abbreviations

BBN	Bayesian belief network
DG	Directed graph
DM	Delphi method
FT	Fuzzy set theory
FDM	Fuzzy Delphi method
UCP	Utility construction projects

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1 Introduction

The introduction presents the topic, the aim of this thesis and the way the research is conducted. Therefore, the introduction describes the Problem Background in Chapter 1.1, the Research Objective in Chapter 1.2, the Research Questions in Chapter 1.3, the Research Design in Chapter 1.4, the Research Boundaries in Chapter 1.5, the Practical and Scientific Relevance in Chapter 1.6 and the Reading Guide in Chapter 1.7.

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1.1 Problem Background

The construction industry in the Netherlands has an important contribution to a good living and working environment in the Netherlands. In 2016, this industry accounted for about 4.5% of the gross domestic product and production of more than sixty billion euros in the Netherlands ("Feiten en cijfers|Bouwend Nederland," n.d.). Within the construction industry in the Netherlands there are three types of projects, namely residential, utility and civil engineering projects. Figure 3 shows the distribution of the production in 2016 between these three types of projects on the basis of the data from Table 3 ("Feiten en cijfers|Bouwend Nederland," n.d.). The production of residential projects (43%) was by far the biggest in the Netherlands followed by the utility projects (31%) and the civil engineering projects (26%).

Table 3: Production of the construction industry in the Netherlands (2016)

Production Construction Industry (in euro)	
Residential projects	25.075 million
Utility projects	18.075 million
Civil engineering projects	15.325 million
Total	58.475 million

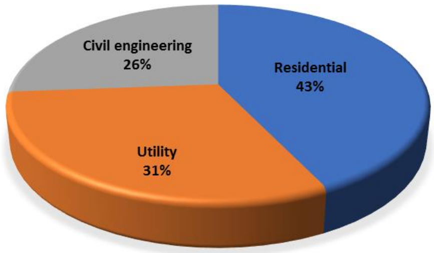

Figure 3: The distribution of construction projects (2016)

This thesis focuses on schedule delays in the execution phase of Utility construction projects (UCP). These are projects without residential areas, for example, shops, offices, factories, schools, business halls and storage areas. UCP are one-off endeavours with many unique features, such as long period, complicated processes, abominable environment, financial intensity and dynamic organisation structures (El-Sayegh, 2008; Zou, Zhang, & Wang, 2007). Within the utility discipline, it is difficult to apply repetitions and reuse knowledge because no project is the same. In addition, it becomes more and more complex to meet the environmental regulations and the needs of the client. The environmental regulations ensure that the impact on the environment during the execution phase is low and the clients demand higher quality products at lower costs. Meeting these environmental regulations and needs involves complicated processes with enormous uncertainties for various parties that take time and money, which are often unavailable.

The successful management of these uncertainties is to a large degree reliant on the expert multi-disciplinary knowledge and experience (Zou, Kiviniemi, & Jones, 2017). The views of the multidisciplinary knowledge and experience are unique and specific for each involved individual that looks at the management process (Houben, 2010). According to El-Sayegh (2008) and Zou et al. (2017), it is still challenging to quantify all potential and relevant uncertainties at an early stage, manage the valuable knowledge effectively and ensure that correct information could be extracted and communicated in time in order to mitigate these uncertainties in the whole dynamic process. Schedules often contain significant uncertainties due to a lack of information and many activities carried out by various parties. Schedules are essential for the successful execution of a construction project because it is difficult to coordinate the diverse activities in the execution phase of a project. Delays are common in the schedule of construction projects and cause considerable losses to project parties (Van Truong, Kim, Van Tuan, & Ogunlana, 2009).

In Saudi Arabia, for example, 70% of the projects experienced delays with the average between 10% and 30% of the original project duration (Assaf & Al-Hejji, 2006). In Qatar, in a period from 2000 to 2013, 72% of the public projects and 50% of the maintenance projects experienced delays (Senouci, Ismail, & Eldin, 2016). On the basis of this data, the following question arises: How many UCP experience delays in the Netherlands?

In the Netherlands, the involved parties within the UCP make agreements to complete the project at a specific date based on the workable days in a year. If the contractor does not meet the agreed contractual finish date, the agreed delay penalties are applicable. This can lead to loss of revenue and additional costs for the contractor. Therefore, the contractor will do everything in its power to finish on the agreed contractual finish date.

Table 4 provides insight into the (original and revised) start and finishing dates of ten selected UCP in the Netherlands. Most of the selected projects rarely start or complete within the first specified contractual dates. Since, the factors that cause these delays are not known in these projects, it is not clear why these projects experienced delays and who is responsible for causing these delays. Therefore, it is important to quantify factors that cause delays and affect the execution phase of UCP in order to prevent potential delays and additional costs when managing the schedules.

Table 4: Performance of selected utility projects in the Netherlands

No.	Type of project*	Original start date	Revised start date	Original finish date	Revised finish date	Remarks
01	Bank	November (2016)	December (2016)	December (2017)	February (2018)	Late start and late finish
02	School	August (2014)	August (2014)	April (2015)	July (2015)	Late finish
03	Office	October (2015)	November (2015)	August (2017)	August (2017)	Late start (renovation)
04	Office	May (2014)	April (2014)	May (2015)	June (2015)	Late start and late finish
05	Office/shops/ residential	March (2013)	April (2013)	May (2014)	December (2014)	Late start and late finish (renovation)
06	Care centre	January (2014)	February (2014)	April (2015)	September (2015)	Late start and late finish
07	School	June (2015)	June (2015)	February (2016)	August (2016)	Late finish
08	Sports hall	November (2015)	November (2015)	September (2016)	October (2016)	Late finish
09	School (university)	September (2015)	October (2015)	June (2016)	March (2017)	Late start and late finish (renovation)
10	Town hall	June (2016)	June (2016)	September (2017)	June (2018)	Late finish (renovation)

* This thesis tries to map sensitive information, therefore, the information about the projects is processed anonymously (by mentioning the type of project) to ensure that the information provided by the graduation company is used confidentially.

1.2 Research Objective

As said before, schedules are essential in construction projects and often contain a large number of uncertainties. Given the major amount of project delays in the examples of studies conducted in Saudi Arabia and Qatar, it can be said that a large number of projects do not complete within the specified contractual time. The reviewed projects confirm this by showing projects rarely start or complete within the first specified contractual dates. Several factors can influence the start or finishing dates within these projects. This thesis tries to quantify the critical factors that cause delays and affect the execution phase of UCP in the Netherlands.

The construction industry of the Middle East (Saudi Arabia and Qatar) is not the same as in the Netherlands. Where the construction industry in the Netherlands recovers from an economic depression, the Middle East realises major expensive utility projects. Due to the differences in the law and legalisation, climate, economy, culture and the living and working environment between the Netherlands and the Middle East, it is expected that the factors that cause delays may differ. The following research objective is central to this thesis:

The purpose of this thesis is to quantify and select the critical factors that cause delays and affect the execution phase of Utility construction projects in the Netherlands. Furthermore, the objectives are to determine how these factors influence each other by identifying the cause-effect relationships and estimate the conditional probabilities among the selected critical factors. The main aim is to develop a Bayesian belief network to predict the probability of factors that cause schedule delays in future projects.

This thesis uses a different method for capturing and reusing valuable knowledge and experiences from executed UCP in order to prevent schedule delays. By getting insights and capturing the critical factors that cause delays in the Netherlands a belief network can be developed. The BBN can predict the probabilities of schedule delays in the execution phase on the basis of the cause-effect relationships and conditional probabilities among the factors. The results can help to take action against the factors and thereby reduce the chance of delays during the execution phase of UCP in future projects. This subject is interesting for multiple parties in the Dutch construction industry because there is no research conducted on the factors that cause delays and affect the execution phase of UCP in the Netherlands.

1.3 Research Questions

The following research question is central to this thesis:

What are the probabilities that the most influential critical factors will cause delays and affect the execution phase of Utility construction projects using the Bayesian belief network?

In order to answer the research question, the following sub-questions have to be answered:

I. Which factors influence construction projects? (literature review)
II. Which critical factors cause delays and affect the execution phase of UCP? (expert interviews)
III. What are the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? (questionnaire (I))

IV. What are the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? (questionnaire (II))
V. What is the rank of the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? (questionnaire (II))
VI. What are the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? (questionnaire (III))

1.4 Research Design

Despite the fact that no research has been conducted on the factors that cause delays in UCP in the Netherlands, this is a research topic in many international articles. A similar research was conducted in Vietnam by Van Truong et al. (2009). Their article describes how a Bayesian belief network (BBN) can be used to predict the probabilities of schedule delays on construction projects in the Vietnam construction industry. Their research model has been adapted in this thesis because their research design is comparable to this research. Figure 4 presents the step-by-step conceptual research design consisting of two phases. The conceptual research design is discussed in more detail in the next sections.

1.4.1 Phase 1: Qualitative analysis

The purpose of this phase is to select delay factors applicable in the UCP during the execution phase in the Netherlands. The *first step* is to conduct a literature review to quantify various factors that influence construction projects, as described in Chapter 2. This step aims at answering sub-question I. Since this is not done thoroughly in the Netherlands the *second step* is to select the critical factors that cause delays and affect the execution phase of UCP through expert interviews. These expert interviews have been held in a structured way on the basis of a general set of questions in order to select the critical factors that cause delays and affect the execution phase of UCP, as discussed in Chapter 3. This step aims at answering sub-question II. The *third step* is to design the questionnaires and collect additional data for making a BBN in Phase 2. This thesis need a total of three questionnaires types, namely:

I. Questionnaire (I) to select the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands (Chapter 4);
II. Questionnaire (II) to identify the cause-effect relationships among the important critical factors (Chapter 5);
III. Questionnaire (III) to estimate the conditional probabilities of the important critical factors (Chapter 6).

Before deciding to go to Phase 2, the *fourth step* is to select the important critical factors that cause delays and affect the execution phase of UCP by using the experience of respondents from questionnaire (I). For evaluating questionnaire (I), the Fuzzy Delphi method (FDM) is used to select the critical factors that cause delays and affect the execution phase of UCP in the Netherlands, as described in Chapter 4. This step aims at answering sub-question III. In the *final step*, a decision needs to be made whether the important factors derived from the FDM are appropriate, this is done looking at the comparison of factors in Europe from Chapter 2. Phase 2 will start when the FDM has been executed correctly.

1.4.2 Phase 2: Quantitative analysis

The purpose of this phase is to determine the cause-effect relationships among the critical factors identified in Phase 1, develop a BBN and estimate the probability that a certain factor will cause delays and affect the execution phase of UCP in future projects. To do this, the *first step* is to determine the preliminary relationships among the critical factors found in Phase 1 and remove the illogical cause-effect relationships for questionnaire (II). In the *second step,* questionnaire (II) is used to identify the cause-effect relationships among the critical factors. In questionnaire (II) the knowledge and experience of respondents (i.e. Clients, contractors, consultants) are used to determine the cause-effect relationships among the identified critical factors from questionnaire (I). In order to validate the response, the procedure of nine logical tests is used that consists of using two statistical values, namely the average and the skewness. These steps aiming at answering sub-question IV and V. After the ranking of the cause-effect relationships, a Directed graph (DG) can be developed in the *third step.* The validation of the DG is tested in discussion sessions with experts in the *fourth step*, as described in Chapter 5. When the DG is not valid, the DG needs to be adjusted in the *third step* of Phase 2 and repeat these steps till the DG is valid. Before it is possible to draw conclusions, the *fourth step* is to assign the conditional probabilities to the critical factors using questionnaire (III). For this step, a data table is developed to obtain the conditional probabilities for each factor and assessed by ten experts. These experts assess the frequencies of a factors' condition on the basis of certain conditions of other factors that have cause-effect relationships. The validation of the BBN is tested for two, by the graduation company, executed projects that experienced delays. These steps are elaborated in Chapter 6 and aiming at answering sub-question VI. In the *final step,* the conclusion of this thesis, the relevance and the recommendations are explained concisely in Chapter 7.

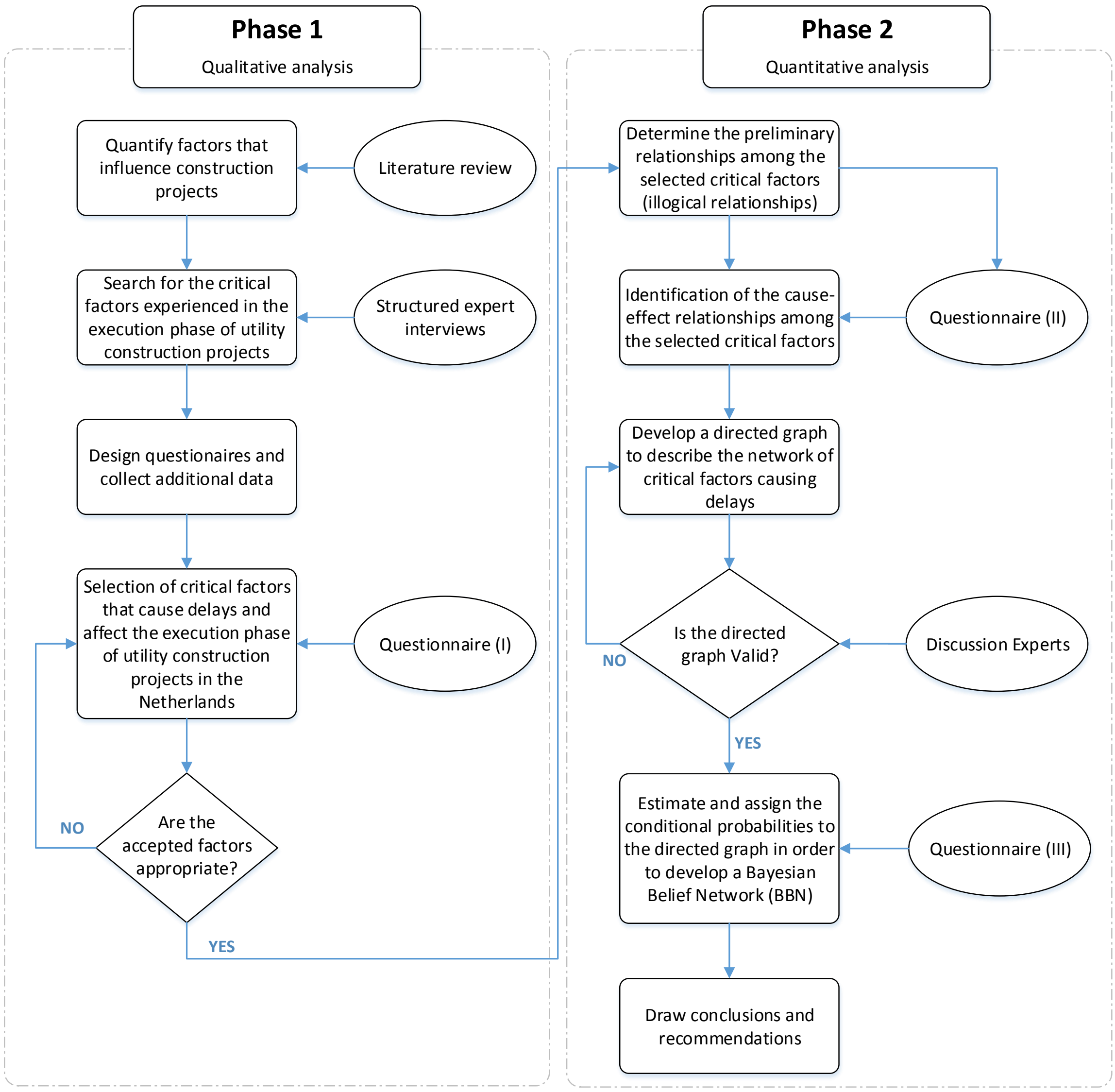

Figure 4: Conceptual research framework (adapted from Van Truong et al. (2009))

1.5 Research Boundaries

It is difficult to apply repetitions and reuse knowledge in UCP because these projects have the most unique features. If the contractual finish date is not met by the contractor, the agreed delay penalties are applicable and can lead to loss of revenue and additional costs. Therefore, the contractor will do everything in its power to finish on the agreed contractual finish date. The fact that it is difficult to reuse knowledge and the pressure for the contractor to deliver the project in time makes it interesting to provide improvements. Therefore, the focus of this thesis lies in the execution phase of UCP in the Netherlands in order to prevent the delays and additional costs when managing the schedules.

The research subject has not been studied thoroughly in the Netherlands, therefore, it is important to collect the right information about the factors that cause delays and affect the execution phase of UCP. A literature review of international articles has been conducted in order to find the various factors influencing constructing projects. In addition, expert interviews have been held in a structured way on the basis of a general set of questions to identify critical factors that cause delays and affect the execution phase of UCP. The literature review and expert interviews will form the basis for the selection of factors that influence construction projects in the questionnaires. It is important to select the right sources in order to secure all questionnaires include the essential information. Due to a lack of data this thesis uses the knowledge and experience of experts in the questionnaires. To ensure the results are reliable and valid, it is important that the sample size is large enough at all times.

1.6 Practical and Scientific Relevance

Many international articles have identified various factors that cause delays and affect construction projects. However, in the Netherlands, there is no research conducted about the factors that cause delays and affect the execution phase of UCP. It is expected that results could differ with international articles because within every country there are differences in the law and legalisation, the climate, the economy, the culture and the living and working environment. These aspects can have a great influence on the decision-making process to successfully manage the uncertainties of schedules at an early stage.

It is not certain what the impact of uncertainties among time will be on the overall performance of the projects in the Netherlands. There are many important factors that cause delays in the execution phase. Therefore, it is helpful to create awareness about these factors that cause delays, the extent to which they can adversely affect the project delivery and their frequencies. This thesis uses a different method for capturing and reusing valuable knowledge and experiences from executed UCP in order to prevent schedule delays.

The research objective central to this thesis is to quantify the most influencing factors that cause delays and affect the execution phase of UCP in the Netherlands. Furthermore, the objectives are to determine how these factors influence each other by identifying the cause-effect relationships and the conditional probabilities among the selected critical factors. The research questions proposed in this thesis are considered to be relevant for both science and practice. Although there will be insights into the factors that cause delays and affect the execution phase of UCP in the Netherlands, there is not a scientific research conducted in the Netherlands that confirms these understandings nor denies it. In practice, the results can help to take actions against the factors that cause delays and affect the execution phase of UCP in the Netherlands. This is necessary to reduce the delays at an early stage for future projects.

1.7 Reading Guide

This thesis consists of seven Chapters, each of them dealing with different aspect of the research. A reading guide has been compiled on the basis of the phasing from the research design in this thesis. The reading guide will be described in more detail below.

Phase 1: Qualitative analysis

First of all, Chapter 2 focuses on relevant Literature about factors that influence construction projects and different types of delay factors. As a result, a list of factors that influence construction projects is compiled out of the reviewed international articles. Subsequently, Chapter 3 focuses on searching the critical factors that cause delays and affect the execution phase of UCP through expert interviews. As a result, a list of critical factors that cause delays and affect the execution phase of UCP is compiled. At last, Chapter 4 focuses on selecting the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands through the FDM. As a result, a list of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands is compiled.

Phase 2: Quantitative analysis

First of all, Chapter 5 focuses on the identification of the cause-effect relationships between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. As a result, a validated DG is developed through the cause-effect relationship between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. Subsequently, Chapter 6 focuses on the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. As a result, a BBN is developed on the basis of the conditional probabilities in the DG. At last, Chapter 7 concisely explain the conclusion of this thesis, the relevance and the recommendations. A detailed overview of the reading guide is shown in Figure 5.

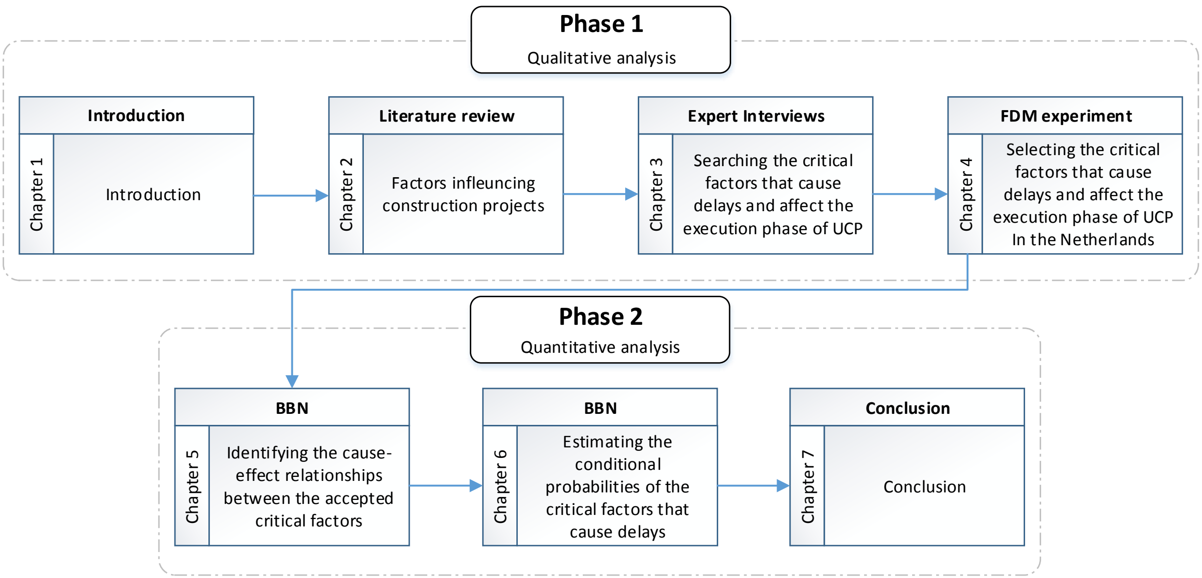

Figure 5: Reading guide of this thesis

2 Literature review: Search for the influencing factors

This Chapter focuses on the literature of the factors that influence construction projects and the different types of delay factors. Relevant prior Literature will provide the theoretical background for this thesis. The purpose of the literature review is to answer sub-question I – Which factors influence construction projects? and collect enough information, for the expert interviews in Chapter 3, to answer sub-question II – Which critical factors cause delays and affect the execution phase of Utility construction projects? Chapter 2.1 discusses the included international articles that have conducted a similar research. The literature has pointed out that dividing factors into groups is done more often, this is presented in Chapter 2.2. The overview of the most mentioned and the least mentioned factors, as a result of the reviewed international articles, are presented in Chapter 2.3. Next, Chapter 2.4 discusses the comparison between the articles that has been conducted in Europe, India, Malaysia and the Middle East in order to find differences and similarities in the same continent or country. Exploring the type of factors gives guidelines for the expert interviews in Chapter 3 to fill the literature gap and find critical factors that cause delays and affect the execution phase of Utility construction projects (UCP), this is elaborated in Chapter 2.5. At last, Chapter 2.6 discusses the conclusion of the conducted literature review and answer sub-question I. As a result, a list of factors that influence construction projects has been compiled out of the reviewed international articles.

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2.1 Factors influencing construction projects

In the construction industry, a delay refers to a situation where a construction project does not complete within the agreed specified contract date (Assaf & Al-Hejji, 2006; Kaliba, Muya, & Mumba, 2009). As said before, delays are common in the schedule of construction projects and can cause considerable losses to project parties (Van Truong et al., 2009). Selecting the factors that influence construction projects, in general, is the starting point of this literature review and helps to answer sub-question I – Which factors influence construction projects?

Several international articles have reviewed factors that cause delays and affect construction projects from different research perspectives (i.e. Client, contractor and consultant). In each article, various numbers of delay factors are found with different important causes and different ways of ranking these causes. The factors that influence construction projects are reviewed out of thirty articles conducted in twenty-two different countries all over the world, as shown in Figure 6. The variation in the number of delays in various articles for each type of construction projects (e.g. General construction, public construction, road construction) ranging from thirteen different delay factors found in the article of Bhadoria, Agrawal, Gupta, & Pandey (2016) to two hundred and ninety-three (293) delay factors found in the article of Aziz & Abdel-Hakam (2016). The factors reviewed from the literature are categorised into groups and numbered by the occurrence in Appendix A – Literature review: Influencing factors.

Figure 6: Overview of the reviewed research countries

2.2 Grouping of the influencing factors

The reviewed articles have pointed out that dividing factors into groups is often used. It is noticeable that the factors are not divided unambiguously into the same number of groups. For example, Van Truong, Sang, & Viet (2015) have grouped the reviewed factors that cause delays under six broad groups, namely owner-related, consultant-related, contractor-related, project conditions-related, contract-related, and external-related. Compared to Van Truong et al. (2015), the article of Gunduz & AbuHassan (2016) has included the groups material-related, labour-related and construction site-related and excluded the groups project-related and contract-related.

On the other hand, Assaf & Al-Hejji (2006); Gündüz, Nielsen, & Özdemir (2013); Megha & Rajiv (2013) and Van Truong et al. (2009) have grouped the reviewed factors that cause delays under nine groups, namely project-related, owner-related (client), contractor-related, consultant-related, design-related, material-related, workforce-related (labour), equipment and environment-related (external). In the extreme case, the article of Aziz & Abdel-Hakam (2016) has reviewed factors that cause delays under fifteen groups and in comparison with the nine groups of Assaf & Al-Hejji (2006); Gündüz et al. (2013); Megha & Rajiv (2013) and Van Truong et al. (2009) and has added the groups financing-related, site-related, contractual relationships-related, contract-related, rules & regulations-related and scheduling and controlling-related.

Table 5: Categorise the groups that influence construction projects

No.	Group of delay factors	Related cause ID	Number of factors
01	Project-related	01 : 12	12
02	Contractual-related	13 : 24	12
03	Client-related	25 : 40	16
04	Contractor-related	41 : 71	31
05	Consultant-related	72 : 79	8
06	Design-related	80 : 87	8
07	Site-related	88 : 95	8
08	Material-related	96 : 105	10
09	Equipment-related	106 : 113	8
10	Labour-related	114 : 121	8
11	External-related	122 : 136	15
Total			136

Since no fixed structure is used in the reviewed literature, there is chosen to divide the factors that cause delays into eleven groups as shown in Table 5. The nine most commonly used categories have been adopted from the articles of Assaf & Al-Hejji (2006); Gündüz et al. (2013); Megha & Rajiv (2013) and Van Truong et al. (2009) and two groups were added, namely site-related and contractual related. These groups resemble efficient groups according to the found factors in multiple literature articles and the expert interviews.

2.3 Analysis of the influencing factors

From the reviewed literature, it is clear that most articles have given priority to identify the factors that cause delays and the relative importance of these delays on the basis of the perceptions of different parties (i.e. Clients, contractors, consultants) in the construction industries. The quantification of the dependencies of one factor over others has received the attention in multiple articles. Within this line of research, some articles have included the link between the factors that cause the delays and the effects, for example, Doloi, Sawhney, Iyer, & Rentala (2012) and Sambasivan & Soon (2007). However, less research has been conducted on predicting the probabilities of delays, despite the vital role in contributing to the success of construction projects, such as Van Truong et al. (2009). The similarity between the reviewed articles is the search for factors that influence construction projects, that makes these articles useful for selecting the factors that influence construction projects.

In the comparison of the reviewed articles, it became clear that the numbers of factors that cause delays differ in each article. The combination of searching for delay factors through a literature review and expert interviews is used often to provide a representation of factors that play a role in a specific country. For example, the articles of Abusafiya & Suliman (2017); Aziz & Abdel-Hakam (2016); Kaliba et al. (2009); Megha & Rajiv (2013); Van Truong et al. (2009) have applied a literature review and expert interviews. The number of factors that influence construction projects highly depend on the reviewed articles by the author, the numbers that have been applied in the reviewed Literature and the experience of the experts in the interviews. Through the literature, a total of one hundred and thirty-six (136) factors that cause delays are collected, taking into account not to repeat any factor. The list of the factors that influence construction project, from the reviewed literature, are categorised in the eleven groups as discussed in Chapter 2.2 and numbered by the occurrence in Appendix A – Literature review: Influencing factors. For a detailed summary of the factors that influence the construction projects mentioned by the author(s), see Appendix B – The Literature review: Detailed overview.

Although some factors are more frequently mentioned than others, this does not necessarily imply that these factor is more important in causing a delay and affecting construction projects. An explanation of the frequency that a particular cause is more mentioned may instead offer an indication of it being easily observable for causing delays as opposed to having a greater impact. For example, it is easier to observe a delay by rework due to errors caused by the contractor (mentioned 21 times) than observe a delay by the contractor's workload (mentioned 4 times). In the process of collecting factors that influence the construction projects, it is really important, how to implement the factors out the reviewed articles. Several articles mention factors that are comparable to other factors as described in the next section.

For each article, it has been carefully considered which cause can be assigned to which factor and group without repeating the factors. For example, El-Sayegh (2008) has mentioned the factors “changes of design” (client-related) and “changes in design” (designers-related) as two separate factors while other articles only assign this factor to the client-related groups as this is the responsibility of the client. Marzouk & El-Rasas (2014) have mentioned the two factors “equipment availability and failure” as one accumulated factor while in other articles it is mentioned separately as “equipment breakdown(s)” and “equipment shortage”. On the other hand, Kaliba et al. (2009) have mentioned the factor “poor supervision” while other articles mention an accumulated similar factor “poor site management and supervision”.

Another example is the article of Shehu, Endut, & Akintoye (2014). They have mentioned seven different factors, namely “contractors poor coordination with the parties involved in the project”, “poor communication by the contractor with the parties involved in the project”, “poor coordination by the consultant engineer with other parties involved”, “poor communication between the consultant engineer and other parties involved”, “owners poor communication with the construction parties and government authorities”, “poor coordination by the owner with the various parties during construction” and “owners failure to coordinate with government authorities during planning”. These factors can be allocated to one factor “poor communication and coordination” as project-related factor.

The most extreme article in mentioning the same factors is the article of Aziz & Abdel-Hakam (2016). For example, they have mentioned four factors “labour injuries”, “site accidents due to negligence”, “site accidents due to lack of safety measures” and “accidents/mistakes during construction” while other articles, only mention the factor “accidents during construction”. Another example in the article of Aziz & Abdel-Hakam (2016) are the nine similar factors, namely “geological problems on site”, “unexpected underground conditions”, “poor terrain condition”, “inaccurate specification of site condition”, “faulty soil investigation paper”, “poor site layout”, “different-unfavourable site conditions”, “poor ground condition” and “poor soil quality” while other articles only mention the factor “unforeseen site conditions”. Not all two hundred and ninety-three (293) factors are taken into account because many factors reviewed by Aziz & Abdel-Hakam (2016) are similar or covered by one factor.

Factors not applicable in the Netherlands, such as “conflict, war, revolution, riot, and public enemy” and “infectious disease” will not be included in the list of factors. Other examples of excluded factors are “monopoly”, “bribes & personal interest (corruption)” and “fraudulent practices”. As these factors are not permitted under the laws and regulations in the Netherlands. After carefully considering the factors that can be assigned to which factor, a list of one hundred and thirty-six (136) factors that cause delays is collected, taking into account not to repeat any factor.

The five most mentioned factors that influence construction projects are “delay in progress payments by the client” (mentioned 27 times), “ineffective planning and scheduling by the contractor” (mentioned 24 times), “unfavourable weather conditions” (mentioned 23 times), “Slowness in clients’ decision-making process” (mentioned 22 times) and “poor site management and supervision” (mentioned 22 times). The other most mentioned factors that influence the construction projects retrieved from the literature review are shown in Table 6.

Table 6: Most mentioned factors influencing construction projects

No.	Cause of delay	Group	Occurrence
1	Delay in progress payments from the client	Client	27
2	Ineffective planning and scheduling	Contractor	24
3	Unfavourable weather conditions	External	23
4	Slowness in the decision-making process	Client	22
	Poor site management and supervision	Contractor	22
6	Rework due to errors	Contractor	21
7	Unforeseen site conditions	Site	20
	Lack of experience of the contractor	Contractor	20
9	Poor communication and coordination	Project	19
	Shortage of labour	Labour	19
	Equipment(s) shortage	Equipment	19
12	Unrealistic enforced contract duration	Contractual	18
13	Contractors' financial difficulties for the project	Contractor	17
	Delay in material delivery	Material	17
	Fluctuation of material prices	Material	17
16	Change orders	Client	16
	Changes in government regulations and laws	External	16
	Shortage of construction materials	Material	16
19	Clients' financial difficulties for the project	Client	15
20	Legal dispute(s) between various parts	Contractual	14
	Delay in obtaining permits from authorities	External	14

Besides the frequently most mentioned factors, there are also factors that are only mentioned a few times. For example, there are fourteen factors that are only mentioned one time, these are “unfairness in tendering”, “poor risk management”, “breach of contract”, “unrealistic contract price”, “unfavourable contract clauses”, “commercial pressure”, “new instructions to additional work”, “time spent to find appropriate subcontractors/suppliers”, “work interference between various contractors”, “replacement contractor”, “lack of motivation for contractors for early finish”, “emergency works”, “replacement of consultants” and “receiving materials that do not fulfil project requirements”. Despite, these factors are mentioned only once, they are included in the expert interviews in order to have a complete assessable list of possible factors.

2.4 Comparison of the influencing factors per country

It cannot be assumed that all factors of the literature review are applicable in the Netherlands. It is expected that results may differ because there are differences in law and legalisation, climate, economy and culture within every country. In the next sections, a comparison is conducted between the articles in Europe, the Middle East, India and Malaysia to see whether the various articles found similar important factors that influence construction projects in a different continent or country. In each comparison, different colours were used to distinguish similar factors. An identical colour means that those factors were considered as similar. The yellow coloured factors do not appear in other articles in the comparison. It was decided to use colours in order to clearly indicate where the similarities and differences are.

2.4.1 Comparison of factors in Europe

The nearest reviewed articles to the Netherlands are the articles conducted in Denmark, Poland, Portugal and Sweden. In Denmark, Larsen, Shen, Lindhard, & Brunoe (2016) have analysed the factors that project managers experience as having the greatest effect on time, cost, and quality, and to discover whether the effects of these factors are significantly different from each other in publicly funded construction projects. In Poland, Głuszak & Lešniak (2015) have presented their findings of a survey aimed at identifying the most important factors that cause delays in construction works from the client's perspective. In Portugal, Arantes, Da Silva, & Ferreira (2015) have aimed to identify the main factors that cause delays and its impact on the construction industry, with the purpose of increasing knowledge on the factors and impacts of delays in Portuguese construction projects. In Sweden, Adam, Josephson, & Lindahl (2014) have investigated the occurrence and the explanations for cost overruns and delays in major construction projects from the public client's perspective on the basis of a literature review.

Most of the European articles are conducted from the perspective of the client in the construction industry. The articles of Arantes et al. (2015); Głuszak & Lešniak (2015); Larsen et al. (2016) have revealed the most important factors that cause delays in construction projects within their research country in a short list of the most important factors. However, this is not the case in the article of Adam et al. (2014). They have investigated the occurrence and explanations of factors that cause cost and time overruns, that makes it difficult to compare the results of Adam et al. (2014) with the other European articles. In these reviewed articles, it is noticeable that various numbers of delay factors are mentioned in each article as shown in Table 7 and Appendix B – The Literature review: Detailed overview. The next section discusses the unusual factors that are included in only one of the European articles.

Table 7: Influencing factors in Europe

Author(s)	Larsen et al. (2016)	Głuszak & Leśniak (2015)	Arantes et al. (2015)
Country	Denmark	Poland	Portugal
Number of factors	26	18	47
Type of projects	Publicly funded projects	Construction industry	Construction industry
Research representative(s)	Project managers	Client	Client, contractor and consultant
Most important factors that cause delays	(1) State of market conditions (2) Weather conditions (3) Selection and assignment criteria (4) Soil conditions (5) Change of partners in the project organisation (6) Lack of requirement specifications in tender documents (7) Miscommunication between project partners (8) Unforeseeable authority requirements or restrictions (9) Lack of project structure or material (10) Inexperienced or newly qualified construction supervisors	(1) Mistakes and inconsistencies in the design documentation (2) Workforce quality – hiring untrained workers (3) Adverse weather conditions (4) Poor quality of the management and supervision of the construction (5) The contractor company's internal problems (6) Difficulties in obtaining the necessary permits to implement the works (7) Unrealistic (too short) period of project implementation (8) Ineffective planning (9) Investor's difficulties in obtaining funds to finance the investment (10) Insufficient necessary equipment at the construction site	(1) Slow decision-making by developer (2) Change orders (3) Unrealistic time schedule and specifications in contract (4) Financial constraints on the part of contractor (5) Bidding and contract award process (6) Delay in progress payments by developer (7) Improper planning and scheduling (8) Developer interference (9) Increase in scope of work (10) Mistakes and discrepancies in drawings

* Different colours were used to distinguish similar factors (yellow coloured factors do not appear in other articles in the comparison)

Larsen et al. (2016) have taken the factors "state of the market conditions", "lack of requirement specifications in tender documents" and "unforeseeable authority requirements or restrictions" into account in their article while this is not the case in the other European articles. The article of Głuszak & Leśniak (2015) has considered the factor "insufficient necessary equipment at the construction site" as important in their article although this is not the case in Adam et al. (2014); Arantes et al. (2015); Larsen et al. (2016). Arantes et al. (2015) have taken the factors "financial constraints on the part of contractor" and "developer interference" into account while this is not the case in the other European articles. Although these factors are not mentioned in all the European articles, these factors are several times mentioned in other conducted articles. Now the unusual used factors in Europe are discussed, the similarities between these articles are elaborated in the next sections.

In the article of Larsen et al. (2016) mentioned factor “weather conditions” and in the article of Głuszak & Lešniak (2015) mentioned factor “adverse weather conditions” are considered to have an impact on causing delays in the construction industry of the research country. These factors can be assigned to the factor “unfavourable weather conditions” in this thesis.

The factor “selection and assignment criteria” mentioned in the article of Larsen et al. (2016) and the “bidding and contract award process” mentioned in the article of Arantes et al. (2015) appears to cause delays. These factors can be allocated to the factor “selection and assignment criteria” in this thesis. Another similar factor that appears to cause delays is the factor “lack of project structure or material” mentioned in the article of Larsen et al. (2016) and the “increase in scope of work” mentioned in the article of Arantes et al. (2015). These factors can be assigned to the factor “lack/increase of scope definition” in this thesis.

In the article of Głuszak & Lešniak (2015) mentioned factor “mistakes and inconsistencies in the design documentation” and in the article of Arantes et al. (2015) mentioned factor “mistakes and discrepancies in drawings” are considered to have an impact on causing delays in the construction industry of the research country. These factors can be allocated to the factor “mistakes and discrepancies in design documents” in this thesis. The factor “unrealistic (too short) period of project implementation” mentioned in the article of Głuszak & Lešniak (2015) and the factor “unrealistic time schedule and specifications in contract” mentioned in the article of Arantes et al. (2015) seems to have an impact on causing delays. These factors can be assigned to the factor “unrealistic enforced contract duration” in this thesis. At last, the factor “ineffective planning” mentioned in the article of Głuszak & Lešniak (2015) and the factor “improper planning and scheduling” mentioned in the article of Arantes et al. (2015) appears to cause delays in the construction industry of the research country. These factors can be assigned to the factor “ineffective planning and scheduling” in this thesis.

2.4.2 Comparison of factors in the Middle East

A total of eight reviewed articles have been conducted in the Middle East. The three most similar articles to this thesis, are compared in the next sections. The comparison of the Middle East is interesting because of the differences in law and legalisation, climate, economy and culture compared to the Netherlands. The article of Gunduz & AbuHassan (2016) has investigated the significant project factors affecting construction delays in Qatar construction projects. Gündüz et al. (2013) have aimed to identify delay factors on construction projects in Turkey and analyse these factors with the Relative Importance Index. The article of El-Sayegh (2008) has identified and assessed the significant risks in the United Arab Emirates construction industry and addresses their proper allocation.

The compared articles conducted in the Middle East are conducted from a general perspective. The articles of El-Sayegh (2008); Gunduz & AbuHassan (2016); Gündüz et al. (2013) have revealed the most important factors that cause delays in construction projects within the research country in a short list of the most important factors. The comparison between the articles conducted in the Middle East in Table 8 and Appendix B – The Literature review: Detailed overview shows that not all articles included the same number of factors. The next section discusses the unusual mentioned factors that are included in only one of the articles conducted in the Middle East.

The article of Gündüz et al. (2013) has taken the factor "unreliable subcontractors" into account while this is not the case in the other articles. On the other hand, El-Sayegh (2008) has taken the factors "owners' improper intervention during construction" and "lack or departure of qualified staff" into account while this is not the case in the other articles. In addition, the other articles conducted in the Middle East, that are not considered in the comparison, do mention these factors multiple times. Now the unusual included factors in the comparison are discussed, the similarities between factors that cause delays mentioned in the Middle East articles are elaborated in the next sections.

In the article of Gunduz & AbuHassan (2016) mentioned factor "delays due to material delivery", the factor "late delivery of materials" mentioned in the article of Gündüz et al. (2013) and the factor "delay of material supply by suppliers" mentioned in the article of El-Sayegh (2008) can be assigned to the factor "delay in material delivery" in this thesis. This factor appears to cause delays in the articles conducted in the Middle East.

Table 8: Influencing factors in the Middle East

Author(s)	**Gunduz & AbuHassan (2016)**	**Gündüz et al. (2013)**	**El-Sayegh (2008)**
Country	Qatar	Turkey	United Arab Emirates
Number of factors	42	83	42
Type of projects	Construction industry	Construction industry	Construction industry
Research representative(s)	Client, contractor, consultant, designer, subcontractor, supplier	Project managers, site managers, technical office managers etc.	International & national companies
Most important factors that cause delays	(1) Delay in decision-making (2) Poor site management and supervision by the contractor (3) Shortage of construction materials (4) Changes to the project by owner (5) Shortage of labour (6) Delays due to material delivery (7) Low productivity of labour (8) Unqualified workforce (9) Delay in approval of submittals, design drawings, shop drawings, and sample materials (10) Deficiency in planning and scheduling of project	(1) Inadequate contractor experience (2) Ineffective project planning and scheduling (3) Poor site management and supervision (4) Delay in progress payments from the clientdesign changes by the owner or his agent during construction (5) Late delivery of materials (6) Unreliable subcontractors (7) Delay in performing inspection and testing (8) Unqualified/inexperien ced workers (9) Change orders (10) Delay in site delivery	(1) Inflation and sudden changes in prices (2) Owners' unreasonably imposed tight schedule (3) Subcontractors' poor performance and management (4) Delay of material supply by suppliers (5) Change of design required by owners (6) Owners' improper intervention during construction (7) Shortage in manpower supply and availability (8) Delays in approvals (9) Lack or departure of qualified staff (10) Shortage in material supply and availability

* Different colours were used to distinguish similar factors (yellow coloured factors do not appear in other articles in the comparison)

The mentioned factor “deficiency in planning and scheduling of the project” in the article of Gunduz & AbuHassan (2016) and the mentioned factor “ineffective project planning and scheduling” in the article of Gündüz et al. (2013) can be assigned to the factor “ineffective planning and scheduling” in this thesis. This factor seems to cause delays and is often mentioned in the articles that have been conducted in the Middle East. Gunduz & AbuHassan (2016) and Gündüz et al. (2013) have considered the factor “poor site management and supervision” as a factor that cause delays. The factor “changes to the project by owner” mentioned in the article of Gunduz & AbuHassan (2016) and the “change orders” mentioned in the article of Gündüz et al. (2013) seems to be factors that cause delays. These factors can be allocated to the factor “changed conditions of the project” in this thesis. The factor “unqualified workforce” mentioned in the article of Gunduz & AbuHassan (2016) and the “unqualified/inexperienced workers” mentioned in the article of Gündüz et al. (2013) appears to cause delays and can be assigned to the factor “unqualified workforce” in this thesis.

Another similar factor that cause delays are the factors “shortage of construction materials” mentioned in Gunduz & AbuHassan (2016) and the mentioned factor “shortage in material supply and availability” in the article of El-Sayegh (2008). These factors can be assigned to the factor “delay in progress payments from the client” in this thesis. In the article of Gunduz & AbuHassan (2016) mentioned factor “shortage of labour” and in the article of El-Sayegh (2008) mentioned factor “shortage in manpower supply and availability” appears to cause delays. These factors can be assigned to the factor “shortage of labour” in this thesis. The in Gunduz & AbuHassan (2016) mentioned factor “delay in approval of submittals, design drawings, shop drawings, and sample materials” and in El-Sayegh (2008) mentioned “delays in approvals” seems to be factors that cause delays. These factors can be allocated to the factor “late in revising and approving design documents” in this thesis.

The factor “inadequate contractor experience” mentioned in the article of Gündüz et al. (2013) and the factor “subcontractors’ poor performance and management” mentioned in the article of El-Sayegh (2008) appears to be a common factor that cause delays and can be assigned to the factor “lack of experience of the contractor” in this thesis. At last, the factor “design changes by the owner or his agent during construction” mentioned in the article of Gündüz et al. (2013) and the “change of design required by owners” mentioned in the article of El-Sayegh (2008) appears to cause delays. These factors can be assigned to the factor “design changes” in this thesis.

2.4.3 Comparison of factors in India

Several articles are conducted in India about factors that cause delays. Although the Indian construction industry is different compared to the Netherlands, it is interesting to know if there are similar results from the articles within the same country. Bhadoria et al. (2016) have identified the factors that cause delays and evaluated these factors by the Relative Importance Index & importance index technique. This technique has proved to be extremely effective on identifying causes of delay in building construction projects. The article of Doloi et al. (2012) has aimed to identify the various factors for construction delays, to identify the relationship between these factors by statistical methods and to predict the impact of these identified factors on construction delay using a regression model in the Indian construction sector. Rajgor, Paresh, Dhruv, Chirag, & Dhrmesh (2016) have conducted a survey in India to identify and evaluate the relative importance of the significant factors contributing to delays in construction projects. The article of Ravisankar, Anandakumar, Krishnamoorthy, & Phill (2014) has aimed to identify the major factors that cause delays in the construction industry of India.

Most articles in India are conducted from a general perspective in the construction industry by using knowledge of the client, contractor and the consultant. The articles of Bhadoria et al. (2016); Doloi et al. (2012); Rajgor et al. (2016); Ravisankar et al. (2014) have revealed the most important factors that cause delays in construction projects within India, this resulted in a short list of the most important factors. The comparison between the articles in India in Table 9 and Appendix B – The Literature review: Detailed overview shows that not all articles included the same number of factors that cause delays. The next section discusses the factors that are included in only one of the Indian articles.

The article of Rajgor et al. (2016) has taken the factors “shortage of unskilled & skilled labour” into account while this is not the case in the other articles conducted in India. It can be argued that the factor “shortage of unskilled & skilled labour” can be assigned to the factor “shortage of labour”, however, the reviewed literature often describes these factors separately. It is taken into account that these factors look similar however they are not allocated as a similar factor in this thesis. Now the unusual included factors are discussed, the similarities between the Indian articles are elaborated in the next sections.

Table 9: Influencing factors in India

Author(s)	Bhadoria et al. (2016)	Doloi et al. (2012)	Rajgor et al. (2016)	Ravisankar et al. (2014)
Country	India	India	India	India
Number of factors	34	45	16	50
Type of projects	construction industry	construction industry	All types of projects	Construction industry
Research representative(s)	Clients, contractors and consultants	Client, contractor and design/architect	Contractors, project engineers, client, consultant etc.	Various construction industries
Most important factors that cause delays	(1) Rework due to errors during construction (2) Inadequate planning and scheduling of project by contractor (3) Original contract duration is too short (4) Delay in material delivery (5) Shortage of labour (6) Poor site management and supervision by the contractor (7) Inadequate contractor's work experience (8) Difficulties in financing project by contractor (9) Delay in progress payment by client (10) Shortage of equipment	(1) Lack of commitment - (Delay in material delivery) (2) Inefficient site management - (Inadequate contractor experience) (3) Poor site coordination – (Slow decision-making, unrealistic time schedule and poor site management and supervision) (4) Improper planning - (Extreme weather conditions) (5) Lack of clarity in project scope - (Rework due to errors) (6) Lack of communication (7) Substandard contract	(1) Change orders by client during construction (2) Original contract duration is too short (3) Poor communication and coordination by client and other parties (4) Slowness in the decision-making process by client (5) Poor site management and supervision by contractor (6) Delay in material delivery (7) Delay in progress payments from the client (8) Personal conflicts among labours (9) Delay in providing services from utilities (10) Improper construction methods implemented by contractor	(1) Shortage of unskilled & skilled labour (2) Design changes by client or his agent during construction (3) Fluctuation of prices (4) High waiting time for availability of work teams (5) Rework due to errors (6) Delay in financial support by client to the contractor (Stage by stage payment) (7) Geological problems on site (8) Poor site management & Inaccurate site investigation (9) Wrong selection of type /capacity of equipment (10) Bad weather conditions /Natural disasters

* Different colours were used to distinguish similar factors (yellow coloured factors do not appear in other articles in the comparison)

In the articles of Bhadoria et al. (2016); Doloi et al. (2012); Rajgor et al. (2016) mentioned factor “poor site management and supervision (by the contractor)” and in the article of Ravisankar et al. (2014) mentioned factor “poor site management & Inaccurate site investigation” can be assigned to the factor “poor site management and supervision” in this thesis. This factor seems to be a common factor that cause delays in the reviewed articles conducted in India. Bhadoria et al. (2016); Doloi et al. (2012); Ravisankar et al. (2014) all have considered the factor “rework due to errors (during construction)” in their article as a factor that cause delays. The factor “original contract duration is too short” mentioned in Bhadoria et al. (2016); Rajgor et al. (2016) and the factor “unrealistic time schedule” mentioned in Doloi et al. (2012) can be assigned to the factor “unrealistic enforced contract duration” in this thesis. The factor “unrealistic enforced contract duration” is a factor that can cause delays. The articles of Bhadoria et al. (2016); Doloi et al. (2012); Ravisankar et al. (2014) all have mentioned the factor “delay in material delivery” as factor that cause delays. Another factor that can cause delays, is the factor “delay in progress payment by client” mentioned in Bhadoria et al. (2016); Rajgor et al. (2016) and the factor “delay in financial support by client to the contractor (Stage by stage payment)” mentioned in Ravisankar et al. (2014). These factors can be assigned to “delay in progress payments from the client” in this thesis.

The factor “inadequate contractor’s (work) experience” mentioned in the articles of Bhadoria et al. (2016); Doloi et al. (2012) seems to be a factor that cause delays. This factor can be assigned to the factor “lack of experience of the contractor” in this thesis. The mentioned factor “shortage of labour” in Bhadoria et al. (2016) and the factor “high waiting time for availability of work teams” mentioned in Ravisankar et al. (2014) seems to be a factor that cause delays and can be allocated to the factor “shortage of labour” in this thesis. The article of Doloi et al. (2012) has mentioned the factor “slow decision-making” and Rajgor et al. (2016) have mentioned the factor “slowness in the decision-making process by client” as a factor that can cause delays. These factors can be assigned to the factor “slowness in the decision-making process” in this thesis. At last, the factor “extreme weather conditions” in the article of Doloi et al. (2012) and the factor “bad weather conditions/natural disasters” in the article of Ravisankar et al. (2014) seems to cause delays. This can be allocated to the factor “unfavourable weather conditions” in this thesis.

2.4.4 Comparison of factors in Malaysia

Three reviewed articles in Malaysia have conducted a research about the factors that cause delays. The previous sections confirmed that there are some similarities between the articles within a continent or country. Malaysia is a small country with fewer inhabitants compared to India, making it interesting to know whether the results show other similarities. The article of Sambasivan & Soon (2007) has purposed to identify the delay factors and their impacts (effect) on project completion in Malaysia. Shehu et al. (2014) have aimed to assess those factors leading to time overrun in Malaysian construction projects. The project delays on the Ninth Malaysia Plan as evidenced in the Universiti Kebangsaan Malaysia campus have been described in the article of Tawil, Khoiry, Arshad, & Hamzah (2013).

Similar to the Indian and the Middle East articles, most of the articles in Malaysia are conducted from a general perspective in the construction industry by using knowledge of the client, contractor and the consultant. The articles of Sambasivan & Soon (2007); Shehu et al. (2014); Tawil et al. (2013) have revealed the most important factors that cause delays in construction projects within Malaysia in a short list of the most important factors. Not all the reviewed articles in Malaysia included the same number of factors as shown in Table 10 and Appendix B – The Literature review: Detailed overview. The next section discusses the unusual factors that are included in only one of the Malaysian articles.

Table 10: Influencing factors in Malaysia

Author(s)	Sambasivan & Soon (2007)	Shehu et al. (2014)	Tawil et al. (2013)
Country	Malaysia	Malaysia	Malaysia
Number of factors	28	84	22
Type of projects	Construction industry	Construction industry	Government projects
Research representative(s)	Clients, contractors and consultants	Clients, contractors and consultants	Contractors and consultants
Most important factors that cause delays	(1) Contractor's improper planning (2) Contractor's poor site management (3) Inadequate contractor experience (4) Inadequate client's finance and payments for completed work (5) Problems with subcontractors (6) Shortage in material (7) Labour supply (8) Equipment availability and failure (9) Lack of communication between parties (10) Mistakes during the construction stage	(1) Cash flow problems faced by the contractor (2) Late payment from the contractor to sub-contractors or suppliers (3) Problems between the contractor and his sub-contractors with regards to payments (4) Ineffective planning and scheduling by the contractor (5) Difficulties in financing the project by the contractor (6) Ineffective control of the project progress by the contractor (7) Late payment from client to contractor (8) Bureaucracy in government agencies (9) Slow permits by local authorities (10) Delay in progress payments by the client	(1) Insufficient capital (2) Delay in getting progress payment (3) Delay in getting work approval (4) Contractor management problems (5) Scarce / Insufficient construction materials (6) New instructions for additional works (7) Weather and surroundings (8) Professional management (9) Structure re-checking* (10) Increase in price of materials

* Different colours were used to distinguish similar factors (yellow coloured factors do not appear in other articles in the comparison)

The article of Sambasivan & Soon (2007) has taken the factors “mistakes during the construction stage” into account while this is not the case in all the conducted articles in Malaysia. On the other hand, Shehu et al. (2014) have taken the most deviant factors into account because the factors “cash flow problems faced by the contractor”, “late payment from the contractor to sub-contractors or suppliers”, “difficulties in financing the project by the contractor, “ineffective control of the project progress by the contractor” and “slow permits by local authorities” are not used in the other articles in Malaysia. The article of Tawil et al. (2013) has incorporated the factors “insufficient capital”, “contractor management problems”, “new instructions for additional works” and “professional management” while this is not the case in the other Malaysian articles. Now the unusual included factors are discussed, the similarities between the Malaysian articles are elaborated in the next sections.

In the article of Sambasivan & Soon (2007) mentioned factor “inadequate client’s finance and payments for completed work”, the in Shehu et al. (2014) mentioned factors “late payment from client to contractor” and “delay in progress payments by the client” and the in Tawil et al. (2013) mentioned factor “delay in getting progress payment” appears to be a common factor that cause delays. These factors can be assigned to the factor “delay in progress payments from the client” in this thesis.

The factor “contractor’s improper planning” mentioned in the article of Sambasivan & Soon (2007) and the “ineffective planning and scheduling by the contractor” mentioned in the article of Shehu et al. (2014) seems to be factors that cause delays. These factors can be allocated to the factor “ineffective planning and scheduling” in this thesis. In the article of Sambasivan & Soon (2007) mentioned factor “problems with subcontractors” and in the article of Shehu et al. (2014) mentioned factor “problems between the contractor and his sub-contractors with regards to payments” appears to cause delays. These factors can be assigned to the factor “frequent change of sub-contractors/suppliers” in this thesis.

At last, the factor “shortage in material” mentioned in the article of Sambasivan & Soon (2007) and the “scarce / insufficient construction materials” mentioned in the article of Tawil et al. (2013) seems to cause delays and can be assigned to the factor “shortage of construction materials” in this thesis.

2.4.5 Conclusion comparison of the influencing factors per country

The results were expected to vary because there are differences in law and legalisation, climate, economy and culture in each country. The comparison shows that the most important factors that influence construction projects are of an economic or cultural nature. This economic nature refers, for example, to the state of the market, financial problems in the project and the availability of materials, equipment and labour. On the other hand, the cultural nature refers to all human actions from changes in the project to decision-making and management. The studies conducted in Europe, the Middle East, India and Malaysia in the comparison shows that the law and legalisation and the climate have less impact on the factors that cause delays. In the studies conducted in Malaysia, it is noticeable that more factors have an economic nature compared to studies conducted in Europe, the Middle East and India. Looking at the studies conducted in the Middle East, the factors with an economic nature play a smaller role in comparison with the studies conducted in Europe and India.

The comparison shows differences in the most important factors that cause delays in the various countries. This means that the factors cannot be implemented directly from the literature. To fill the gap in the literature and find the factors that are applicable in the execution phase of Utility construction projects (UCP), a number of expert interviews are needed as described in the next Chapter of this thesis.

2.5 Types of factors that cause delays

As discussed in the previous chapter, this thesis focuses on the critical delay factors. In order to find the critical factors, the next step is to make a difference between critical and non-critical factors. expert interviews are needed because the critical factors that cause delays are not extensively described in the literature, this is discussed in Chapter 3. While reviewing the literature a definition for describing the critical factors is found in the article of Ravisankar et al. (2014). This definition has been adopted in this thesis. In the literature, the terms excusable and non-excusable delays are commonly used for determining who is responsible for causing the delay (Arditi, Nayak, & Damci, 2017; Gardezi, Manarvi, & Gardezi, 2014; Tawil et al., 2013). These concepts are included in the expert interviews to distinguish the critical factors that cause delays in the execution phase of UCP and who is responsible for causing these delays.

2.5.1 Critical Factors

Critical factors are causes where the milestones or project completion date are affected (Ravisankar et al., 2014). When a critical factor occurs, the project completion date or a milestone date will be delayed. Determining the activities that influence the project completion date depends on the project itself, the contractor's plan and schedule, the requirement of the contract for sequence and phasing, the physical constraint of the project (Ravisankar et al., 2014). This means that knowledge from experts is required for insights into the critical factors that cause delays and affect the execution phase of UCP.

2.5.2 Excusable versus Non-excusable

Excusable delays are caused by an unforeseeable event beyond the contractor's or the subcontractor's control (Arditi et al., 2017; Gardezi et al., 2014; Tawil et al., 2013). On the other hand, *Non-excusable delays* are caused by the contractor, its sub-contractors or its suppliers (Arditi et al., 2017; Gardezi et al., 2014; Tawil et al., 2013). In such case, the contractor does not receive any compensation and is obliged to expedite the progress of works or make compensations to the client (Arditi et al., 2017; Gardezi et al., 2014; Tawil et al., 2013).

2.5.3 Conclusion types of factors that cause delays

Since this thesis focuses on critical delay factors that cause delays in the execution phase of UCP a definition is required. In the literature, a definition has been found for the critical factors that cause delays and whether these factors are excusable or non-excusable. Exploring the type of factors gave guidelines for the expert interviews in the next Chapter of this thesis. In these expert interviews, these definitions make it possible to distinguish the critical factors that cause delays from factors whose impact is considered less severe and who is responsible for causing the delay. The experiences of the interviewees help to fill the literature gap for this thesis and find the critical factors that cause delays and affect the execution phase of UCP.

2.6 Conclusion literature review: Search for the influencing factors

The focus of this literature review was to quantify the various factors that influence construction projects. Although the aim of this thesis is to select the critical factors in the execution phase of UCP in particular, the literature review showed that several international articles viewed factors that cause delays and affect construction projects from different research perspectives. In each article, various numbers of important delay factors were found from different groups of representatives (i.e. Client, contractor and consultant).

The literature review has answered sub-question I – which factors influence construction projects? The answer to sub-question I includes a total of one hundred and thirty-six (136) factors that influence construction projects. These factors are reviewed from the literature review and are shown in Appendix A – Literature review: Influencing factors. These one hundred and thirty-six (136) factors are categorised in eleven groups, namely project-related, contractual-related, client-related, contractor related, consultant related, design-related, site-related, material-related, equipment-related, labour-related and external-related without repeating any cause.

Unfortunately, the literature review, has not answered whether these influencing factors are critical and applicable in the execution phase of UCP. Since this is an important part of this thesis, this gap in literature has to be further explained. The literature review provided the definitions to distinguish the critical factors that cause delays from factors whose impact are considered less severe. A number of expert interviews will help to find the factors that are critical and applicable in the UCP during the execution phase. In these expert interviews, the factors that influence construction projects, collected from the literature review, will form the guidelines for carrying out a delay analysis. In the next Chapter of this thesis, the results of the expert interviews will help to find an answer to which critical factors cause delays and affect the execution phase of UCP in order to answer sub-question II and develop questionnaire (I).

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3 Expert Interviews: Search for the critical factors

This Chapter focuses on searching the critical factors that cause delays and affect the execution phase of Utility construction projects (UCP). The literature review gave guidelines for these factors, however, it turned out to be a limited overview of factors that influence construction projects. For now, the factors that are critical and applicable in the execution phase of UCP are not known. To obtain an overview of the critical factors that cause delays and affect the execution phase of UCP, expert interviews are carried out. The purpose of the expert interviews is to answer sub-question II – Which critical factors cause delays and affect the execution phase of UCP? For the expert interviews, an interview framework is used that is discussed in Chapter 3.1. The results of the expert interviews are presented in Chapter 3.2. At last, Chapter 3.3 discusses the conclusion of the conducted literature review and answer sub-question II. As a result, a list of critical factors that cause delays and affect the execution phase of UCP is compiled.

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3.1 Set- up expert interviews

The stated research objective, research question(s) and the knowledge already acquired in the literature review on the factors that influence construction projects are the guidelines for the conducted expert interviews. The structure of the interviews is on the basis of a general set of questions to formally quantify the applicable critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in order to answer sub-question II. The interviewees had to be experts on the factors that cause delays and affect the execution phase of UCP. Therefore, experts with multiple years of work experience and a managerial occupational level were interviewed. These experts have a broad overview of factors that cause delays and affect UCP because they often know the ins and outs of multiple UCP. The expert interviews were guided by an interview framework that is designed by means of the literature review in Appendix C – Expert Interviews: Set-up. The interview framework was divided into two parts, namely the demographic questions and the discussion of the critical factors.

The first part was intended to collect demographic data from the expert interviews. Demographic questions were asked regarding occupational level, gender, age, level of education, working experience, the average project size and some case studies of executed UCP by the expert with the corresponding contract type. By doing this, it was intended to collect information about the respondents' profile. With this respondents' profile, it is possible to determine the level of experience of the interviewed experts.

The second part was intended to get the perception of the applicable critical factors that cause delays and affect the execution phase of UCP. This second part was divided into two main components. In the first component, the examples of executed UCP were used to identify whether the case studies are executed in time, which factors influenced these projects and whether these factors were critical, excusable or non-excusable. In the second component, the experts assessed the factor list retrieved from the literature review by appointing the critical factors and whether these factors are excusable or non-excusable.

It was expected that the results of the expert interviews are useful for answering sub-question II and make a shorter list of applicable critical factors that cause delays and affect the execution phase of UCP. The shorter list with applicable critical factors serves as input for Questionnaire (I). The analysis and results of the expert interviews are discussed in the next sections of this thesis.

3.2 Results expert interviews

This thesis tries to map sensitive information. Therefore, the interviews were processed anonymously to ensure that the information provided by the interviewed expert is used confidential. In total seven interviews were held with business/project managers. The average level of education was the University of applied science (HBO) and all the interviewed experts worked in the construction industry for more than ten years. This suggests that there is sufficient knowledge and rich experience to make their answers reliable to take into account.

The expert interviews made clear that it is difficult to determine factors that play a critical role during the execution phase of UCP. As said before, UCP are one-off endeavours with many unique features. The factors that play a critical role during the execution phase of UCP will strongly depend on the parties involved in the project, the type of contract and the circumstances of the project. In the search for critical factors, the selected case studies by the interviewee helped to highlight factors that encountered in these specific projects. The interviewed experts have mentioned multiple critical factors applicable in the execution phase of UCP that can be assigned to the factors from the literature review in Appendix A – Literature review: Influencing factors. Table 11 shows the critical factors mentioned in the interviewed experts. All the mentioned factors from the case studies of the interviews can be placed under factors found in the literature review. The factors encountered in the case studies are included in questionnaire (I) in the next sections.

Table 11: Factors encountered in the case studies of the interviewed experts

No.	Factors mentioned in case studies
Interview 1	Unforeseen site conditions/ Effects of subsurface conditions (e.g. Soil, high water table, etc.)
	Legal dispute(s) between various parts
	Rework due to errors
	Poor project management
	Ineffective planning and scheduling/ Inaccurate time and cost estimations
	Inaccurate time and cost estimations
	Discrepancy between design specification and construction/ Mistakes or discrepancies in document(s) or specifications/ Incomplete and unclear drawings
Interview 2	Clients' financial difficulties for the project
Interview 4	New instructions to additional work
	Discrepancy between design specification and construction/ Mistakes or discrepancies in document(s) or specifications/ Incomplete and unclear drawings
	Environmental restrictions
Interview 5	Improper equipment
Interview 6	Shortage of construction materials/ Equipment(s) shortage
	Ineffective planning and scheduling
	New instructions to additional work
	Problem with nearby neighbours, structure or facilities
	Discrepancy between design specification and construction/ Unforeseen site conditions/ Improper feasibility study
	Conflicts between the contractor and other parties/ Unreliable sub-contractors/suppliers
	Slowness in the decision-making process
Interview 7	Not familiar with the condition of the contract
	Incomplete and unclear drawings
	Financial difficulties client

After the critical factors encountered in the case studies were collected, the experts were asked to share their experience and assessed the overall list of collected factors from the literature review in Appendix A – Literature review: Influencing factors. On the basis of the working experience, the expert indicated whether a factor can be considered as critical on the basis of the definition from Chapter 2.4. After a factor was considered as critical, the experts were asked to indicate whether a critical factor is excusable or non-excusable by responsibility on the basis of the acquired definitions. The expert interviews showed that the critical factors applicable in the execution phase of UCP can be divided into three main groups on the basis of responsibility, namely client-related, contractor-related and external-related. When a factor is considered as critical by three or more experts, this factor is included in questionnaire (I) in the next Chapter of this thesis.

To complete the list of critical factors for questionnaire (I) the most mentioned factors, in the literature review that were not mentioned in the expert interviews, are included in the list of critical factors applicable in the execution phase of UCP. To include a factor from the literature review in the list of critical factors the following condition has to be met, namely the factor occurred at least ten times in the reviewed articles. The total list of critical factors compiled on the basis of the expert interviews and the literature review can be found in Appendix D – Expert Interviews: Results.

3.3 Conclusion expert interviews: Search for the critical factors

The expert interviews focused on searching the critical factors that cause delays and affect the execution phase of UCP. These interviews were necessary to obtain an overview of the critical factors that cause delays and affect the execution phase of UCP. More insights were needed because the literature review could only indicate the factors that influence construction projects. The purpose of the expert interviews was to answer sub-question II - Which critical factors cause delays and affect the execution phase of UCP?

On the basis of factors applicable in the case studies of the expert interviews and the assessment of the factor list from Appendix A – Literature review: Influencing factors, the critical factors applicable in the execution phase of UCP could be found. To ensure that the list is complete, the factors that occurred ten times or more in the literature review were included in the list of critical factors that cause delays and affect the execution phase of UCP. The list of one hundred and thirty-six (136) factors that influence construction projects is reduced to fifty-nine (59) critical factors that cause delays and affect the execution phase of UCP as shown in Appendix D – Expert Interviews: Results. The expert interviews helped to answer sub-question II by providing a list of fifty-nine (59) critical factors. In addition, it emerged that the factors can be divided into three main groups emerged by the responsibilities, namely client-related, contractor-related and external-related.

After answering sub-question II by compiling a list of critical factors on the basis of the expert interviews and the literature review, questionnaire (I) can be designed in the next chapter of this thesis. In this Chapter, the critical factors from Appendix D – Expert Interviews: Results are assessed by the opinion of a large group of respondents in order to select the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands.

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4 Questionnaire (I): Selection of the critical factors

This Chapter focuses on selecting the important critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in the Netherlands. The expert interviews gave a limited overview of the critical factors that cause delays and affect the execution phase of UCP. To obtain an overview of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands, the Fuzzy Delphi method (FDM) has been carried out to analyse the results of questionnaire (I). The purpose of the FDM is to answer sub-question III – What are the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? The methodology and the set-up of the FDM are discussed in Chapter 4.1. The data collection of questionnaire (I) is discussed in Chapter 4.2. Next, Chapter 4.3 presents the results of the FDM per representative group. The important critical factors that cause delays and affect the execution phase of UCP in the Netherlands are selected in Chapter 4.4. At last, Chapter 4.5 presents the conclusion of the FDM and answer sub-question III. As a result, a list of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands is compiled.

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4.1 Fuzzy Delphi methodology

In order to select the most important and most common critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in the Netherlands, the Fuzzy Delphi method (FDM) has been implemented for analysing the results of questionnaire (I). For the FDM an experiment was executed by means of questionnaire (I). This methodology is mainly used in order to find consensus within the human judgement of a panel of experts. The FDM is derived from the traditional Delphi method (DM) in combination with the fuzzy set theory (FT) (Glumac, Han, Smeets, & Schaefer, 2011; Ishikawa et al., 1993).

The traditional DM is one of the effective methods that enables forecasting by converging a possibility value through anonymous response, iteration and controlled feedback on the basis of expert judgements (Hsu, Lee, & Kreng, 2010; Ishikawa et al., 1993). Any error or inconsistency in the assessments of the expert's judgement affects the result of calculations (Habibi, Jahantigh, & Sarafrazi, 2015). The involved human factor in evaluating the importance of the critical factors may contain a large number of uncertainties, fuzziness or vagueness in the conclusion. Since the uncertainties or vagueness in the estimations results in a lack of clarity, the FT is helpful in dealing with the uncertainties or vagueness of the human judgement (Hsu et al., 2010). The fuzzy concepts, from the opinions of experts, about the critical factors are taken into consideration within the FDM. By combining the DM and the FT, a selection can be provided of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands.

Since the literature review and expert interviews does not address the most critical factors that cause delays and affect the execution phase of UCP in the Netherlands, additional information was needed for this thesis. The literature review provided a list of one hundred and thirty-six (136) factors that influence construction projects. In addition, expert interviews were conducted in order to find the critical factors applicable in the execution phase of UCP. The expert interviews reduced the list of one hundred and thirty-six (136) factors to fifty-nine (59) critical factors applicable in the execution phase of UCP. However, it remains unclear whether these critical factors are important for the Netherlands in general. Therefore, information from experts in the Netherlands on the critical factors that cause delays and affect the execution phase of UCP needs to be collected through questionnaire (I). The FDM is chosen to evaluate questionnaire (I) because it is an excellent method to collect such diverse panel data. It captures the uncertainty due to the human factor in valuation and improves the validity of the factor quantification (Glumac et al., 2011).

The following steps are discussed in more detail in the next sections:

I. Collect opinions and Set-up questionnaire (I) (Chapter 4.1.1);
II. Overall triangular fuzzy number and defuzzification (Chapter 4.1.2);
III. After screen evaluation indexes (Chapter 4.1.3).

4.1.1 Collect opinions and Set-up questionnaire (I)

In order to select the important and most common factors that cause delays in the execution phase of UCP, the literature review and expert interviews were used as input for the set-up of questionnaire (I). The literature provided a total list of factors that influence construction projects as discussed in Chapter 2. This list of factors from the literature was very general and applicable in multiple construction disciplines. This thesis intended to find the most critical factors that cause delays and affect the execution phase of UCP. In order to find these critical factors, the opinions of experts were collected through expert interviews as discussed in Chapter 3. These experts have executed multiple projects and have much experience that help to make the list specific for questionnaire (I). The list of fifty-nine (59) critical factors applicable in the UCP has been made on the basis of the expert interviews and can be found in Appendix D – Expert Interviews: Results. The FDM started with the set-up of questionnaire (I) on the basis of the fifty-nine (59) critical factors from the expert interviews. For questionnaire (I), different representatives involved in the execution phase of UCP were asked to score the different factors on a seven-point Likert scale. The representatives that have participated to complete questionnaire (I) are divided in three groups (i.e. Client, contractor and consultant).

The Likert scale used in questionnaire (I) is shown in Table 12 including the triangular fuzzy numbers derived from Figure 7. To ensure the scales were interpreted correctly by the respondents a seven-point scale is used supported by text. There was chosen for a seven-point scale because there is a possibility to give a more precise answer by the respondents' ideas compared to a four- or five-point scale. In a four- or five-point scale the differentiation between the answer possibilities is less. The list of fifty-nine (59) critical factors were presented in questionnaire (I) to the respondents. Respondents were asked to rate the factors in the carefully designed questionnaire (I) to evaluate the importance of the factors that cause delays and affect the execution phase of UCP in the Netherlands. The full set-up of questionnaire (I) can be found in Appendix E – FDM: Set-up Questionnaire (I).

Table 12: Seven-point Likert scale with the accompanying fuzzy numbers

Description	**no effect**		**weak effect**		**strong effect**		**very strong effect**
Value	1	2	3	4	5	6	7
Fuzzy numbers (a_{ij}, b_{ij}, c_{ij})	$\tilde{1}$ (1,1,2)	$\tilde{2}$ (1,2,3)	$\tilde{3}$ (2,3,4)	$\tilde{4}$ (3,4,5)	$\tilde{5}$ (4,5,6)	$\tilde{6}$ (5,6,7)	$\tilde{7}$ (6,7,7)

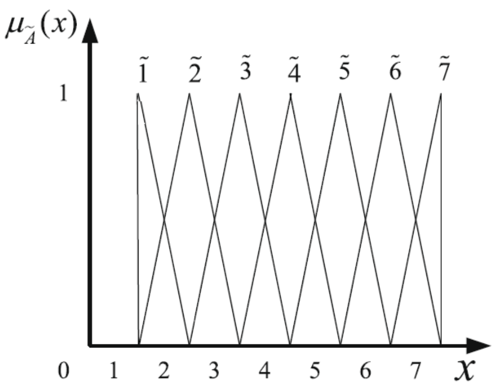

Figure 7: Scale of fuzzy numbers (adapted from Hsu et al. (2010))

4.1.2 Overall triangular fuzzy number and defuzzification

Questionnaire (I) results in a matrix, that shows the effect-scores for the factors that cause delays and affect the execution phase of UCP in the Netherlands by all the different respondents:

	R_1	R_2	…	R_n
F_1	L_{11}	L_{21}	…	L_{n1}
F_2	L_{12}	L_{22}	…	L_{n2}
…	…	…	…	…
F_m	L_{1m}	L_{2m}	…	L_{mn}

Where:

$R_i = The\ i^{th}\ respondent, i = 1, 2, \dots, n$

$F_j = The\ j^{th}\ factor, j = 1, 2, \dots, n$

$L_{i,j} = The\ evaluation\ of\ the\ criterion\ j\ by\ respondent\ i$

To calculate the evaluation value of each critical factor that cause delays given by experts, the general mean model proposed by Klir & Yuan (1995) was used, adopted from the research of Hsu et al. (2010) in order to find the common understanding of the group decisions. When using the general mean model, the evaluation value of one of the attributes by a single respondent is expressed as a triangular fuzzy number as shown in Table 12. Assuming the evaluation value of the significance of No. j factor given by No. i respondents out of n respondents is $\tilde{w}_{i,j} = (a_{ij}, b_{ij}, c_{ij}), i = 1, 2, \dots, n, j = 1, 2, \dots, m$. Then the fuzzy weighting $\tilde{w}_j$ of No. j factors is $\tilde{w}_j = (a_j + b_j + c_j), j = 1, 2, \dots, m$. Among which:

$$a_j = \underset{i}{Min}\{a_{ij}\}, b_j = \frac{1}{n}\sum_{i=1}^{n} b_{ij}, c_j = \underset{i}{Max}\{c_{ij}\}$$

The next step is to defuzzify the fuzzy weights $\tilde{w}_j$ of each critical factor, by using the simple centre of gravity method used in the article of Glumac et al. (2011); Hsu et al. (2010), to determine the single derived numbers of S_j where j = 1, 2, …, m:

$$S_j = \frac{(a_j + b_j + c_j)}{3}$$

4.1.3 After screen evaluation indexes

To select the important and most common factors that cause delays in the execution phase of UCP in the Netherlands. The single derived numbers were tested against a threshold (α). The principle is as follows:

If $S_j \geq \alpha$ then No. j factor is very important

If $S_j \geq \alpha$ then No. j factor is less important

In different articles, the threshold varies and is mostly set on the basis of the opinion of the researcher because there is no standard for setting a threshold (Habibi et al., 2015). Therefore, the threshold has to be set on the basis of the needs of the research (Hsu & Chen, 1996). The overall threshold, for all the respondents, was set on $\alpha \geq 0.68$ to ensure a limited number of twenty factors were selected in order to keep the research feasible in the next steps. The overall results are discussed in Chapter 4.4.

4.2 Data collection questionnaire (I)

4.2.1 Contact respondents for questionnaire (I)

Questionnaire (I) was designed using the free ThesisTools Online Enquêtes system. Through LinkedIn has been searched for large companies that have affinity with UCP. Within those companies, people were contacted who might want to cooperate with questionnaire (I). In order to ensure the quality of the respondents' answers, the respondent profiles were checked through LinkedIn. The respondent should be experts working in the execution phase of UCP with multiple years of work experience. These experts have a broad overview of factors that cause delays and affect the execution phase of UCP because they often know the ins and outs of multiple projects. If the person met the requirements of respondents' profile, this person has been contacted by sending an e-mail.

Over five hundred people, that matched the respondents' profile, were contacted to fill in questionnaire (I). In total three different groups of representatives (i.e. Client, contractor and consultant) were contacted. Not all the experts that started filling in questionnaire (I) completed the whole questionnaire. To ensure enough results could be collected a reminder was sent to the contacted persons. By doing this, the total number of completed questionnaires increased. In total one hundred and thirty-eight (138) respondents participated in completing questionnaire (I). The reasons why other respondents did not want to participate were either "Being too Busy", "Survey fatigue" or "Not involved in the execution phase of UCP".

4.2.2 Respondents' profile for questionnaire (I)

During questionnaire (I), it appeared that some level of attributes for the questions could be combined for certain questions because the response rate for one level of attribute was low. For example, the attribute years of work experience contain the attribute levels < 5 years (15 respondents) and 6 – 10 years (4 respondents) that can be combined to a new attribute level, namely < 10 years. By doing this, the response rate for the attribute level is higher and easier to compare the results. Another example is dividing the Netherlands in four parts, namely the West of the Netherlands (Noord-Holland, Utrecht, Zuid-Holland), the South of the Netherlands (Limburg, Noord-Brabant, Zeeland), the East of the Netherlands (Flevoland, Gelderland, Overijssel) and the North of the Netherlands (Drenthe, Friesland, Groningen) instead of all the provinces in the level of attributes. The respondent could work in different provinces, that makes it difficult to only take one province into account. To have better insights into the company location of the respondent and take into account that a respondent might work on different building sites, the Netherlands is divided in four parts.

It was not a wise choice to give the respondents the possibility to have multiple choices for the average size of their projects. This led to multiple answers by some of the respondents. Since the several choices, did not help with analysing the data of the respondents, the data had to be cleaned up. When cleaning up the data, it was decided to only include the lowest attribute level for the average project size when two attributes levels were chosen by the respondent. This done because it was expected that the smaller projects will occur more frequently. When the respondent had chosen for three attributes levels, the decision was made to include the average project size of the attribute levels.

Questionnaire (I) included seventy-eight (78) respondents for Contractors (56.5%), forty-six (46) respondents for the Consultants (33.3%) and fourteen respondents for the Clients (10.1%). All the respondents have worked for multiple years in the execution phase of UCP in the Netherlands. As shown in Table 13, 76.8% of respondents had a minimal level of University of applied science (HBO), while 55.1% had worked in the construction industry for more than 20 years. This suggests that there was sufficient knowledge and rich experience to make their answers reliable to take into account. Most respondents work with an average project size between the 6 and 50 million (67.4%). Out of 138 respondents, 65.2% work in the West of the Netherlands (Noord-Holland, Utrecht, Zuid-Holland), 23.2% work in the South of the Netherlands (Limburg, Noord-Brabant, Zeeland), 7.3% work in the East of the Netherlands (Flevoland, Gelderland, Overijssel) and 4.4% work in the North of the Netherlands (Drenthe, Friesland, Groningen).

Table 13: Respondents' profile questionnaire (I)

	Attributes	Response number	Percentage (%)
Gender	Male	128	92.8
	Female	10	7.2
Involvement	Contractor	78	56.5
	Consultant	46	33.3
	Client	14	10.2
Age	20 – 29 years	12	8.7
	30 – 39 years	28	20.3
	40 – 49 years	39	28.3
	50 > years	59	42.7
Level of education	Intermediate vocational education (MBO)	32	23.2
	University of applied science (HBO)	62	44.9
	University of science (WO)	44	31.9
Working experience	< 10 years	19	13.8
	11 – 15 years	18	13.0
	16 – 20 years	25	18.1
	> 20 years	76	55.1
Average project size	< 5 million euros	17	12.3
	6 – 20 million euros	55	39.9
	21 – 50 million euros	38	27.5
	51 – 100 million euros	16	11.6
	> 100 million euros	12	8.7
Work area	North of the Netherlands	6	4.4
	East of the Netherlands	10	7.3
	South of the Netherlands	32	23.1
	West of the Netherlands	90	65.2

4.3 Overview results questionnaire (I)

It cannot be assumed that the same factors were accepted by each group of representatives. Therefore, the results of questionnaire (I) had to be tested against the threshold value after the results were converted to single derived numbers (S_j). The factors were tested against different thresholds for the representatives' groups. For the respondents representing the client a threshold of α ≥ 0.64 was used, for the contractor a threshold of α ≥ 0.69 was used and for the consultant a threshold of α ≥ 0.65 was used. The reason for setting different thresholds was to ensure a limited number of factors were selected in order to compare these results with the overall results of all respondents. The critical factors accepted by the different groups can be found in Table 14 (client), Table 15 (contractor) and Table 16 (consultant). The results of the different groups are discussed in more detail in the next sections.

4.3.1 Overview results representatives of the client

The respondent group of the client was limited, only fourteen respondents have completed questionnaire (I) representing the group of the clients. State-of-the-art literature (Delbecq et al., 1975; Schmidt, 1997; Schmidt et al., 2001) suggests the number of ten to fifteen participants from a homogeneous group could give results that are more reliable (Glumac et al., 2011). The experts were considered as homogeneous since they were involved in large projects for large companies in the Netherlands. According to the literature, it is possible to draw proper conclusions from the sufficient data of the client respondents. The reasoning for setting the threshold value for the client on α ≥ 0.64 was to ensure a limited number of factors were selected in order to compare these results easily with the other representative groups. The threshold for the representatives of the client was set on the basis of the weighting results of the clients, as shown in Figure 8. The important critical factors accepted by the client respondents can be seen in Table 14. The rejected factors with their single derived number (S_j) can be found in Table 33 in Appendix F – FDM: Rejected factors Questionnaire (I).

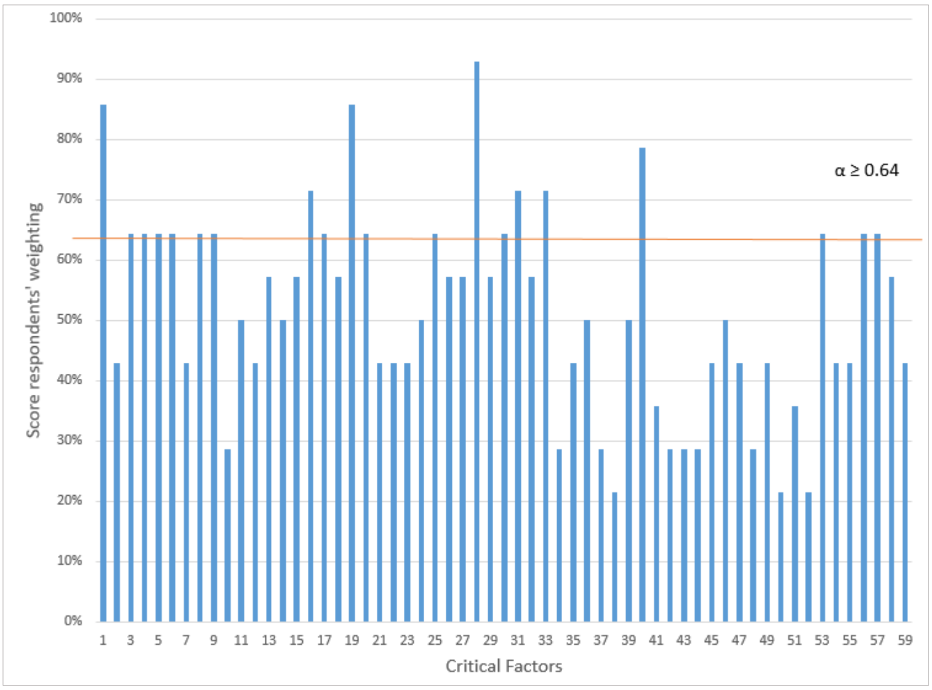

Figure 8: Client ranking setting the threshold of the single derived numbers

Table 14: Client rank accepted factors (single derived number α ≥ 0.64)

No.	Factors	S_j (%)	Accepted/ Rejected
1	Improper construction methods implemented	92.9	Accepted
2*	Poor communication and coordination	85.7	Accepted
	Lack/increase of scope definition	85.7	Accepted
4	Unforeseen site conditions (e.g. Soil, high water table, etc.)	78.6	Accepted
5	Change orders	71.4	Accepted
	Inaccurate time and cost estimations	71.4	Accepted
	Discrepancy between design specification and construction	71.4	Accepted
8	Poor project management	64.3	Accepted
	Information delays and lack of information exchange between the parties	64.3	Accepted
	Improper feasibility study	64.3	Accepted
	Incompetent project team	64.3	Accepted
	Unrealistic enforced contract duration	64.3	Accepted
	Legal dispute(s) between various parts	64.3	Accepted
	Clients' financial difficulties for the project	64.3	Accepted
	Delay to furnish and deliver the site on time	64.3	Accepted
	Rework due to errors	64.3	Accepted
	Delays related to sub-contractors/supplier's work	64.3	Accepted
	Delay in obtaining permits from authorities	64.3	Accepted
	State of market conditions	64.3	Accepted
	Problem with nearby neighbours, structure or facilities	64.3	Accepted

* When factors have the same Single derived number (S_j) they were ranked at the same number

Comparing the client ranking with the overall ranking of accepted critical factors in Table 17, it is noticeable that not all factors chosen by the representatives of the client are mentioned in the overall ranking. The following accepted important critical factors did not return in the overall ranking, namely "Lack/increase of scope definition", "Inaccurate time and cost estimations", "Poor project management", "Legal dispute(s) between various parts", "Clients' financial difficulties for the project", "Delay to furnish and deliver the site on time", "Delay in obtaining permits from authorities" and "State of market conditions". These results differ because of the fact that the representatives of the client only contain fourteen respondents.

4.3.2 Overview results representatives of the contractor

The respondent group of the contractor was large enough to draw proper conclusions from the results. The respondents who represent the contractor have a greater impact on the overall ranking of accepted critical factors because this group consist of seventy-eight (78) respondents. The reasoning for setting the threshold value for the contractor on α ≥ 0.69 was to ensure a limited number of factors were selected in order to compare these results easily with the other representative groups. The threshold for the representatives of the contractor was set on the basis of the weighting results of the contractors, as shown in Figure 9. The critical factors accepted by the representatives of the contractor can be seen in Table 15. The rejected factors with their single derived number (S_j) can be found in Table 34 in Appendix F – FDM: Rejected factors Questionnaire (I).

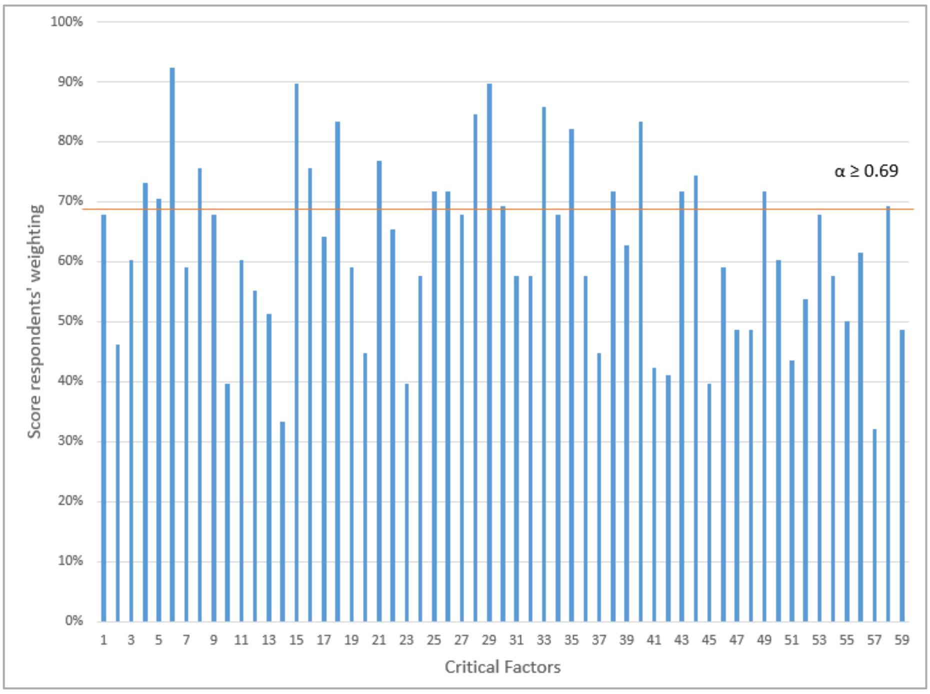

Figure 9: Contractor ranking setting the threshold of the single derived numbers

Table 15: Contractor rank accepted factors (single derived number α ≥ 0.69)

No.	Factors	S_j (%)	Accepted/ Rejected
1	Incompetent project team	92.3	Accepted
2*	Slowness in the decision-making process	89.7	Accepted
	Conflicts between the contractor and other parties	89.7	Accepted
4	Discrepancy between design specification and construction	85.9	Accepted
5	Improper construction methods implemented	84.6	Accepted
6	Late in revising and approving design documents	83.3	Accepted
	Unforeseen site conditions (e.g. Soil, high water table, etc.)	83.3	Accepted
8	Unreliable sub-contractors/suppliers	82.1	Accepted
9	Non-availability of drawing/design on time	76.9	Accepted
10	Unrealistic enforced contract duration	75.6	Accepted
	Change orders	75.6	Accepted
12	Shortage of construction materials	74.4	Accepted
13	Information delays and lack of information exchange between the parties	73.1	Accepted
14	Rework due to errors	71.8	Accepted
	Lack of experience of the contractor	71.8	Accepted
	Mistakes or discrepancies in document(s) or specifications	71.8	Accepted
	Delay in material delivery	71.8	Accepted
	Shortage of (un)skilled labour	71.8	Accepted
19	Improper feasibility study	70.5	Accepted
20	Delays related to sub-contractors/supplier's work	69.2	Accepted
	Delay in providing services from utilities (such as water, electricity)	69.2	Accepted

* When factors have the same Single derived number (S_j) they were ranked at the same number

Comparing the contractor ranking with the overall ranking of accepted critical factors in Table 17, it is noticeable that not all factors chosen by the respondents from the contractor group are mentioned in the overall ranking. The following accepted important critical factors did not return in the overall ranking, namely “Mistakes or discrepancies in document(s) or specifications”, “Shortage of (un)skilled labour”, “Improper feasibility study” and “Delay in providing services from utilities (such as water, electricity)”. Since, a large number of important critical factors accepted by the respondents representing the contractor group in the overall acceptance ranking, it can be concluded that the group representing the contractor group has a high influence on the overall results in questionnaire (I).

4.3.3 Overview results representatives of the consultant

The group representing the consultant was large enough to have an impact on the overall ranking of accepted critical factors because this group consists of forty-six (46) respondents. The reasoning for setting the threshold value for the consultant on $\alpha \geq 0.65$ was to ensure a limited number of factors were selected in order to compare these results easily with the other representative groups. The threshold for the representatives of the consultant was set on the basis of the weighting results of the consultants, as shown in Figure 10. The important critical factors accepted by the group representing the consultant can be seen in
Table 16. The rejected factors with their single derived number (S_j) can be found in Table 35 in Appendix F – FDM: Rejected factors Questionnaire (I).

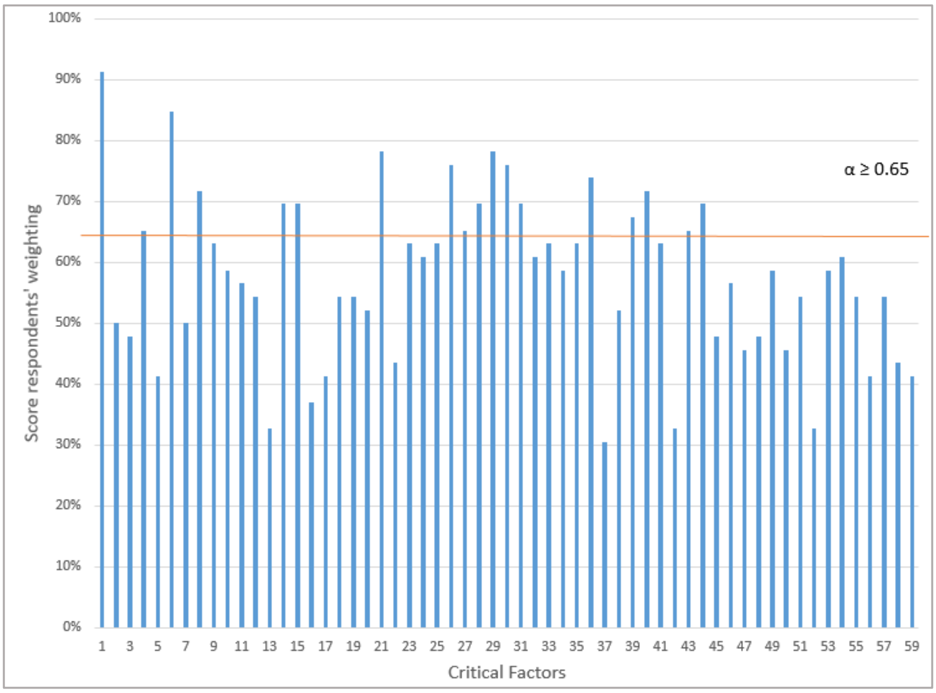

Figure 10: Consultant ranking setting the threshold of the single derived numbers

Table 16: Consultant rank accepted factors (single derived number α ≥ 0.65)

No.	Factors	S_j (%)	Accepted/ Rejected
1	Poor communication and coordination	91.3	Accepted
2	Incompetent project team	84.8	Accepted
3*	Non-availability of drawing/design on time	78.3	Accepted
	Conflicts between the contractor and other parties	78.3	Accepted
5	Lack of experience of the contractor	76.1	Accepted
	Delays related to sub-contractors/supplier's work	76.1	Accepted
7	Lack of experience of the consultant	73.9	Accepted
8	Unrealistic enforced contract duration	71.7	Accepted
	Unforeseen site conditions (e.g. Soil, high water table, etc.)	71.7	Accepted
10	Delay in progress payments from the client	69.6	Accepted
	Slowness in the decision-making process	69.6	Accepted
	Improper construction methods implemented	69.6	Accepted
	Inaccurate time and cost estimations	69.6	Accepted
	Shortage of construction materials	69.6	Accepted
15	Incomplete and unclear drawings	67.4	Accepted
16	Information delays and lack of information exchange between the parties	65.2	Accepted
	Contractors' financial difficulties for the project	65.2	Accepted
	Delay in material delivery	65.2	Accepted

* When factors have the same Single derived number (S_j) they were ranked at the same number

Comparing the consultant ranking with the overall ranking of accepted critical factors in Table 17, it is noticeable that not all factors chosen by the respondents from the consultant group are mentioned in the overall ranking. The following accepted important critical factors did not return in the overall ranking, namely "Lack of experience of the consultant", "Delay in progress payments from the client", "Inaccurate time and cost estimations" and "Contractors' financial difficulties for the project". The respondents representing the consultant group have a high impact on the overall acceptance ranking of questionnaire (I).

4.3.4 Conclusion overview results questionnaire (I)

The results of the different representatives' groups have shown that there were differences between the group and the overall ranking. By using different thresholds on the basis of the respondents' weighting for each group of representatives every group has around the same number of accepted factors that could be compared with the overall results with the emphasis on the differences. It was striking to see that most of the accepted critical factors of the client group did not come back in the overall ranking. This was probably due to the fact that the client group was the smallest group and has less influence on the overall ranking. It was wiser to continue the research with the overall ranking of the accepted critical factors because of the differences in the number of respondents representing each group. In the next sections, the selection of critical factors for questionnaire (II) are discussed based on the overall ranking.

4.4 Selection of the critical factors

To determine the critical factors for questionnaire (II), the results of all respondents were used in order to avoid irregularities by only looking from the perspective of one group. There are large differences in the number of respondents representing each group, therefore, an overall ranking ensures that every answer from each respondent is considered equally important. Every answer is considered equally important because some of the respondents, despite being assigned to a group, are representing another groups as well. This makes it difficult to ensure that each respondent is not influenced by the perspective of the other group. The reasoning for setting the threshold value for the overall ranking on $\alpha \geq 0.68$ was to ensure a limited number of twenty factors were selected in order to keep the research feasible. The threshold for the overall ranking was set on the basis of the weighting results of all the respondents, as shown in Figure 11. In total twenty critical factors were selected that cause delays and affect the execution phase of UCP in the Netherlands. In Table 17 the important critical factors that were accepted can be seen. The ranking of the critical factors was done according the single derived numbers (S_j) from the FDM. It was interesting to see the critical factors with the highest single derived number “Non-availability of drawing/design on time” with a score of 90.6% and “Incompetent project team” with a score of 89.9%. These scores showed that these critical factors are very important in causing delays and affect the execution phase of UCP in the Netherlands. On the other hand, the lowest single derived number “Delay in progress payments from the client” gets a score of 32.6%. This score shows that the factor was not important in causing delays and affect the execution phase of UCP in the Netherlands. All the rejected factors of the overall ranking with their single derived numbers can be found in Table 36 in Appendix F – FDM: Rejected factors Questionnaire (I). Due to the differences between the highest and lowest score it could be said that the list of critical factors presented to the respondents showed an overview containing a large number of factors that were not important for causing delays and affecting the execution phase of UCP in the Netherlands.

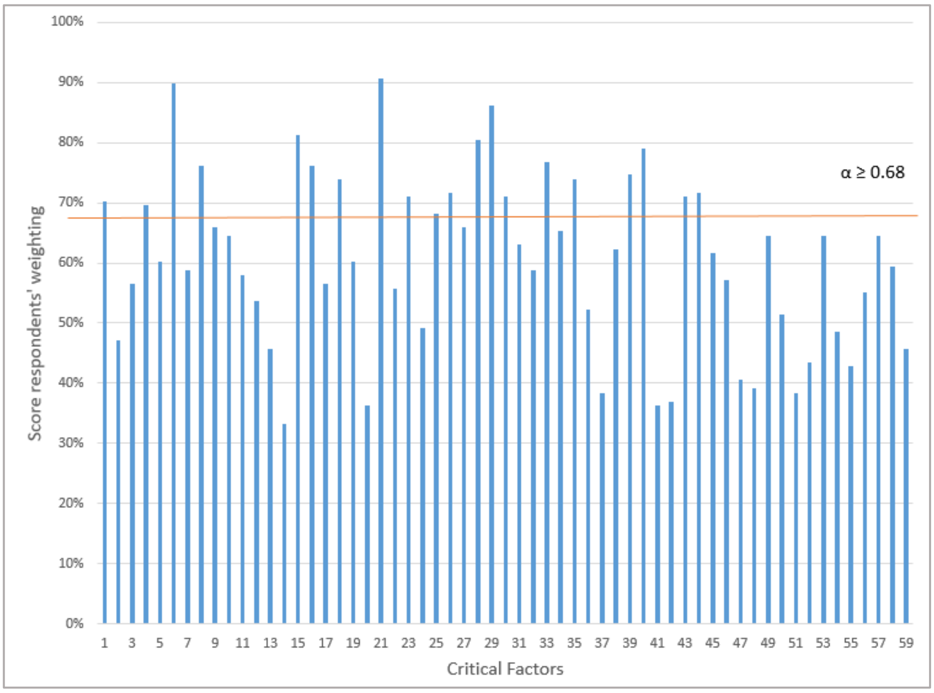

Figure 11: Overall ranking setting the threshold of the single derived numbers

Table 17: Overall rank accepted factors (single derived number α ≥ 0.68)

No.	Factors	S_j (%)	Accepted/ Rejected
1	Non-availability of drawing/design on time	90.6	Accepted
2	Incompetent project team	89.9	Accepted
3	Conflicts between the contractor and other parties	86.2	Accepted
4	Slowness in the decision-making process	81.2	Accepted
5	Improper construction methods implemented	80.4	Accepted
6	Unforeseen site conditions (e.g. Soil, high water table, etc.)	79.0	Accepted
7	Discrepancy between design specification and construction	76.8	Accepted
8*	Unrealistic enforced contract duration	76.1	Accepted
	Change orders	76.1	Accepted
10	Incomplete and unclear drawings	74.6	Accepted
11	Late in revising and approving design documents	73.9	Accepted
	Unreliable sub-contractors/suppliers	73.9	Accepted
13	Lack of experience of the contractor	71.7	Accepted
	Shortage of construction materials	71.7	Accepted
15	Ineffective planning and scheduling	71.0	Accepted
	Delays related to sub-contractors/supplier's work	71.0	Accepted
	Delay in material delivery	71.0	Accepted
18	Poor communication and coordination	70.3	Accepted
19	Information delays and lack of information exchange between the parties	69.6	Accepted
20	Rework due to errors	68.1	Accepted

* When factors have the same Single derived number (S_j) they are ranked at the same number

Looking at the comparison of the factors in Europe (Chapter 2.4.1) there were some similarities in the accepted critical factors chosen by the respondents. The first similar factor "unforeseen site conditions (e.g. Soil, high water table, etc.)" was ranked as important under the name "soil conditions" in the research of Larsen et al. (2016). The critical factor "Unrealistic enforced contract duration" and "Ineffective planning and scheduling" were ranked as important in the studies of Głuszak & Lešniak (2015) and Arantes et al. (2015). The last similar critical factor "Change orders" was ranked as important in the research of Arantes et al. (2015). It was not possible to show irregularities within the threshold test by the literature review because there is no research conducted on the critical factors that cause delays and affect in the execution phase of UCP in the Netherlands. Therefore, the important critical factors accepted in the experiment of the FDM were taken into account in questionnaire (II).

4.5 Conclusion questionnaire (I): Selection of the critical factor

Questionnaire (I) focused on selecting the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. More insights were needed from experts in the Netherlands because the expert interviews gave a limited overview of the critical factors that cause delays and affect the execution phase of UCP. The FDM was applied to analyse the result of questionnaire (I). The purpose of the FDM was to answer sub-question III – What are the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands?

The list of fifty-nine (59) critical factors compiled from the literature review and expert interviews were assessed by a total of one hundred and thirty-eight (138) respondents through questionnaire (I). The results of the FDM were analysed by using different thresholds in order to ensure a limited number of factors were selected to keep the research feasible. The different thresholds ensured that each group has accepted the same number of critical factors to easily compare the results between all the representatives' groups. It turned out that the threshold of each group depends on the weighting results of the respondents. The results of the representatives' groups were compared to see which critical factors were accepted by a representative group and do not return in the overall ranking. It was striking to see that most of the accepted critical factors of the client group do not come back in the overall ranking. This was probably due to the fact that the client group has a low response rate and has less influence on the overall ranking. An overview of results by the representatives' groups can be found in Chapter 4.3.

To determine the critical factors for questionnaire (II), the results of all respondents were used in order to avoid irregularities by only looking from the perspective of one group. There are large differences in the number of respondents representing each group, therefore, an overall ranking ensures that every answer from each respondent is considered equally important. Every answer is considered equally important because some of the respondents, despite being assigned to a group, are representing another groups as well. This makes it difficult to ensure that each respondent is not influenced by the perspective of the other group. The overall overview of accepted critical factors that cause delays and affect the execution phase of UCP in the Netherlands can be found in Chapter 4.4. In total twenty factors were ranked above the threshold ($\alpha \geq 0.68$) as important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The five most important critical factors that cause delays and affect the execution phase of UCP in the Netherlands on the basis of the overall ranking of questionnaire (I) were: "Non-availability of drawing/design on time", "Incompetent project team", "Conflicts between the contractor and other parties", "Slowness in the decision-making process" and "Improper construction methods implemented".

After answering sub-question III by providing twenty important critical factors, questionnaire (II) can be designed in the next chapter of this thesis. In this Chapter, the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands were assessed by the opinion of a group of respondents in order to identify the cause-effect relationships between the selected critical factors.

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5 Questionnaire (II): Identification of relationships

This Chapter focuses on the identification of the cause-effect relationships between the important critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in the Netherlands. To obtain an overview of the relationships between the important critical factors selected in Chapter 4, questionnaire (II) has been conducted. The purpose of questionnaire (II) is to answer sub-question IV – What are the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? and sub-question V – What is the rank of the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? In order to answer sub-questions IV and V, the Bayesian belief network (BBN) methodology has been used to describe the cause-effect relationships among the critical factors through a Directed graph (DG). In Chapter 5.1, the methodology of the BBN is described together with the set-up of questionnaire (II) and the Logical rules for analysing the data of questionnaire (II). The data collection of questionnaire (II) is discussed in Chapter 5.2. Next, the results of questionnaire (II) with the development of the DG and the set-up of the Expert discussions are presented in Chapter 5.3. The results of the Expert discussions are elaborated in Chapter 5.4. At last, Chapter 5.5 presents the conclusion of questionnaire (II) and the development of a DG. As a result, a validated DG is developed on the basis of the cause-effect relationship between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands.

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5.1 Bayesian belief network Methodology

In order to take action against the various critical factors, it is important to know the relationship between these factors. When the relationships between the critical factors are known the probability of other critical factors can be predicted for future projects. A useful methodology to predict the behaviour of a system under certain conditions is the Bayesian belief network (BBN) methodology. This methodology is quite often used as a decision or support tool in different fields of research and for a large number of different reasons. The BBN methodology is derived from the Bayesian theorem and network theory. The method can give a clear overview of the cause-effect relationships among the critical factors through a graphical simplification and predict the outcome of the problem on the basis of the conditional probabilities that are connected to the network. The graphical structure allows different types of causes and knowledge from various sources to be integrated within a single framework (Rizzo & Blackburn, 2015). This thesis will use the BBN methodology because these networks can be calibrated and validated with expert data to gain confidence in the results.

A Belief network consists of nodes, representing factors of the domain, and arrows, representing dependence relationships between the nodes (Van Truong et al., 2009). In the Belief Network, the parent node (tail of the arrow) directly affects the child node (head of the arrow). The cause-effect relationship between the parent node and the child node is often represented by an arrow referred to as edge (Van Truong et al., 2009). Figure 12 shows a simplified BBN structure describing the discussed definitions.

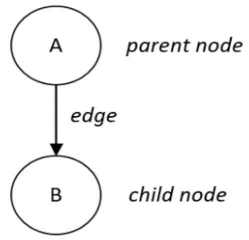

Figure 12: Simplified BBN structure (adopted from Van Truong et al. (2009))

Since, there is no data available about the impact of critical factors that cause delays in the execution phase of Utility construction projects (UCP) the graphical BBN is constructed on the basis of expert opinions. These opinions can provide a valuable source of information for the BBN. There are several methodologies that can be used for constructing a BBN on the basis of expert opinions. In this thesis, a relationship matrix is used for questionnaire (II) to determine the relationships among the most critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The BBN can be used for *predictive reasoning*, this helps users to take actions against the critical factors and reducing delays at an early stage during the execution phase of UCP for the projects in the future. Predictive reasoning follows the direction of the arrows within the network, where certain critical factors influences the probability for the condition of another factor, as shown in Figure 13 (Korb & Nicholson, 2004).

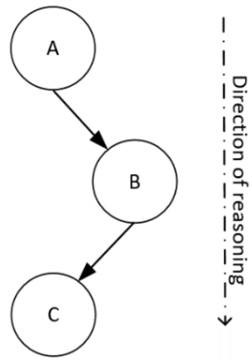

Figure 13: Predictive reasoning (Korb & Nicholson, 2004)

For identifying the relationships between the most critical factors applicable in the execution phase of UCP, a matrix questionnaire has been developed. The following steps are discussed in more detail in the next sections:

I. Selection of the important critical factors (Chapter 4);
II. Set-up questionnaire (II) (Chapter 5.1.1);
III. Analysing data using Logical rules (Chapter 5.1.2).

5.1.1 Set-up questionnaire (II)

The Directed graph (DG), was constructed by using a matrix questionnaire. The studies of Nasir, McCabe, & Hartono (2003) and Van Truong et al. (2009) have shown that constructing a DG is possible by using a matrix questionnaire. The Fuzzy Delphi method (FDM) in Chapter 4 provided twenty important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. Questionnaire (II) was prepared in a matrix form, as shown in Appendix G – BBN: Set-up Questionnaire (II), where the critical factors in the left column represent the causes and the factors listed across the top represent the effects. Relationships that were considered as being illogical were excluded from the questionnaire. The cause-effect relationships between the important critical factors were reviewed to identify the preliminary relationships among the accepted critical factors.

Reasons for removing cause-effect relations between factors are:

I. The relationship in the other direction is accepted and more logical (A → B: B ← A);
II. No relationship from both directions (A X B);
III. Overlap between two critical factors that are selected looking at the relationship (A=B).

After re-evaluating the cause-effect relationships between the critical factors a total of one hundred and thirteen (113) cause-effect relationships were removed. Appendix H – BBN: Preselection deleted factors Questionnaire (II) shows the factors that have been removed with their reason for excluding. The relationships between the illogical critical factors should not be filled in by the respondents. This reduces the number of relationships that need to be assessed by the respondents. In total, the respondents need to review two hundred and sixty-seven (267) relationships between the important critical factors from the FDM in Chapter 4. The entire set-up of questionnaire (II) can be found in Appendix G – BBN: Set-up Questionnaire (II).

In order to facilitate the answers of each expert, a four-point scale for rating the relationships by the respondents has been adopted from Nasir et al. (2003). Participants were asked to rate the cause-effect relationships between the critical factors using the following values:
0 = “no relationship”
1 = “weak relationship”
2 = “strong relationship”
3 = “very strong relationship”

5.1.2 Analysing data using Logical rules

In several studies, Logical rules were used to test the results of a matrix questionnaire that uses a four-point scale. This methodology proved to be successful in, for example, the articles of Nasir et al. (2003) and Van Truong et al. (2009). The nine logical tests utilising two statistical values, namely the average and the skewness, is developed to evaluate the data (Nasir et al., 2003). The skewness statistic describes the weight of opinion where a positive skewness indicates the majority of experts gave a low score and a few gave a high score and vice versa (Nasir et al., 2003). This thesis uses the nine Logical rules instead of the FDM because it was expected that the FDM is not sensitive enough for identifying the relationships. The FDM does not consider the skewness and the number of strong and weak relationships. When looking at these aspects, it was expected that the data from questionnaire (II) about the relationships were better identified by using the Logical rules.

A relationship is named Weak [W] when the number of experts scored the relationship as either a nought or one. A relationship is named Strong [S] when the number of experts scored the relationship as either a two or three. The difference between the total Strong [S] and Weak [W] values, [S – W], provides a measure of the weight of opinion of the experts (Nasir et al., 2003). As shown in Table 18, the logical test T1 to T3 are rejection tests whereas test T4 to T7 are acceptance tests. A relationship that has a false value for test T1 to T7 is exposed to Test T8 and T9. According to Nasir et al. (2003), these two tests were defined as subjective tests on the basis of the expert's opinions. When the data seems to incline towards three then test T8 will accept the relationship. On the other hand, as soon as the data incline to nought then test T9 rejects the relationship.

Table 18: Logical rules to analyse questionnaire (II) (adopted from Nasir et al. (2003))

Tests	Condition	If Condition True	If Condition False
T1	Average < 1.01	Reject Relationship	Go to rule T2
T2	Average < 1.50 AND [W – S] > 4	Reject Relationship	Go to rule T3
T3	Average < 1.50 AND Skewness = Positive	Reject Relationship	Go to rule T4
T4	Average > 2.50	Accept Relationship	Go to rule T5
T5	Average > 1.99 AND [S – W] > 4	Accept Relationship	Go to rule T6
T6	Average > 1.99 AND Skewness = Negative	Accept Relationship	Go to rule T7
T7	No 0 scores, experts see some relationship	Accept Relationship	Go to rule T8 & T9
T8	Scores are inclined toward 3	Accept Relationship	Reject Relationship
T9	Scores are inclined toward 0	Reject Relationship	Reject Relationship

5.2 Data collection questionnaire (II)

5.2.1 Contact respondents for questionnaire (II)

To identify the cause-effect relationships between the important critical factors derived from the FDM, questionnaire (II) was designed using Excel. The respondents of questionnaire (I) who have indicated that they want to work on questionnaire (II) were contacted. About 100 people were contacted to fill in questionnaire (II). Not all the experts that started filling in the questionnaire completed the whole questionnaire. To ensure enough results could be collected a reminder was sent to the contacted persons. By doing this, the total number of completed questionnaires increased. In total forty respondents participated in completing questionnaire (II). The reasons why other respondents not wanting to participate were "Being too Busy". In total three different groups of representatives (i.e. Client, contractor and consultant) were contacted. It was not possible to compare the results of the different groups of representatives because the number of respondents in each group was not large enough.

5.2.2 Respondents' profile for questionnaire (II)

Questionnaire (II) included 22 respondents for the Contractors (55.0%), 15 respondents for the Consultants (37.5%) and 3 respondents for the Clients (7.5%). All the respondents have worked for multiple years in the execution phase of UCP in the Netherlands. As shown in Table 19, 85.0% of respondents had a minimal level of University of applied science (HBO), while 77.5% had worked in the construction industry for more than 20 years. This suggests that there was sufficient knowledge and rich experience to make their answers reliable to take into account. In questionnaire (II) it appeared that some levels of attributes for the questions could be combined for certain attributes because the response rate for one level of an attribute was low. The procedure described in Chapter 4.2.2 for adding attributes together were used. It appeared that most respondents work in the West (67.5%) of the Netherlands and the South (22.5%) of the Netherlands, that makes it difficult to compare the results from all the level of attributes.

Table 19: Respondents' profile questionnaire (II)

	Attributes	Response number	Percentage (%)
Gender	Male	40	100.0
Involvement	Contractor	22	55.0
	Consultant	15	37.5
	Client	3	7.5
Age	20 – 39 years	3	7.5
	40 – 49 years	14	35.0
	50 > years	23	57.5
Level of education	Intermediate vocational education (MBO)	6	15.0
	University of applied science (HBO)	26	65.0
	University of science (WO)	8	20.0
Working experience	< 15 years	4	10.0
	16 – 20 years	5	12.5
	> 20 years	31	77.5
Average project size	< 20 million euros	17	42.5
	20 – 50 million euros	12	30.0
	> 50 million euros	11	27.5

5.3 Overview results Questionnaire (II)

In total two hundred and sixty-seven (267) possible relationships had to be reviewed by the respondents in questionnaire (II). The results were analysed by using the nine Logical rules, as shown in Table 18. In order to analyse the data, SPSS was used to compute the average score and the skewness. Details of this procedure are available in Nasir et al. (2003). On the basis of the analysis, using the Logical rules from Table 18, a total of eighty-seven (87) cause-effect relationships were accepted and one hundred and eighty cause-effect relationships were rejected. The number of relationships that were selected was very high, therefore, the Logical rules had to be made stricter. No literature could be found on how to make stricter rules, since the methodology of accepting relationships on the basis of the average and skewness with the nine Logical rules has not been broadly used. Therefore, the decision was made to keep the structure of the rules the same and only adjust the average to a higher number. In Table 20 the adjusted stricter rules can be found. After applying stricter rules to analyse the data a total of fifty-six (56) cause-effect relationships were accepted and two hundred and eleven (211) cause-effect relationships were rejected. The overview of accepted relationships, applying stricter rules from Table 20, can be found in Appendix I – BBN: Results Questionnaire (II). The accepted relationships were ranked on the average score from questionnaire (II). In addition, the frequencies of the different answers and the skewness number corresponding to the relationships are shown in Appendix I – BBN: Results Questionnaire (II).

Table 20: Stricter Logical rules to analyse the data questionnaire (II)

Tests	Condition	If Condition True	If Condition False
T1	Average < 1.01	Reject Relationship	Go to rule T2
T2	Average < 1.50 AND [W – S] > 4	Reject Relationship	Go to rule T3
T3	Average < 1.50 AND Skewness = Positive	Reject Relationship	Go to rule T4
T4	Average > 2.50	Accept Relationship	Go to rule T5
T5	Average > 2.25 AND [S – W] > 4	Accept Relationship	Go to rule T6
T6	Average > 2.25 AND Skewness = Negative	Accept Relationship	Go to rule T7
T7	No 0 scores, experts see some relationship	Accept Relationship	Go to rule T8 & T9
T8	Scores are inclined toward 3	Accept Relationship	Reject Relationship
T9	Scores are inclined toward 0	Reject Relationship	Reject Relationship

5.3.1 Development Directed graph

On the basis of the relationship ranking of questionnaire (II), a DG was developed. In this DG, the requirements to develop a BBN was not to have reciprocal relationships, a maximum limit of four parent nodes for each factor and no cycles were allowed between relationships. As shown from Figure 18 to Figure 23, the development of the DG started with the accepted relationships by means of the highest average scores, according to the results in Appendix I – BBN: Results Questionnaire (II). The step-by-step development of the DG is shown in Appendix J – BBN: Development DG. In order to keep the DG user-friendly, a maximum of thirty cause-effect relationships has been included.

As said before a BBN cannot contain reciprocal relationships in both directions (A→B, B→A). In the first step of developing the DG, a *red line* is shown in Figure 18, between “Shortage of construction materials” and “Delay in material delivery” that means the respondents assessed this relationship in questionnaire (II) in both directions equivalent. In Table 21, all relationships that raise questions during the development of the DG need to be validated in structured Expert discussions.

The relationships mentioned in Table 21 are not yet included in the DG because of reciprocal relationships, an exceeding of the maximum limit of parent nodes, cycles between relationships or an exceeding of the maximum relationships in the DG. In total eight accepted relationships were almost equally assessed by the respondents in both directions this is shown with *red lines* in Figure 23. Structured Expert discussions need to be held to validate the direction of these reciprocal relationships in the next section.

Table 21: Actions in development of the Directed graph

No.	Cause	Effect	Average	Direction
1	Shortage of construction materials	Delay in material delivery	2.56	A→B
			2.55	B→A
2	Poor communication and coordination	Information delays and lack of information exchange between the parties	2.53	A→B
			2.45	B→A
3	Poor communication and coordination	Conflicts between the contractor and other parties	2.46	A→B
			2.24	B→A
4	Non-availability of drawing/design on time	Information delays and lack of information exchange between the parties	2.45	A→B
			2.28	B→A
5	Incomplete and unclear drawings	Discrepancy between design specification and construction	2.41	A→B
			2.31	B→A
6	Information delays and lack of information exchange between the parties	Incomplete and unclear drawings	2.33	A→B
			2.29	B→A
7	Information delays and lack of information exchange between the parties	Conflicts between the contractor and other parties	2.30	A→B
			2.14	B→A
8	Delays related to sub-contractors/supplier’s work	Conflicts between the contractor and other parties	2.28	A→B
			2.27	B→A
9	Unrealistic enforced contract duration	Delays related to sub-contractors/supplier’s work	2.29	Limit of parent nodes
10	Unreliable sub-contractors/suppliers	Conflicts between the contractor and other parties	2.24	Limit of parent nodes
11	Lack of experience of the contractor	Conflicts between the contractor and other parties	2.23	Limit of parent nodes
12	Delays related to sub-contractors/supplier’s work	Delay in material delivery	2.23	Maximum relationships
13	Discrepancy between design specification and construction	Non-availability of drawing/design on time	2.21	Maximum relationships

No.	Cause	Effect	Average	Direction
14	Incomplete and unclear drawings	Non-availability of drawing/design on time	2.21	Limit of parent nodes
15	Late in revising and approving design documents	Information delays and lack of information exchange between the parties	2.21	Limit of parent nodes
16	Incompetent project team	Conflicts between the contractor and other parties	2.18	Limit of parent nodes
17	Lack of experience of the contractor	Poor communication and coordination	2.18	Maximum relationships
18	Ineffective planning and scheduling	Conflicts between the contractor and other parties	2.18	Limit of parent nodes
19	Delay in material delivery	Delays related to sub-contractors/supplier's work	2.18	Limit of parent nodes
20	Conflicts between the contractor and other parties	Information delays and lack of information exchange between the parties	2.14	Limit of parent nodes
21	Incompetent project team	Delays related to sub-contractors/supplier's work	2.05	Limit of parent nodes
22	Incomplete and unclear drawings	Delays related to sub-contractors/supplier's work	2.05	Limit of parent nodes
23	Lack of experience of the contractor	Information delays and lack of information exchange between the parties	2.05	Limit of parent nodes
24	Conflicts between the contractor and other parties	Delay in material delivery	1.95	Maximum relationships
25	Incomplete and unclear drawings	Conflicts between the contractor and other parties	1.95	Limit of parent nodes
26	Discrepancy between design specification and construction	Improper construction methods implemented	1.69	Cycle

5.3.2 Set-up Expert discussions

It was not possible to create a BBN on the basis of the results derived from questionnaire (II). There were too many relationships accepted to create a BBN without having reciprocal relationships, exceeding the limit of four parent nodes and cycles included in the network. In order to validate the relationships in the DG structured Expert discussions were held. In total nine experts were involved in the Expert discussions. The set-up of these Expert discussions is shown in Appendix K – Expert Discussion: Set-up .

The Expert discussions consist of three parts:

I. Discussion: which direction needs to be chosen between the reciprocal relationships;
II. Discussion: which parent nodes directly cause delays;
III. Discussion: which adjustments could be made in the DG.

In the first part, the experts need to choose the relationship that was more logical in order of time. Both relationships were presented, whereby the expert makes the choice which relationship was more likely to happen. Figure 23 in Appendix J – BBN: Development DG shows the reciprocal relationships that needs to be assessed by the expert in red. In order to add a decision function in the BBN more information was needed about the parent nodes that directly cause delays in the execution phase of UCP. In the second part of the Expert discussions, all factors that have a function as parent node were assessed by the experts. The expert will assess the level of impact (1 = low; 2 = moderate; 3 = high) for these factors. In the third part of the Expert discussions, the expert will give recommendations about the completeness of the DG.

It was expected that the results of the Expert discussions are useful for completing the DG. The analysis and results of the Expert discussions are discussed in the next sections of this thesis. When the results of the Expert discussions were taken into account in the DG, the strong relationships excluded in the DG need to be assessed again.

5.3.3 Conclusion overview results questionnaire (II)

Questionnaire (II) focused on the identification of the cause-effect relationships between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The purpose of questionnaire (II) was to answer sub-question IV – What are the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? and sub-question V – What is the rank of the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands?

In total two hundred and sixty-seven (267) possible relationships had to be reviewed by the respondents. The results were analysed by using the nine Logical rules. On the basis of the analysis, using the Logical rules from Table 18, a total of eighty-seven (87) cause-effect relationships were accepted and one hundred and eighty (180) cause-effect relationships were rejected. The number of relationships that were selected was very high, therefore, the Logical rules had to be made stricter. After applying stricter rules from Table 20 a total of fifty-six (56) cause-effect relationships were accepted and two hundred and eleven (211) cause-effect relationships were rejected. The overview of accepted relationships can be found in Appendix I – BBN: Results Questionnaire (II).

After answering sub-question IV by accepting fifty-six (56) cause-effect relationships using the nine Logical rules and answering sub-question V by ranking the accepted factors on the average score a DG was developed. After creating the DG, a validation was needed in order to continue the research because of the included reciprocal relationships. To validate the DG, discussions with experts were held in a structured manner. In the next sections, the results of the discussions are elaborated.

5.4 Results expert discussions

In total nine structured discussions have been held with experts that represents the contractor and work in the execution phase of UCP. The University of applied science (HBO) and University of science (WO) was the most common educational level among the experts. In addition, most of the experts worked in the construction industry for more than ten years. This suggests that there was sufficient knowledge and rich experience to make the answers reliable to take into account. The logical reasoning of the reciprocal relationships needs to be assessed by the experts. Both relationships were presented, whereby the expert makes the choice which relationship was more likely to happen. Table 22 shows the assessment of the expert among the reciprocal relationships. The direction most chosen by the experts was included in the final DG in Appendix L – Expert Discussion: DG.

Table 22: Assessment of the reciprocal relationships by Expert Discussions

No.	Cause	Effect	Direction	Choice
1	Shortage of construction materials	Delay in material delivery	A→B	8
			B→A	1
2	Poor communication and coordination	Information delays and lack of information exchange between the parties	A→B	7
			B→A	2
3	Poor communication and coordination	Conflicts between the contractor and other parties	A→B	9
			B→A	0
4	Non-availability of drawing/design on time	Information delays and lack of information exchange between the parties	A→B	7
			B→A	2
5	Incomplete and unclear drawings	Discrepancy between design specification and construction	A→B	2
			B→A	7
6	Incomplete and unclear drawings	Information delays and lack of information exchange between the parties	A→B	3
			B→A	6
7	Conflicts between the contractor and other parties	Information delays and lack of information exchange between the parties	A→B	2
			B→A	7
8	Delays related to sub-contractors/supplier's work	Conflicts between the contractor and other parties	A→B	4
			B→A	5

It was striking to see that the experts have a clear opinion on the directions of the relationships. This was not expected due to the fact that both relationships were assessed as strong relationships in questionnaire (II). It turned out that the reciprocal relationship of "Delays related to sub-contractors/supplier's work" and "Conflicts between the contractor and other parties" in both directions was accepted by the experts. Appendix L – Expert Discussion: DG shows that the directions from "Delays related to sub-contractors/supplier's work" to "Conflicts between the contractor and other parties" was included in the DG. There was chosen for this direction because the maximum limit of four parent nodes for the factor "Delays related to sub-contractors/supplier's work" was already saturated. This was the only reciprocal relationship where the predefined requirements determined the direction of the relationship.

Table 23: Average impact scores of the parent nodes that can directly cause delays

No.	Parent nodes	Score
1	Non-availability of drawing/design on time	2.67
2	Incompetent project team	2.22
3	Conflicts between the contractor and other parties	2.44
4	Improper construction methods implemented	2.11
5	Incomplete and unclear drawings	2.44
6	Late in revising and approving design documents	2.22
7	Ineffective planning and scheduling	2.11
8	Delays related to sub-contractors/supplier's work	1.67
9	Delay in material delivery	2.00
10	Poor communication and coordination	2.67
11	Information delays and lack of information exchange between the parties	2.67
12	Rework due to errors	2.11

It was not easy to assess the parent nodes that directly cause delays and affect the execution phase of UCP in the Netherlands. Questionnaire (I) has already shown that these causes can be considered as the most critical factors. By the assessment of the level of impact (1 = low; 2 = moderate; 3 = high), of the most critical factors, it can be determined which factors will directly cause delays and affect the execution phase of UCP. The average scores of the experts helped to make this decision. Table 23 shows the average scores of the parent nodes that can directly cause a delay in the execution phase of UCP in the Netherlands. A parent node that scores on average around the 2.50 in the Expert discussions was considered as one of the most influential critical factors. In the expert discussions, a total five parent nodes in the DG were assessed as the most influential critical factors that cause delays and affect the execution phase of Utility construction projects. The factors "Non-availability of drawing/design on time (2.67)", "Poor communication and coordination (2.67)" and "Information delays and lack of information exchange between the parties (2.67)" were considered as the most influential critical factors. In addition, the factors "Conflicts between the contractor and other parties (2.44)" and "Incomplete and unclear drawings (2.44)" were included because these factors have an average score around the 2.50. Another reason for including these factors was because otherwise they only function as child nodes that makes these factors superfluous in the DG. The parent nodes linked to the decision node are shown in Appendix L – Expert Discussion: DG. It is striking to see that the factor "Poor communication and coordination" is not linked to the decision node. This factor is already linked indirectly to the decision node through the factors "Information delays and lack of information exchange between the parties", "Conflicts between the contractor and other parties" and "Incomplete and unclear drawings". Therefore, it was not chosen to link this factor to the decision node.

In the Expert Discussions additional comments were made about creating clusters, work with colours or categorise factors to make the DG more readable for everyone. The Expert Discussions helped to validate the DG before start designing questionnaire (III). In the validated DG, two factors only act as a child node, namely "Delay in material delivery" and "Rework due to errors". In these child nodes, the DG will stop. As shown in Appendix M – BBN: Final DG, these factors were excluded in the final DG. In questionnaire (III), it was expected to find the conditional probabilities of the factors. With this information, a BBN can be developed from the DG in Appendix M – BBN: Final DG.

5.5 Conclusion questionnaire (II): Identification of relationships

Questionnaire (II) focused on the identification of the cause-effect relationships between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The purpose of questionnaire (II) was to answer sub-question IV – What are the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? and sub-question V – What is the rank of the cause-effect relationships among the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands?

In total two hundred and sixty-seven (267) possible relationships had to be reviewed by the respondents. The results were analysed by using the nine Logical rules from Table 20. On the basis of the analysis a total of fifty-six (56) cause-effect relationships were accepted and two hundred and eleven (211) cause-effect relationships were rejected. The overview of accepted relationships can be found in Appendix I – BBN: Results Questionnaire (II). The accepted relationships were ranked on the basis of the average score.

To validate the DG, discussions with experts were held in a structured manner. First, the logical reasoning of the reciprocal relationships was assessed by the experts. Both relationships were presented, whereby the expert makes the choice which relationship was more likely to happen and need to be included in the DG. The direction that was most chosen by the experts were included in the final DG in Appendix L – Expert Discussion: DG. Second, the experts need to assess the parent nodes to decide which factors that directly cause delays in the execution phase of UCP. The factors “Non-availability of drawing/design on time”, “Conflicts between the contractor and other parties”, “Incomplete and unclear drawings” and “Information delays and lack of information exchange between the parties” were considered as factors that directly cause delays in the execution phase of UCP by the expert discussions. These factors differ with the rank of selected critical factors in Chapter 4.4 because the most influential critical factors were chosen on the basis of the directed graph in Appendix L – Expert Discussion: DG. These four parent nodes were linked to a decision node as shown in Appendix L – Expert Discussion: DG. In the validated DG of Appendix L – Expert Discussion: DG, two factors only act as a child node, namely “Delay in material delivery” and “Rework due to errors”. In these child nodes, the DG stops. For this reason, these factors were excluded in the final DG as shown in Appendix M – BBN: Final DG.

After answering sub-question IV, V and the validation of the DG, a BBN can be developed when the conditional probabilities were known. These conditional probabilities were collected by questionnaire (III) and are described in the next Chapter. In this Chapter, the BBN was developed from the results of questionnaire (III). When the conditional probabilities are included in the DG of Appendix M – BBN: Final DG, this will function as a BBN.

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6 Questionnaire (III): Estimation of the probabilities of critical factors

This Chapter focuses on the estimation of the conditional probabilities of the important critical factors that cause delays and affect the execution phase of Utility construction projects (UCP) in the Netherlands. To obtain an overview of the conditional probabilities questionnaire (III) has been conducted. The purpose of questionnaire (III) is to answer sub-question VI – What are the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? With these conditional probabilities, a Bayesian belief network (BBN) can be developed out the Directed graph (DG). In Chapter 6.1 the set-up of questionnaire (III) is described. The data collection of questionnaire (III) is presented in Chapter 6.2. Next, the results of questionnaire (III) are described in Chapter 6.3 and the development from the DG to the BBN by the conditional probabilities is discussed In Chapter 6.4. At last, Chapter 6.5 presents the conclusion of questionnaire (III) and the development of a BBN. As a result, a BBN is developed from the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands on the basis of the conditional probabilities derived from questionnaire (III).

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6.1 Set-up questionnaire (III)

The procedure of Van Truong et al. (2009) was used in the design of questionnaire (III) to obtain the conditional probabilities. As described in Chapter 5, the nine Logical rules accepted fifty-six (56) cause-effect relationships that resulted in a validated Directed graph (DG). The free academic computer program GeNIe was used to develop a Bayesian belief network (BBN) including the conditional probabilities for each factor.

In the first part of questionnaire (III), it was intended to collect demographic data from the respondents. Demographic questions were asked regarding gender, age, level of education, working experience and the average project size. This was done in order to to collect information about the respondents' profile. With this respondents' profile, it was possible to determine the level of experience of the respondents in questionnaire (III). For example, when most of the respondents have followed a high level of education and have several years of work experience, it can be assumed that the answers of the respondents are reliable.

In the second part of questionnaire (III), experts were asked to assess the occurrence of a factors' condition on the basis of certain conditions of other factors that have a relationship. Figure 14 shows what was expected from the respondent with an example out of questionnaire (III). The respondent needs to answer the following question, what is the effect on the project when the following factors occurred during the execution phase of Utility construction projects (UCP)? Each case was assessed by awarding a possible delay in a percentage of the total project duration.

Direct schedule delay								
Non-availability of drawing/design on time	*Information delays and lack of information exchange between the parties*	*Incomplete and unclear drawings*	*Conflicts between the contractor and other parties*	*<5%*	*5 – 10%*	*10 – 15%*	*15 – 20%*	*>20%*
Yes	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
No	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐

Figure 14: Example assessment of effects in the project

In the example of Figure 14, "Non-availability of drawing/design on time" **(YES)** occurred in the project, "Information delays and lack of information exchange between the parties" **(NO)** not occurred in the project, "Incomplete and unclear drawings" **(YES)** occurred in the project and "Conflicts between the contractor and other parties" **(NO)** not occurred in the project. Then, the respondent needs to answer the following question, what is the effect on the project during the execution phase of UCP? In each case, the respondent chooses whether this delay was < 5% of the total project duration, 5 - 10% of the total project duration, 10 - 15% of the total project duration, 15 - 20% of the total project duration or > 20% of the total project duration.

In the last part of questionnaire (III), experts were asked to assess the probability of occurrence on the basis of other applicable factors that have a cause-effect relationship. Figure 15 shows the expectations of the respondent with an example out of questionnaire (III). The respondent needs to answer the following question, what is the probability that the following factor occurs during the execution phase of UCP when other factors are applicable? Each case was assessed by awarding whether the chance of occurrence is likely (Yes) or unlikely (No).

Non-availability of drawing/design on time				
Late in revising and approving design documents	*Slowness in decision-making process*	*Change orders*	*Yes*	*No*
Yes	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐
No	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐

Figure 15: Example assessment of probabilities when other factors are applicable

In the example of Figure 15, "Late in revising and approving design documents" **(YES)** occurred in the project, "Slowness in the decision-making process" **(NO)** not occurred in the project and "Change orders" **(NO)** not occurred in the project. Then, the respondent needs to answer the following question, what is the probability that "Non-availability of drawing/design on time" occurred during the execution phase of UCP when 'Late in revising and approving design documents' is applicable? The respondent chooses whether this factor is likely (Yes) or unlikely (No) to occur.

It was expected that the results of questionnaire (III) are useful for answering sub-question IV and develop the BBN out of the DG. The BBN developed using GeNIe helps to answer the research question central to this thesis in Chapter 7. The full set-up of questionnaire (III) can be found in Appendix N – BBN: Set-up questionnaire (III) and the analysis and results of questionnaire (III) are discussed in the next sections of this thesis.

6.2 Data collection questionnaire (III)

6.2.1 Contact respondents for questionnaire (III)

Questionnaire (III) for estimating the conditional probabilities of the important critical factors has been designed using Word. About 60 experts who work in the execution phase of UCP, within the graduation company, were contacted by sending an e-mail. The full set-up of questionnaire (III) can be found in Appendix N – BBN: Set-up questionnaire (III). To ensure enough results could be collected a reminder was sent to the contacted persons. By doing this, the total number of completed questionnaires increased. In total ten experts participated in completing questionnaire (III).

6.2.2 Respondents' profile for questionnaire (III)

All the respondents have worked for multiple years in the execution phase of UCP in the Netherlands. As shown in Table 24, 90% of respondents had a minimal level of University of applied science (HBO) and 60% had worked in the construction industry for more than 20 years. This suggests that there was sufficient knowledge and rich experience to make their answers reliable to take into account. The results of ten respondents helped to find the conditional probabilities. It was expected that the results are reliable and can be used to evaluate the effect of a factors' condition on the basis of certain conditions of other factors. In Chapter 6.4 the validation of the conditional probabilities in the BBN was tested for two, by the graduation company, executed projects that experienced delays. In Appendix O – BBN: Results questionnaire (III), the results of questionnaire (III) are described according to the set-up of questionnaire(III).

Table 24: Respondents' profile questionnaire (III)

	Attributes	Response number	Percentage (%)
Gender	Male	10	100.0
Age	30 – 39 years	3	30.0
	40 – 49 years	2	20.0
	50 > years	5	50.0
Level of education	Intermediate vocational education (MBO)	1	10.0
	University of applied science (HBO)	7	70.0
	University of science (WO)	2	20.0
Working experience	< 10 years	1	10.0
	10 – 15 years	2	20.0
	16 – 20 years	1	10.0
	> 20 years	6	60.0
Average project size	< 20 million euros	6	60.0
	20 – 50 million euros	3	30.0
	> 50 million euros	1	10.0

6.3 Overview results questionnaire (III)

6.3.1 Assessment effects: Factors that cause delays

In the second part of questionnaire (III), experts were asked to assess the occurrence of a factors' condition on the basis of certain conditions of other factors that have a relationship. The respondent needs to answer the following question, what is the effect on the project when the following factors occurred during the execution phase of UCP? In each case, the delay represents a percentage of the total project duration. In Figure 16 the assessment results for the effects on the project are shown. An overview of all the results of questionnaire (III) can be found in Appendix O – BBN: Results questionnaire (III).

Direct schedule delay								
Non-availability of drawing/design on time	*Information delays and lack of information exchange between the parties*	*Incomplete and unclear drawings*	*Conflicts between the contractor and other parties*	*<5%*	*5 – 10%*	*10 – 15%*	*15 – 20%*	*>20%*
Yes	Yes	Yes	Yes	0%	0%	0%	30%	70%
			No	10%	0%	20%	50%	20%
		No	Yes	0%	30%	40%	20%	10%
			No	30%	20%	30%	20%	0%
	No	Yes	Yes	0%	20%	60%	20%	0%
			No	10%	50%	40%	0%	0%
		No	Yes	20%	50%	30%	0%	0%
			No	50%	50%	0%	0%	0%
No	Yes	Yes	Yes	0%	20%	20%	50%	10%
			No	30%	30%	10%	30%	0%
		No	Yes	0%	60%	30%	10%	0%
			No	30%	40%	30%	0%	0%
	No	Yes	Yes	0%	70%	30%	0%	0%
			No	30%	70%	0%	0%	0%
		No	Yes	20%	80%	0%	0%	0%
			No	80%	20%	0%	0%	0%

Figure 16: Assessment results for the effects in the project

For example, when 'Non-availability of drawing/design on time' **(YES)** occurred in the project, 'Information delays and lack of information exchange between the parties' **(YES)** occurred in the project, 'Incomplete and unclear drawings' **(NO)** not occurred in the project and 'Conflicts between the contractor and other parties' **(NO)** not occurred in the project. Then, 30% of the respondents assessed the delay < 5%, 20% of the respondents assessed the delay between the 5 - 10%, 30% of the respondents assessed the delay between 10 - 15% and 20% of the respondents assessed the delay between 15 - 20% of the total project duration.

6.3.2 Assessment probabilities: Occurrence factors

In the last part of questionnaire (III), experts were asked to assess the probability of occurrence on the basis of other applicable factors that have a relationship. The respondent needs to answer the following question, what is the probability that the following factor occurs during the execution phase of UCP when other factors are applicable? The respondent assessed whether the chance of occurrence is likely (Yes) or unlikely (No). In Figure 17 the assessment results by the respondents for the factor 'Non-availability of drawing/ design on time' is shown to give an idea of the results. An overview of all the results of questionnaire (III) can be found in Appendix O – BBN: Results questionnaire (III).

Non-availability of drawing/design on time				
Late in revising and approving design documents	*Slowness in the decision-making process*	*Change orders*	*Yes (%)*	*No (%)*
Yes	Yes	Yes	100	0
		No	90	10
	No	Yes	70	30
		No	50	50
No	Yes	Yes	100	0
		No	50	50
	No	Yes	60	40
		No	20	80

Figure 17: Assessment results for the factor 'Non-availability of drawing/design on time'

For example, when "Late in revising and approving design documents" **(NO)** not occurred in the project, "Slowness in the decision-making process" **(NO)** not occurred in the project and "Change orders" **(YES)** occurred in the project. Then 60% of the respondents assessed the chance of occurrence likely *(Yes)* and 40% of the respondents assessed unlikely *(No)*.

6.3.3 Conclusion overview results questionnaire (III)

Questionnaire (III) focused on the estimation of the conditional probabilities between the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The purpose of questionnaire (III) was to answer sub-question VI – What are the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? In total ten experts participated in completing questionnaire (III).

In the second part of questionnaire (III), experts were asked to assess the occurrence of a factors' condition on the basis of certain conditions of other factors that have a relationship. The respondent needs to answer the following question, what is the effect on the project when the following factors occurred during the execution phase of UCP? Each case was assessed by awarding a delay representing a percentage of the total project duration. This resulted in a percentage of respondents choosing for a certain delay option.

In the last part of questionnaire (III), experts were asked to assess the probability of occurrence on the basis of other applicable factors that have a relationship. The respondent needs to answer the following question, what is the probability that the following factor occurs during the execution phase of UCP when other factors are applicable? Each case was assessed by awarding whether the chance of occurrence is likely (Yes) or unlikely (No). This resulted in a percentage of respondents choosing for a certain option.

The overview of conditional probabilities derived from questionnaire (III) can be found in Appendix O – BBN: Results questionnaire (III). After answering sub-question VI by finding the conditional probabilities from questionnaire (III) a BBN can be developed out the DG. In the next section, the transformation from the DG to BBN is discussed.

6.4 From a Directed graph to Bayesian belief network

The conditional probabilities, derived from questionnaire (III) as shown in Appendix O – BBN: Results questionnaire (III), were included in the BBN by using the free academic computer program GeNIe. After the data was implemented, the DG in GeNIe will function as a BBN and could be used to identify and evaluate the probabilities of a factors' condition on the basis of certain conditions of other factors that have a relationship. The BBN was tested for two, by the graduation company, executed projects that experienced delays. Table 25 presents brief information on both projects.

Table 25: Brief information Project A and Project B

	Project A	**Project B**
Project type	Sports Hall	School
Owner	Public	Public
Project scope	New-build project	Renovation + New-build project
Commencement date	November 2015	September 2015
Completion date on the basis of the contract	September 2016	June 2016
Original duration on the basis of the contract *(in workable weeks)*	38 weeks	36 weeks
Actual completion date	October 2016	March 2017
Delay	2 weeks	34 weeks
Percentage delay	5.3%	94.4%

According to the expert interviews in Chapter 3, the factors “Conflicts between the contractor and other parties” and “Ineffective planning and scheduling” occurred in Project A. It was estimated that the likelihood in Project A is approximately 20.0% for a delay of “< 5%” and 80.0% for a delay between the “5 – 10%” of the original project’s duration, as shown in Table 26,. According to the BBN, the chance is likely the project experiences a delay between the 5 – 10% of the original project duration. In reality, Project A experienced a delay of two weeks that resulted in an actual completion date in October 2016. There is a delay of 5.3% of the original duration (38 weeks) in Project A. This example suggests that the prediction of the BBN is in line with the delay occurred in Project A. The conditional probabilities for Project A are shown in Figure 24 in Appendix P – BBN: Results testing BBN.

Table 26: Probabilities of time-overrun on the basis of the output of the BBN

Delay	**Project A (%)**	**Project B (%)**
“< 5%”	20.0	0.0
“5 – 10%”	80.0	0.6
“10 – 15%”	0	0.8
“15 – 20%”	0	29.8
“> 20%”	0	68.8

According to the expert interviews in Chapter 3, the factors “Change orders”, “Slowness in the decision-making process”, “Unreliable sub-contractors/suppliers”, “Poor communication and coordination”, “Ineffective planning and scheduling” and “Unrealistic enforced contract duration” occurred in Project B. It was estimated that the likelihood in Project B is approximately 29.8% for a delay between the “15 – 20%” and 68.8% for a delay of “> 20%” of the original project’s duration, as shown in Table 26. According to the BBN, the chance is likely the project experiences a delay of > 20% of the original project duration. In reality, Project B experienced a delay of thirty-four (34) weeks that resulted in an actual completion date in March 2017. There is a delay of 94.4% of the original duration (36 weeks) in Project B. This example suggests that the prediction of the BBN is in line with the delay occurred in Project B. The conditional probabilities for Project B are shown in Figure 25 in Appendix P – BBN: Results testing BBN.

The BBN can be used to evaluate the effect of a factors’ condition on the basis of certain conditions of other factors. It has to be noted that it is important to control the factors that can lead to a direct delay. This concerns the following factors, namely “Incomplete and unclear drawings”, “Non-availability of drawing/design on time”, “Information delays and lack of information exchange between the parties” and “Conflicts between the contractor and other parties”. When this is not the case, the chances of major delays are likely to occur. The BBN can help project managers to execute a project-specific sensitivity analysis to make estimates that certain factors occur, together with the associated effects on the project. This is useful to make right decisions in order to avoid delays in the execution phase of UCP in the Netherlands.

6.5 Conclusion questionnaire (III): Probabilities of critical factors

Questionnaire (III) focused on the estimation of the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. The purpose of questionnaire (III) was to answer sub-question VI – What are the conditional probabilities of the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands? With these conditional probabilities, a Bayesian belief network (BBN) can be developed out the DG.

In the second part of questionnaire (III), experts were asked to assess the occurrence of a factors’ condition on the basis of certain conditions of other factors that have a relationship. The respondent needs to answer the following question, what is the effect on the project when the following factors occurred during the execution phase of UCP? Each case was assessed by awarding a possible delay in a percentage of the total project duration.

In the last part of questionnaire (III), experts were asked to assess the probability of occurrence on the basis of other applicable factors that have a relationship. The respondent needs to answer the following question, what is the probability that the following factor occurs during the execution phase of UCP when other factors are applicable? Each case was assessed by awarding whether the chance of occurrence is likely (Yes) or unlikely (No). The overview of results can be found in Appendix O – BBN: Results questionnaire (III). These results were included in the BBN using the free academic computer program GeNIe.

After the data was implemented, the DG will function as a BBN and could be used to identify and evaluate the probabilities of a factors’ condition on the basis of certain conditions of other factors that have a relationship. The BBN was tested for two, by the graduation company, executed projects that experienced delays. The results suggested that the prediction of the BBN is in line with the delays occurred in both projects.

After answering sub-question VI and testing the BBN with two executed projects that experienced delays. A BBN was developed from the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands on the basis of the conditional probabilities derived from questionnaire (III). The BBN can be used to evaluate the effect of a factors’ condition on the basis of certain conditions of other factors. A project-specific sensitivity analysis can be made by project managers to make estimates that certain factors will occur in a project, together with the associated effects. The conclusion and recommendations of this thesis are described in the next Chapter.

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7 Conclusion

In the final Chapter, the conclusion of this thesis, the relevance and the recommendations are explained concisely. The overall conclusion with an answer to the main research question is carried out in Chapter 7.1. The reflection on the literature review, the methodologies and the results are presented in Chapter 7.2. The societal and scientific relevance of this thesis is discussed in Chapter 7.3. At last, the recommendations for future research is elaborated in Chapter 7.4.

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7.1 Research findings

This thesis used a different method for capturing and reusing valuable knowledge and experiences from executed Utility construction projects (UCP) in order to prevent schedule delays. The purpose of this thesis was to quantify the critical factors that cause delays and affect the execution phase of UCP in the Netherlands using a Bayesian belief network (BBN). In order to fulfil this purpose, this thesis focused on selecting the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands, identifying the cause-effect relationships between the important critical factors and estimating the associated conditional probabilities. By capturing the cause-effect relationships and conditional probabilities a BBN was developed.

The research question central to this thesis was:

What are the probabilities that the most influential critical factors will cause delays and affect the execution phase of Utility construction projects using the Bayesian belief network?

The factors that influence construction projects have been collected through a literature review. With expert interviews, the factors that influence construction projects has been reduced to critical factors that cause delays and affect the execution phase of UCP. These critical factors have been assessed by the respondents in questionnaire (I). The critical factors that cause delays and affect the execution phase of UCP in the Netherlands have been selected using the Fuzzy Delphi Method (FDM). Using nine Logical rules, the cause-effect relationships between the selected critical factors have been accepted by the respondents in questionnaire (II). On the basis of these cause-effect relationships a Directed graph (DG) has been developed. The knowledge and experience of experts have been used to create a BBN out of the DG by estimating the conditional probabilities in questionnaire (III). The found conditional probabilities are implemented in the DG using the free academic computer program GeNIe (https://www.bayesfusion.com/). This BBN can be used to identify and evaluate the probabilities of a factors' condition on the basis of certain conditions of other factors.

The most influential critical factors that cause delays in the execution phase of UCP in the Netherlands according to the Expert discussions are:

I. Non-availability of drawing/design on time;
II. Poor communication and coordination;
III. Information delays and lack of information exchange between the parties;
IV. Conflicts between the contractor and other parties;
V. Incomplete and unclear drawings.

The probabilities of schedule delays for these factors can be determined by means of the BBN. The results of the most influential critical factors that cause delays in the execution phase of UCP are described below.

When the factor ***"Non-availability of drawing/design on time"*** occur during the execution phase of the project and the other most influential critical factors that not have a cause-effect relationship to this factor are controlled, the BBN estimates the probabilities as shown in Table 27. According to the BBN, the chance is likely that the critical factor "*Incomplete and unclear drawings*" will also occur in the project and the schedule delay is somewhere between the ***5 – 20%*** of the original project duration.

Table 27: Probabilities of delay for "Non-availability of drawing/design on time"

	Delay*	Chance of occurrence according the BBN (%)
1	< 5%	11.4
2	5 – 10%	20.4
3	10 – 15%	26.9
4	15 – 20%	29.5
5	> 20%	11.8

* The delay is expressed in percentage (%) of the original project duration

When the factor ***"Conflicts between the contractor and other parties"*** occur during the execution phase of the project and the other most influential critical factors that not have a cause-effect relationship to this factor are controlled, the BBN estimates the probabilities as shown in Table 28. According to the BBN, the schedule delay is somewhere between the ***5 – 10%*** of the original project duration.

Table 28: Probabilities of delay for "Conflicts between the contractor and other parties"

	Delay*	Chance of occurrence according the BBN (%)
1	< 5%	14.7
2	5 – 10%	74.7
3	10 – 15%	8.0
4	15 – 20%	2.7
5	> 20%	0.0

* The delay is expressed in percentage (%) of the original project duration

When the factor ***"Poor communication and coordination"*** occur during the execution phase of the project and the other most influential critical factors that not have a cause-effect relationship to this factor in the BBN are controlled, the BBN estimates the probabilities as shown in Table 29. According to the BBN, the chance is likely that the critical factors "*Incomplete and unclear drawings*", "*Information delays and lack of information exchange between the parties*" and "*Conflicts between the contractor and other parties*" will also occur in the project and the schedule delay is somewhere between the ***5 – 20%*** of the original project duration.

Table 29: Probabilities of delay for "Poor communication and coordination"

	Delay*	Chance of occurrence according the BBN (%)
1	< 5%	0.6
2	5 – 10%	30.5
3	10 – 15%	22.0
4	15 – 20%	39.4
5	> 20%	7.5

* The delay is expressed in percentage (%) of the original project duration

When the factor ***"Information delays and lack of information exchange between the parties"*** occur during the execution phase of the project and the other most influential critical factors that not have a cause-effect relationship to this factor are controlled, the BBN estimates the probabilities as shown in Table 30. According to the BBN, the chance is likely that the critical factors "*Incomplete and unclear drawings*", "*Non-availability of drawing/design on time*" and "*Conflicts between the contractor and other parties*" will also occur in the project and the schedule delay is somewhere between the ***15 – > 20%*** of the original project duration.

Table 30: Probabilities of delay for "Information delays and lack of information exchange between the parties "

	Delay*	Chance of occurrence according the BBN (%)
1	< 5%	1.8
2	5 – 10%	1.8
3	10 – 15%	4.9
4	15 – 20%	33.8
5	> 20%	57.7

* The delay is expressed in percentage (%) of the original project duration

When the factor ***"Incomplete and unclear drawings"*** occur during the execution phase of the project and the other most influential critical factors that not have a cause-effect relationship to this factor are controlled, the BBN estimates the probabilities as shown in Table 31. According to the BBN, the chance is likely that the critical factor "*Non-availability of drawing/design on time*" will also occur in the project and the schedule delay is somewhere between the ***5 – 20%*** of the original project duration.

Table 31: Probabilities of delay for "Incomplete and unclear drawings"

	Delay*	Chance of occurrence according the BBN (%)
1	< 5%	12.3
2	5 – 10%	24.7
3	10 – 15%	24.6
4	15 – 20%	27.5
5	> 20%	10.9

* The delay is expressed in percentage (%) of the original project duration

The most influential critical factors "*Information delays and lack of information exchange between the parties*", "*Incomplete and unclear drawings*", "*Non-availability of drawing/design on time*" and "*Poor communication and coordination*" in the Netherlands need to be controlled in future UCP to avoid schedule delays in advance. It appears that these factors have a high chance of causing delays and affecting the execution phase of UCP in the Netherlands, as shown in Table 32.

Table 32: Probabilities that the most influential critical factors cause delays

	Critical factors	Delay *
1	Information delays and lack of information exchange between the parties	*15 – > 20%*
2	Incomplete and unclear drawings	*5 – 20%*
3	Non-availability of drawing/design on time	*5 – 20%*
4	Poor communication and coordination	*5 – 20%*
5	Conflicts between the contractor and other parties	*5 – 10%*

* The delay is expressed in percentage (%) of the original project duration

7.2 Reflection

The most important learning moment of the past months is it pays to invest enough time in the development of the proposal to be able to write a consistent story on paper. Looking back at my proposal, relatively much attention has been paid to the research design of this thesis that has helped enormously in writing this thesis. During the process, more and more puzzle pieces fell into place by considering the following questions, namely what do I want to achieve, why do I need to achieve this, how do I achieve this and what are the results in the end? When all the questions were answered, the follow-up steps have been taken. This is a good way to be able to justify certain choices made in the process. I found it difficult to integrate this way of reasoning in the storyline of this thesis.

It can be concluded that choosing the methods has been applied in the correct way. Not all the available methods were tested and compared with each other. On the basis of the theory, choices were made which methods can be applied for analysing the results. It is important to know that the results have been acquired using a chosen method, but that the results may differ with the use of another method. It is known that using a method involves a certain error in the results, therefore, a reliability or validity check had been done for each method. The reliability or validity for the literature review, applied research methodologies and research results are discussed in more in the next sections.

7.2.1 Reflection literature review

The literature review provided useful theory for the research. Sufficient data about the influencing factors was provided by the literature review. The literature review included in total thirty international articles, despite the fact that this could have been more, the results were considered as reliable. As more articles were included in the literature review, fewer factors could be added to the list of influencing factors. Since this thesis focussed on the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands, the gap in literature had to be further explained.

In order to achieve this, the list of factors that influence construction projects was reduced to critical factors that cause delays and affect the execution phase of UCP by expert interviews. These interviews have been held with business/project managers that know the ins and outs of UCP. It remains questionable whether these interviews provided all the critical factors that cause delays and affect the execution phase of UCP. To overcome this issue and ensure that the list of critical factors was complete, the factors that occurred ten times or more in the literature review were included as well in the list of critical factors.

7.2.2 Reflection research methodologies

With the assumption that the list of critical factors is complete, questionnaire (I) has been carried out in order to select the important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. I have chosen to analyse the results of the respondents, from questionnaire (I), using the FDM because this method captures the uncertainty caused by the human factor. Since this method took the uncertainty of the human factor into account, this seemed a better method than, for example, using the relative importance index or the Cronbach’s alpha where this is not the case. An overall ranking ensured that every answer from each respondent was considered equally important because some of the respondents are representing another groups as well. This makes it difficult to ensure that each respondent was not influenced by the perspective of the other group. In total twenty factors were ranked as important critical factors that cause delays and affect the execution phase of UCP in the Netherlands. It remains questionable whether the use of another method will lead to different results. However, when discussing the results of questionnaire (I) with people in practice this does not seem to contain strange results. To increase the reliability and validity of questionnaire (I), I could have held extra interviews to discuss the results of the FDM.

With the known important critical factors, questionnaire (II) has been carried out in order to identify the cause-effect relationships between the important critical factors. I have chosen to analyse the results of the respondents, from questionnaire (II), using the nine logical rules because it was expected that the FDM was not sensitive enough for identifying the relationships. It seemed a reasonable choice to apply the nine logical rules in questionnaire (II) because this method assured that the strongest cause-effect relationships were captured. It is possible that another method will lead to different results, but this methodology already proved to be successful in several articles, for example, the articles of Nasir et al. (2003) and Van Truong et al. (2009).

With the identified cause-effect relationships a DG was developed on the basis of the accepted relationships by means of the highest average scores. The development of the DG started with the accepted relationships by means of the highest average scores. A questionnaire (III) was carried out to estimate the conditional probabilities of the important critical factors in the DG. After the data of the respondents, from questionnaire (III), was implemented, the DG will function as a BBN. It remains questionable whether a larger number of respondents for questionnaire (III) will influence the results of the conditional probabilities in the BBN. To validate the result, the BBN was tested for two executed projects that experienced delays. The results suggested that the prediction of the BBN is in line with the delays occurred in both projects. It is important to know that the applicability may depend on the circumstances of the project, the parties involved in the project and the type of contract.

7.2.3 Reflection research results

As said before, this thesis used a different method for capturing and reusing valuable knowledge and experiences from executed UCP in order to prevent schedule delays in the future. Using the literature review and the experience of experts have helped to develop a BBN that laid the grounds for a tool that can help predict schedule delays by reusing the captured valuable knowledge and experiences from executed UCP. After the BBN was tested for two, by the graduation company, executed projects that experienced delays it can be concluded that this thesis has managed to successfully use this different method. As a result, project managers can perform a project-specific sensitivity analysis to make estimates that certain factors will occur, together with the associated effects. The sensitivity analysis can emerge very interesting information and can be very useful in practice.

Although this thesis has successfully achieved its objectives, some parts of the research could be improved. For example, it remains questionable whether a larger number of respondents for questionnaire (II) and (III) will influence the results of the cause-effect relationships and the conditional probabilities in the BBN. Therefore, a follow-up research can use the results of this thesis and check the results with more projects in order to explore the utility of the BBN. In the end, I did not expect that the results of ten respondent in questionnaire (III) were in line with the delays experienced in the tested already executed projects. Whether the BBN is useful in practice must be tested in future projects.

Unfortunately, the results from this thesis cannot be compared to the results of Van Truong et al. (2009) because within every country there are differences in the law and legalisation, the climate, the economy, the culture and the living and working environment. This led to different results throughout the whole process of the thesis. Despite these differences in results this thesis can be seen as a follow-up exploratory research, on the basis of the research of Van Truong et al. (2009), towards quantifying critical factors that cause delays and affect the execution phase of UCP in the Netherlands by using a Bayesian belief network. For now, the research findings provide sufficient insights for the relevance and recommendations in the next sections.

7.3 Relevance

7.3.1 Scientific relevance

In the Literature, the quantification of the dependencies of one factor over others has received the attention in multiple international articles. Within this line of research, some articles included the link between the causes and the effects. However, less research has been conducted on predicting the probabilities of delays, despite the vital role in contributing to the success of construction projects. For this reason, this thesis about quantifying critical factors that cause delays and affect the execution phase of UCP in the Netherlands by using a Bayesian belief network is relevant to science.

Many international articles have identified various factors that cause delays and affect construction projects. However, in the Netherlands, there is no research conducted on the factors that cause delays and affect the execution phase of UCP. This fact makes this thesis interesting for science and multiple parties in the Dutch construction industry. This thesis laid the ground for a tool that can help predict schedule delays by reusing the captured valuable knowledge and experiences from executed UCP. With the BBN, a sensitivity analysis can be performed to make estimates that certain factors occur, together with the associated effects on the project. To my knowledge, this is the first time a network approach is used for structuring schedule delays in the Netherlands.

7.3.2 Societal relevance

It was expected that the results could differ with international articles because within every country there are differences in the law and legalisation, the climate, the economy, the culture and the living and working environment. This thesis has shown that the results are indeed different compared to international articles and provides valuable information for multiple parties in the Dutch construction industry. There are many important factors that cause delays, therefore, the awareness alone about the factors that cause delays and the extent to which they can adversely affect project delivery is valuable.

This thesis will confirm the understandings and insights in the factors that cause delays and affect the execution phase of UCP in the Netherlands. In practice, the results will help to take action against the factors and thereby reducing delays at an early stage during the execution phase of future UCP. A project-specific sensitivity analysis can be made by project managers, to make estimates that a certain factor occurs in the project together with the associated effects.

7.4 Recommendations

7.4.1 Construction industry in the Netherlands

It is recommended, that project managers should understand their responsibility, to control the conditions of the factors "*Information delays and lack of information exchange between the parties*", "*Incomplete and unclear drawings*", "*Non-availability of drawing/design on time*" and "*Poor communication and coordination*" in order to avoid schedule delays in future projects. In this thesis, it appears that these factors have a high chance of causing delays and affecting the execution phase of UCP in the Netherlands.

In addition, the BBN can be used to identify and evaluate more probabilities of factors on the basis of certain conditions of other factors. The results in the thesis suggested that the BBN gave a good prediction for the tested delays. As a result, project managers can perform project-specific sensitivity analysis to make estimates that certain factors occur together with their associated effects. The sensitivity analysis can emerge very interesting information and can be very useful in practice for the construction industry in the Netherlands.

7.4.2 Future research

This thesis can be seen as a follow-up exploratory research, on the basis of the research of Van Truong et al. (2009), towards quantifying critical factors that cause delays and affect the execution phase of UCP in the Netherlands by using a Bayesian belief network. Future research is needed to check the results with more projects and gain more insights on the subject of this thesis and to explore its utility of the BBN.

During the graduation project, it was difficult to determine the factors that play a critical role during the execution phase of UCP. As said before in the thesis, UCP are one-off endeavours with many unique features. According to the interviews and discussions with experts, the factors that play a critical role during the execution phase of UCP will strongly depend on the circumstances of the project, the parties involved in the project and the type of contract. When project-specific delay factors or cause-effect relationships are not included in the BBN, it should be possible to extend the BBN to accurately quantify project-specific. Future research could use the BBN in other construction projects, in different phases or with a specific type of contract in order to explore the full utility from the power of BBNs.

Since some results in this thesis are derived from sufficient knowledge and rich experiences of only a few experts, it would be interesting to further validate and develop the BBN. If the representatives' groups were about the same size, it would have been possible to make separate BBNs for every representative group. By making separate BBNs in the future, the differences between these groups can be studied. Such a research could help in identifying the problem areas in the decision-making process to successfully manage the uncertainties of schedules at an early stage.

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Eindhoven University of Technology

Appendices Book

J. Boeters

Master Construction Management and Engineering

February 2018

Appendix A – Literature review: Influencing factors

No.	Cause of delay influencing construction projects	Group	Occurrence
01	Poor communication and coordination	Project	19
02	Complexity of the project (e.g. Location, project size, etc.)	Project	10
03	Selection and assignment criteria	Project	9
04	Poor project management	Project	8
05	Changed conditions of the project	Project	7
06	Poor monitoring and control	Project	7
07	Information delays and lack of information exchange between the parties	Project	5
08	Improper feasibility study	Project	5
09	Conflicts between joint-ownership of the project	Project	4
10	Incompetent project team	Project	2
11	Unfairness in tendering	Project	1
12	Poor risk management	Project	1
13	Unrealistic enforced contract duration	Contractual	18
14	Legal dispute(s) between various parts	Contractual	14
15	Ineffective delay penalties	Contractual	7
16	Mistakes or discrepancies in the contract document(s)	Contractual	6
17	Poor contract management	Contractual	6
18	contractual claims	Contractual	4
19	Lack of strictness and binding in the contract document(s)	Contractual	2
20	Not familiar with the condition of the contract	Contractual	2
21	Type of construction contract (Turnkey, building team, DBFMO)	Contractual	2
22	Breach of contract	Contractual	1
23	Unrealistic contract price	Contractual	1
24	Unfavourable contract clauses	Contractual	1
25	Delay in progress payments from the client	Client	27
26	Slowness in the decision-making process’	Client	22
27	Change orders	Client	16
28	Clients' financial difficulties for the project	Client	15
29	Design changes	Client	13
30	Late in revising and approving design documents	Client	12
31	Lack/increase of scope definition	Client	12
32	Delay to furnish and deliver the site on time	Client	11
33	Lack of incentives for contractor to finish ahead of schedule	Client	8
34	Interference of the client	Client	8
35	Delay in handing over process or approval of completed work	Client	8
36	Lack of experience of the client	Client	7
37	Suspension of work	Client	7
38	Non-availability of drawing/design on time	Client	5
39	Commercial pressure	Client	1
40	New instructions to additional work	Client	1

No.	Cause of delay influencing construction projects	Group	Occurrence
41	Ineffective planning and scheduling	Contractor	24
42	Poor site management and supervision	Contractor	22
43	Rework due to errors	Contractor	22
44	Lack of experience of the contractor	Contractor	20
45	Contractors' financial difficulties for the project	Contractor	17
46	Improper construction methods implemented	Contractor	13
47	Conflicts between the contractor and other parties	Contractor	7
48	Delays related to sub-contractors/supplier's work	Contractor	6
49	Inaccurate time and cost estimations	Contractor	6
50	Poor qualification of the technical staff	Contractor	6
51	Frequent change of sub-contractors/suppliers	Contractor	5
52	Delay in progress payments to sub-contractor/supplier	Contractor	5
53	Discrepancy between design specification and construction	Contractor	5
54	Application of safety aspects	Contractor	4
55	Cash flow problems faced by the contractor	Contractor	4
56	Contractor's workload	Contractor	4
57	Inefficient quality control by the contractor	Contractor	3
58	Personnel changes of staff	Contractor	3
59	Inaccurate quantities	Contractor	3
60	Low bidding of the contractor in the tendering	Contractor	3
61	Conflicts in sub-contractor's schedule in execution of project	Contractor	2
62	Unreliable sub-contractors/suppliers	Contractor	2
63	Multiple projects by the contractor	Contractor	2
64	Lack of access to modern technologies	Contractor	2
65	Lack of control over subcontractor / supplier	Contractor	2
66	Contractor's compensation issues	Contractor	2
67	Time spent to find appropriate subcontractors/suppliers	Contractor	1
68	Work interference between various contractors	Contractor	1
69	Replacement contractor	Contractor	1
70	Lack of motivation for contractors for early finish	Contractor	1
71	emergency works	Contractor	1
72	Lack of experience of the consultant	Consultant	11
73	Delay in performing inspection and testing	Consultant	10
74	Late in reviewing and approving design documents	Consultant	8
75	Inflexibility of the consultant	Consultant	5
76	Delay in approving major changes in the scope of work	Consultant	4
77	Conflicts between the consultant and design engineer	Consultant	4
78	Mistakes or discrepancies in document(s) or specifications	Consultant	4
79	Replacement of consultants	Consultant	1

No.	Cause of delay influencing construction projects	Group	Occurrence
80	Mistakes and discrepancies in design documents	Design	13
81	Incomplete and unclear drawings	Design	9
82	Lack of experience of design team	Design	6
83	Delays in producing design documents	Design	6
84	Complexity of project design	Design	6
85	Misunderstanding of client's requirements by design engineer	Design	5
86	Insufficient data collection and survey before design	Design	5
87	No use of advanced engineering design software	Design	3
88	Unforeseen site conditions	Site	20
89	Loss of time by traffic control and restriction(s) on site	Site	9
90	Unavailability of utilities on site (such as, water, electricity, telephone, etc.)	Site	7
91	Inaccurate investigation on site	Site	7
92	Delay in mobilisation on site	Site	6
93	Effects of subsurface conditions (e.g. Soil, high water table, etc.)	Site	5
94	Storage of materials and equipment on site	Site	3
95	Unsafe practice on site	Site	2
96	Fluctuation of material prices	Material	17
97	Delay in material delivery	Material	17
98	Shortage of construction materials	Material	16
99	Low quality of material(s)	Material	10
100	Problems with the procurement of materials	Material	10
101	Changes in material types and specifications during construction	Material	8
102	Damage of sorted materials while they are needed	Material	5
103	Delay in manufacturing building materials	Material	4
104	Late in the selection of finishing materials	Material	3
105	Receiving materials that do not fulfil project requirements	Material	1
106	Equipment(s) shortage	equipment	19
107	Equipment breakdown(s)	equipment	13
108	Low productivity and efficiency of equipment	equipment	8
109	Lack of high-technology mechanical equipment	equipment	8
110	Improper equipment	equipment	6
111	Low level of equipment-operator's skill	equipment	4
112	Equipment allocation problem	equipment	3
113	Slow mobilisation of equipment	equipment	2
114	Shortage of labour	labour	19
115	Low productivity of labours	labour	13
116	Shortage of unskilled and skilled labour	labour	13
117	(Personal) Conflicts among labours	labour	6
118	Labour strikes	labour	6
119	Unqualified workforce	labour	5
120	Too many responsibilities	labour	2
121	Nationality of labours	labour	2

No.	Cause of delay influencing construction projects	Group	Occurrence
122	Unfavourable weather conditions	External	23
123	Changes in government regulations and laws	External	16
124	Delay in obtaining permits from authorities	External	14
125	Organisational structure (e.g. Bureaucracy)	labour	12
126	Accident during construction	External	11
127	State of market conditions	External	9
128	Natural disasters (flood, hurricane, earthquake)	External	8
129	Delay in performing final inspection and certification by a third party	External	7
130	Inflation	External	7
131	Problem with nearby neighbours, structure or facilities	External	7
132	Delay in providing services from utilities (such as water, electricity)	External	5
133	Effect of social and cultural factors	External	5
134	Changes in government policy	External	4
135	Environmental restrictions (Flora and Fauna)	External	3
136	Difficulty in claiming insurance	External	2

Appendix B – The Literature review: Detailed overview

Author(s)	Project-related factors	01	02	03	04	05	06	07	08	09	10	11	12	Contractual-related factors	13	14	15	16	17	18	19	20	21	22	23	24	Client-related factors	25	26	27	28	29	30
Abusafiya & Suliman (2017)		X	X		X		X	X												X								X	X		X	X	X
Adam et al. (2014)		X	X				X								X													X	X	X			
Al-Hazim & Abusalem (2015)																												X	X	X			
Alinaitwe, Apolot, & Tindiwensi (2013)		X	X				X									X		X										X					
Arantes et al. (2015)		X		X											X	X		X										X	X	X			
Arditi et al. (2017)			X			X													X									X	X	X		X	
Assaf & Al-Hejji (2006)		X		X						X					X	X	X						X					X	X	X			X
Aziz & Abdel-Hakam (2016)		X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X		X			X	X	X	X	X	X
Bagaya & Song (2016)		X				X										X		X	X									X	X	X	X		X
Bhadoria et al. (2016)															X													X	X	X			
Doloi et al. (2012)		X													X	X		X										X	X			X	X
El-Sayegh (2008)												X			X	X			X					X				X			X	X	X
Gardezi et al. (2014)						X									X	X												X	X		X	X	
Gluszak & Lešniak (2015)															X													X	X	X	X		
Gunduz & AbuHassan (2016)		X		X		X									X													X	X		X		X
Gündüz et al. (2013)		X	X		X				X	X	X				X	X	X									X		X	X	X		X	X
Islam, Trigunarsyah, Hassanain, & Assaf (2015)				X	X		X																										
Kaliba et al. (2009)		X				X																						X		X	X	X	
Kikwasi (2013)					X			X								X				X								X			X	X	
Larsen et al. (2016)		X	X	X		X			X						X	X													X		X		
Marzouk & El-Rasas (2014)		X		X											X		X											X	X				X
Megha & Rajiv (2013)		X													X	X	X											X	X	X			X
Rajgor et al. (2016)		X													X													X	X	X			
Ravisankar et al. (2014)		X	X						X				X			X												X	X		X	X	X
Sambasivan & Soon (2007)		X													X	X		X	X									X	X	X			
Shehu et al. (2014)		X	X	X			X	X	X	X					X		X		X	X		X						X	X	X		X	
Tawil et al. (2013)					X																							X			X	X	
Van Truong et al. (2009)							X																					X			X		
Van Truong et al. (2015)		X	X	X	X			X									X				X							X	X		X		X
Zou et al. (2007)					X										X															X	X	X	
Total		19	10	9	8	7	7	5	5	4	2	1	1		18	14	7	6	6	4	2	2	2	1	1	1		27	22	16	15	13	12

The numbers cross the top represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

Author(s)	Client-related factors	31	32	33	34	35	36	37	38	39	40	Contractor-related factors	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Abusafiya & Suliman (2017)		X							X				X	X	X	X					X			X			X	X	X				
Adam et al. (2014)							X						X	X	X	X									X								
Al-Hazim & Abusalem (2015)													X								X			X	X								
Alinaitwe et al. (2013)		X											X		X									X					X				
Arantes et al. (2015)		X	X	X	X								X	X	X	X	X	X					X										
Arditi et al. (2017)													X	X	X	X	X			X													
Assaf & Al-Hejji (2006)		X	X	X				X					X	X	X		X	X	X	X		X	X									X	
Aziz & Abdel-Hakam (2016)		X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X		
Bagaya & Song (2016)					X	X							X	X	X	X	X			X													X
Bhadoria et al. (2016)													X	X	X	X	X																
Doloi et al. (2012)		X	X			X			X				X	X	X	X	X	X					X										
El-Sayegh (2008)		X	X		X	X			X						X	X	X					X										X	
Gardezi et al. (2014)													X	X	X	X	X	X															
Głuszak & Lešniak (2015)													X	X					X												X		
Gunduz & AbuHassan (2016)			X			X	X	X					X	X	X	X	X	X		X													
Gündüz et al. (2013)		X	X	X			X	X					X	X	X	X		X					X					X					
Islam et al. (2015)					X								X	X		X					X					X	X		X				
Kaliba et al. (2009)		X											X	X	X		X					X											
Kikwasi (2013)																X			X														
Larsen et al. (2016)		X							X				X		X	X															X		
Marzouk & El-Rasas (2014)		X	X		X			X					X	X	X	X	v			X										X			
Megha & Rajiv (2013)			X	X				X					X	X	X		X	X	X													X	
Rajgor et al. (2016)														X	X			X															
Ravisankar et al. (2014)				X			X						X	X	X	X		X			X				X	X							
Sambasivan & Soon (2007)					X								X	X	X	X		X	X											X			
Shehu et al. (2014)		X	X	X	X	X		X		X			X	X			X	X	X			X		X		X	X			X			
Tawil et al. (2013)						X					X					X																	
Van Truong et al. (2009)			X				X								X	X	X	X															X
Van Truong et al. (2009)				X		X	X							X			X								X								
Zou et al. (2007)													X				X				X	X						X					
Total		12	11	8	8	8	7	7	5	1	1		24	22	22	20	17	13	7	6	6	6	5	5	5	4	4	4	3	3	3	3	2

The numbers cross the top represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

Author(s)	Contractor-related factors	62	63	64	65	66	67	68	69	70	71	Consultant-related	72	73	74	75	76	77	78	79	Design-related factors	80	81	82	83	84	85	86	87	Site-related factors	88	89	90
Abusafiya & Suliman (2017)																						X	X		X								
Adam et al. (2014)													X											X							X		
Al-Hazim & Abusalem (2015)											X																				X		
Alinaitwe et al. (2013)																															X		
Arantes et al. (2015)					X									X	X	X						X			X	X					X		X
Arditi et al. (2017)													X									X	X								X		
Assaf & Al-Hejji (2006)		X											X	X	X	X	X	X				X	X	X	X	X	X	X	X		X	X	X
Aziz & Abdel-Hakam (2016)		X				X	X						X	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X	X
Bagaya & Song (2016)														X																	X		
Bhadoria et al. (2016)																																	
Doloi et al. (2012)					X					X				X		X			X												X	X	
El-Sayegh (2008)				X											X							X	X								X		
Gardezi et al. (2014)															X				X														
Głuszak & Lešniak (2015)				X																		X											
Gunduz & AbuHassan (2016)													X	X	X				X												X	X	X
Gündüz et al. (2013)													X	X	X		X	X				X	X	X	X	X	X	X	X		X	X	
Islam et al. (2015)																																X	
Kaliba et al. (2009)																																	
Kikwasi (2013)			X			X																					X				X		
Larsen et al. (2016)													X									X									X		
Marzouk & El-Rasas (2014)													X									X	X									X	X
Megha & Rajiv (2013)													X	X		X	X	X				X	X		X	X	X	X			X	X	X
Rajgor et al. (2016)																																	
Ravisankar et al. (2014)													X									X	X			X		X			X		
Sambasivan & Soon (2007)														X	X																X		
Shehu et al. (2014)								X						X								X									X		
Tawil et al. (2013)			X						X											X											X	X	
Van Truong et al. (2009)																								X									
Van Truong et al. (2009)													X											X							X		
Zou et al. (2007)																																	X
Total		2	2	2	2	2	1	1	1	1	1		11	10	8	5	4	4	4	1		13	9	6	6	6	5	5	3		20	9	7

The numbers cross the top represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

Author(s)	Site-related factors	91	92	93	94	95	Material-related factors	96	97	98	99	100	101	102	103	104	105	Equipment-related factors	106	107	108	109	110	111	112	113	Labour-related factors	114	115	116	117
Abusafiya & Suliman (2017)								X	X	X									X	X								X	X	X	
Adam et al. (2014)																			X									X	X	X	
Al-Hazim & Abusalem (2015)								X			X										X							X			
Alinaitwe et al. (2013)											X										X									X	
Arantes et al. (2015)			X					X	X	X	X	X	X	X					X				X						X		
Arditi et al. (2017)		X						X	X	X									X	X			X					X	X		
Assaf & Al-Hejji (2006)			X	X					X	X		X	X	X	X	X			X	X	X	X		X				X	X	X	X
Aziz & Abdel-Hakam (2016)		X	X	X	X			X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X	X	X
Bagaya & Song (2016)								X		X	X								X									X			
Bhadoria et al. (2016)									X										X	X								X			
Doloi et al. (2012)		X			X			X	X			X									X	X							X		
El-Sayegh (2008)								X	X	X	X								X									X	X		
Gardezi et al. (2014)								X														X								X	
Głuszak & Lešniak (2015)									X												X									X	
Gunduz & AbuHassan (2016)						X			X	X			X						X	X								X	X		
Gündüz et al. (2013)		X						X	X	X	X	X	X	X	X				X	X	X	X	X		X	X		X	X		X
Islam et al. (2015)								X														X								X	
Kaliba et al. (2009)												X							X												
Kikwasi (2013)										X		X							X											X	
Larsen et al. (2016)																															
Marzouk & El-Rasas (2014)			X	X				X	X	X			X						X	X								X	X		
Megha & Rajiv (2013)			X	X					X			X	X	X	X	X			X	X	X			X				X	X		X
Rajgor et al. (2016)									X																			X			X
Ravisankar et al. (2014)		X						X	X	X	X	X					X			X		X	X	X	X			X		X	X
Sambasivan & Soon (2007)										X	X								X	X								X	X		
Shehu et al. (2014)		X	X	X	X			X	X	X	X	X	X						X	X		X	X					X		X	
Tawil et al. (2013)								X		X									X	X								X		X	
Van Truong et al. (2009)								X		X									X												
Van Truong et al. (2009)								X											X									X			
Zou et al. (2007)		X				X			X																					X	
Total		7	6	5	3	2		17	17	16	10	10	8	5	4	3	1		19	13	8	8	6	4	3	2		19	13	13	6

The numbers cross the top represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

Author(s)	Labour-related factors	118	119	120	121	External-related factors	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136
Abusafiya & Suliman (2017)							X					X						X	X		
Adam et al. (2014)				X			X			X					X						
Al-Hazim & Abusalem (2015)							X	X				X									
Alinaitwe et al. (2013)		X					X			X	X				X						
Arantes et al. (2015)			X				X	X	X	X	X					X					
Arditi et al. (2017)							X	X	X		X	X	X								
Assaf & Al-Hejji (2006)					X		X	X	X		X			X			X	X			
Aziz & Abdel-Hakam (2016)		X		X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	
Bagaya & Song (2016)							X		X												
Bhadoria et al. (2016)																					
Doloi et al. (2012)							X	X	X	X	X										
El-Sayegh (2008)		X					X	X			X				X	X		X			X
Gardezi et al. (2014)							X			X		X			X						
Głuszak & Lešniak (2015)							X	X	X	X											
Gunduz & AbuHassan (2016)			X				X	X			X	X	X	X	X	X					
Gündüz et al. (2013)		X	X				X	X	X		X	X	X	X		X	X				
Islam et al. (2015)									X												
Kaliba et al. (2009)		X					X					X			X						
Kikwasi (2013)										X			X						X		
Larsen et al. (2016)							X					X							X		
Marzouk & El-Rasas (2014)			X				X	X	X		X		X	X		X				X	
Megha & Rajiv (2013)			X				X	X	X		X			X			X	X			
Rajgor et al. (2016)																	X				
Ravisankar et al. (2014)		X					X	X	X		X			X							
Sambasivan & Soon (2007)							X	X		X						X					
Shehu et al. (2014)								X	X	X									X		
Tawil et al. (2013)							X						X								
Van Truong et al. (2009)							X														
Van Truong et al. (2009)								X		X			X								
Zou et al. (2007)									X	X					X					X	X
Total		6	5	2	2		23	16	14	12	11	9	8	7	7	7	5	5	4	3	2

The numbers cross the top represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

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Appendix C – Expert Interviews: Set-up

Demographical questions:	
Name interviewee	
Type of organisation	
Occupational level	
Gender	☐ Male ☐ Female
Age	☐ < 29 years ☐ 30 – 39 years ☐ 40 – 49 years ☐ 50 > years
Level of education	☐ Intermediate vocational education (MBO) ☐ University of applied science (HBO) ☐ University of science (WO)
Work experience	☐ < 5 years ☐ 2 – 5 years ☐ 6 – 10 years ☐ > 10 years
Average project size	☐ < 5 million euros ☐ 6 – 20 million euros ☐ 21 – 50 million euros ☐ > 50 million euros
Case studies of executed UCP	Project 1 → Project 2 → Project 3 →
Which type of contract is used in the projects	Project 1 → Project 2 → Project 3 →

	Questions about examples of executed UCP (execution phase)	
1	Are the case studies of executed UCP started later? (According the contracted start date) If so, how many weeks later?	Project 1 → ☐ Yes, namely … ☐ No Project 2 → ☐ Yes, namely … ☐ No Project 3 → ☐ Yes, namely … ☐ No
2	Are the case studies of executed UCP delivered in time? (According the contracted deliver date) If so, how many weeks later?	Project 1 → ☐ Yes, namely … ☐ No Project 2 → ☐ Yes, namely … ☐ No Project 3 → ☐ Yes, namely … ☐ No
3	What kind of actions are taken to execute the project within the agreed contractual time? (Only when No is answered to the examples of UCP in question 1 or 2)	
4	Which factors influenced these projects to start later?	01. 02. 03. 04. 05. 06. 07. 08. 09. 10.
5	Which factors affected these projects to be delivered later?	11. 12. 13. 14. 15. 16. 17. 18. 19. 20.

	Questions about examples of executed UCP (execution phase)	
6	Could certain factors that cause delays be prevented in advance? If so, how? (When reasoning, indicate the numbers of the factors of question 4 and 5 in the explanation)	

Critical delays affect milestone or the project completion dates					
7	On the basis of the above definition, which mentioned factors in question 4 and 5 can cause critical delays in the execution phase? (only check the critical factors corresponding to the number of factors mentioned in question 4 and 5)	01.	☐	11.	☐
		02.	☐	12.	☐
		03.	☐	13.	☐
		04.	☐	14.	☐
		05.	☐	15.	☐
		06.	☐	16.	☐
		07.	☐	17.	☐
		08.	☐	18.	☐
		09.	☐	19.	☐
		10.	☐	20.	☐

Excusable delays are caused by an unforeseeable event beyond the contractor's or the subcontractor's control Non-excusable delays are caused by the contractor, its sub-contractors or its suppliers				
8	*On the basis of the above definition, are the mentioned critical factors in question 7 excusable or non-excusable delays? (only check whether the critical factors are excusable or/and non-excusable corresponding to the numbers mentioned in question 7)*		**Excusable**	**Non-excusable**
		01.	☐	☐
		02.	☐	☐
		03.	☐	☐
		04.	☐	☐
		05.	☐	☐
		06.	☐	☐
		07.	☐	☐
		08.	☐	☐
		09.	☐	☐
		10.	☐	☐
		11.	☐	☐
		12.	☐	☐
		13.	☐	☐
		14.	☐	☐
		15.	☐	☐
		16.	☐	☐
		17.	☐	☐
		18.	☐	☐
		19.	☐	☐
		20.	☒	☐

	Additional questions about the execution phase in the Netherlands:	
9	On the basis of experience; How many percent of the projects are not executed in time? (In percentage)	
10	On the basis of experience; How big is the average delay on the projects? (Compared to the original scheduled duration, in weeks)	
11	Is there a difference between the possible factors that cause delays in different type of contracts? If Yes, which ones …	
12	When you look back at the projects, what should be different in order to avoid these factors in the future?	

	Questions on the basis of the list of factors
13	On the basis of experiences in the execution phase of UCP; Which factors can cause critical delays in the excusable phase and are these critical factors excusable or non-excusable? (Only check the critical factors and whether these critical factors are excusable or non-excusable in the factor list compile from the literature)

Interview matrix - Factors that cause delays

	No.	Delay Factors	Critical	Excusable	Non-excusable
Project-related	1	Poor communication and coordination	☐	☐	☐
	2	Complexity of the project (e.g. Location, project size, etc.)	☐	☐	☐
	3	Selection and assignment criteria	☐	☐	☐
	4	Poor project management	☐	☐	☐
	5	Changed conditions of the project	☐	☐	☐
	6	Poor monitoring and control	☐	☐	☐
	7	Information delays and lack of information exchange between the parties	☐	☐	☐
	8*	…	☐	☐	☐
	..	…	☐	☐	☐
	..	…	☐	☐	☐

* Only a part of the interview matrix is shown, however, the complete matrix contains a list of factors corresponding to Appendix A – Literature review: Influencing factors

Appendix D – Expert Interviews: Results

	No.	Delay Factors	Critical	EI*	Excusable	Non-excusable	LR **
Client	8	Improper feasibility study	☒	3	☒	☐	5
	17	Poor contract management	☐	3	☒	☐	6
	25	Delay in progress payments from the client	☐	0	☐	☐	27
	26	Slowness in the decision-making process	☒	5	☒	☐	22
	27	Change orders	☒	5	☒	☐	16
	28	Clients' financial difficulties for the project	☐	1	☐	☐	15
	30	Late in revising and approving design documents	☐	2	☐	☐	12
	31	Lack/increase of scope definition	☐	1	☐	☐	12
	32	Delay to furnish and deliver the site on time	☐	1	☐	☐	11
	38	Non-availability of drawing/design on time	☒	4	☒	☐	5
	40	New instructions to additional work	☐	2	☐	☐	1
	73	Delay in performing inspection and testing	☐	2	☐	☐	10

Numbers represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

* EI – times mentioned by the experts in the expert interviews

** LR – times occurred in the articles in the literature review

	No.	Delay Factors	Critical	EI*	Excusable	Non-excusable	LR **
Contractor	12	Poor risk management	☒	4	☐	☒	1
	21	Type of construction contract (Turnkey, building team, DBFMO)	☐	3	☐	☒	2
	41	Ineffective planning and scheduling	☒	5	☐	☒	24
	42	Poor site management and supervision	☐	0	☐	☐	22
	43	Rework due to errors	☐	2	☐	☐	22
	44	Lack of experience of the contractor	☒	3	☐	☒	20
	45	Contractors’ financial difficulties for the project	☐	0	☐	☐	17
	46	Improper construction methods implemented	☐	2	☐	☐	13
	47	Conflicts between the contractor and other parties	☒	5	☐	☒	7
	48	Delays related to sub-contractors/supplier’s work	☒	4	☐	☒	6
	49	Inaccurate time and cost estimations	☐	1	☐	☐	6
	50	Poor qualification of the technical staff	☒	3	☐	☒	6
	61	Conflicts in sub-contractor’s schedule in execution of project	☒	4	☐	☒	2
	62	Unreliable sub-contractors/suppliers	☒	5	☐	☒	2
	95	Unsafe practice on site	☒	3	☐	☒	2
	96	Fluctuation of material prices	☐	0	☐	☐	17
	97	Delay in material delivery	☒	5	☐	☒	17
	98	Shortage of construction materials	☐	2	☐	☐	16
	99	Low quality of material(s)	☐	0	☐	☐	10
	100	Problems with the procurement of materials	☐	1	☐	☐	10
	106	Equipment(s) shortage or breakdown(s)	☐	0	☐	☐	19
	110	Improper equipment	☐	0	☐	☐	6
	114	Shortage of (un)skilled labour	☒	6	☐	☒	19
	115	Low productivity of labours	☐	1	☐	☐	13
	126	Accident during construction	☒	4	☐	☒	11
	127	State of market conditions	☒	4	☐	☒	9

Numbers represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors

* EI – times mentioned by the experts in the expert interviews

** LR – times occurred in the articles in the literature review

	No.	Delay Factors	Critical	EI*	Excusable	Non-excusable	LR **
Extern	1	Poor communication and coordination	☒	6	☒	☒	19
	2	Complexity of the project (e.g. Location, project size, etc.)	☒	5	☒	☒	10
	4	Poor project management	☒	3	☒	☒	8
	7	Information delays and lack of information exchange between the parties	☒	5	☒	☒	5
	10	Incompetent project team	☒	5	☒	☒	2
	13	Unrealistic enforced contract duration	☒	3	☒	☒	18
	14	Legal dispute(s) between various parts	☐	1	☐	☐	14
	16	Mistakes or discrepancies in the contract document(s)	☒	4	☒	☒	6
	20	Not familiar with the condition of the contract	☐	2	☐	☐	2
	53	Discrepancy between design specification and construction	☒	4	☒	☒	5
	72	Lack of experience of the consultant	☒	3	☒	☒	11
	78	Mistakes or discrepancies in document(s) or specifications	☒	4	☒	☒	4
	81	Incomplete and unclear drawings	☒	3	☒	☒	9
	88	Unforeseen site conditions (e.g. Soil, high water table, etc.)	☒	6	☒	☒	20
	122	Unfavourable weather conditions	☒	3	☒	☐	23
	123	Changes in government regulations and laws	☐	0	☐	☐	16
	124	Delay in obtaining permits from authorities	☐	2	☐	☐	14
	125	Organisational structure (e.g. Bureaucracy)	☒	3	☒	☐	12
	131	Problem with nearby neighbours, structure or facilities	☐	1	☐	☐	7
	132	Delay in providing services from utilities (such as water, electricity)	☒	4	☒	☒	5
	135	Environmental restrictions (Flora and Fauna)	☐	0	☐	☐	3

Numbers represents the factors corresponding to the numbers used in Appendix A – Literature review: Influencing factors
* EI – times mentioned by the experts in the expert interviews
** LR – times occurred in the articles in the literature review

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Appendix E – FDM: Set-up Questionnaire (I)

Critical factors that cause delays in the execution phase of utility construction projects in the Netherlands

Thank you very much for taking time and effort to fill in the questionnaire! The purpose of the questionnaire is to identify which factors are critical in the execution phase of UCP in the Netherlands. Based on a literature review and expert interviews a list of factors is compiled that influence construction projects. To determine which of these factors are relevant and important (critical), you are asked to indicate the importance of the different factors.

The questionnaire consists of 2 parts:
1. General questions (5 minutes)
2. Assesment of the factors (10 minutes)

Start

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Critical factors that cause delays in the execution phase of utility construction projects in the Netherlands

The first part of the questionnaire consists of 9 general questions.
This takes about 5 minutes of your time.

1.

What is your gender?*

- Male
- Female

2.

What is your age?*

- 20-29 years
- 30-39 years
- 40-49 years
- >50 years

3.

What is your level of education?*

- Intermediate vocational education (MBO)
- University of applied science (HBO)
- University of science (WO)
- Differently, namely ...

4.

How many years of work experience do you have?*

- < 5 years
- 6 - 10 years
- 11 - 15 years
- 16 - 20 years
- > 20 years

5.

What is the average size of your projects?

- ☐ < 5 million
- ☐ 6 - 20 million
- ☐ 21 - 50 million
- ☐ 51 - 100 million
- ☐ > 100 million

6.

How are you involved in UCP?*

- ○ Contractor
- ○ Consultant
- ○ Client
- ○ Differently, namely ... ________

7.

What is your occupational level?*

- ○ Executive
- ○ Business manager
- ○ Project manager
- ○ Foreman
- ○ Adviser
- ○ Differently, namely ________

8.

In which province is your company located?*

- ○ Drenthe
- ○ Flevoland
- ○ Friesland
- ○ Gelderland
- ○ Groningen
- ○ Limburg
- ○ Noord-Brabant
- ○ Noord-Holland
- ○ Overijssel
- ○ Utrecht
- ○ Zeeland
- ○ Zuid-Holland

Next

In the second part of the survey you assess the impact of the factors in the execution phase of utility construction projects.
This takes about 10 minutes of your time.

9.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Poor communication and coordination	○	○	○	○	○	○	○
Complexity of the project (e.g. location, project size, etc.)	○	○	○	○	○	○	○
Poor project management	○	○	○	○	○	○	○
Information delays and lack of information exchange between the parties	○	○	○	○	○	○	○
Improper feasibility study	○	○	○	○	○	○	○
Incompetent projectteam	○	○	○	○	○	○	○
Poor riskmanagement	○	○	○	○	○	○	○
Unrealistic enforced contract duration	○	○	○	○	○	○	○
Legal dispute(s) between various parts	○	○	○	○	○	○	○
Mistakes or discrepancies in the contract document(s)	○	○	○	○	○	○	○

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10.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Poor contract management	○	○	○	○	○	○	○
Not familiar with the condition of the contract	○	○	○	○	○	○	○
Type of construction contract (Turnkey, building team, DBFMO)	○	○	○	○	○	○	○
Delay in progress payments by client	○	○	○	○	○	○	○
Slowness in decision making process	○	○	○	○	○	○	○
Change orders	○	○	○	○	○	○	○
Clients' financial difficulties for the project	○	○	○	○	○	○	○
Late in revising and approving design documents	○	○	○	○	○	○	○
Lack/increase of scope definition	○	○	○	○	○	○	○
Delay to furnish and deliver the site on time	○	○	○	○	○	○	○

Continue

11.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Non-availability of drawing/design on time	○	○	○	○	○	○	○
New instructions to additional work	○	○	○	○	○	○	○
Ineffective planning and scheduling	○	○	○	○	○	○	○
Poor site management and supervision	○	○	○	○	○	○	○
Rework due to errors	○	○	○	○	○	○	○
Lack of experience of the contractor	○	○	○	○	○	○	○
Contractors' financial difficulties for the project	○	○	○	○	○	○	○
Improper construction methods implemented	○	○	○	○	○	○	○
Conflicts between the contractor and other parties	○	○	○	○	○	○	○
Delays related to sub-contractors/suppliers work	○	○	○	○	○	○	○

Continue

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12.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Inaccurate time and costs estimates	○	○	○	○	○	○	○
Poor qualification of the technical staff	○	○	○	○	○	○	○
Discrepancy between design specification and construction	○	○	○	○	○	○	○
Conflicts in sub-contractor's schedule in execution of project	○	○	○	○	○	○	○
Unreliable sub-contractors/suppliers	○	○	○	○	○	○	○
Lack of experience of the consultant	○	○	○	○	○	○	○
Delay in performing inspection and testing	○	○	○	○	○	○	○
Mistakes or discrepancies in document(s) or specifications	○	○	○	○	○	○	○
Incomplete and unclear drawings	○	○	○	○	○	○	○
Unforeseen site conditions (e.g., soil, high water table, etc.)	○	○	○	○	○	○	○

Continue

13.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Unsafe practice on site	○	○	○	○	○	○	○
Fluctuation of material prices	○	○	○	○	○	○	○
Delay in material delivery	○	○	○	○	○	○	○
Shortage of construction materials	○	○	○	○	○	○	○
Low quality of material(s)	○	○	○	○	○	○	○
Problems with the procurement of materials	○	○	○	○	○	○	○
Equipment(s) shortage or breakdown(s)	○	○	○	○	○	○	○
Improper equipment	○	○	○	○	○	○	○
Shortage of (un)skilled labour	○	○	○	○	○	○	○
Low productivity of labours	○	○	○	○	○	○	○

Continue

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14.

What is the effect of the following factors causing delays in the execution phase of utility construction projects in the Netherlands?
Rated on a 7-point scale ..

	1 no effect	2	3 weak effect	4	5 strong effect	6	7 very strong effect
Unfavourable weather conditions	○	○	○	○	○	○	○
Changes in government regulations and laws	○	○	○	○	○	○	○
Delay in obtaining permits from authorities	○	○	○	○	○	○	○
Organisational structure (e.g. bureaucracy)	○	○	○	○	○	○	○
Accident during construction	○	○	○	○	○	○	○
State of market conditions	○	○	○	○	○	○	○
Problem with nearby neighbours, structure or facilities	○	○	○	○	○	○	○
Delay in providing services from utilities (such as water, electricity)	○	○	○	○	○	○	○
Environmental restrictions (Flora and Fauna)	○	○	○	○	○	○	○

Send

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This is the last page of this questionnaire. I would like to thank you very much for completing the questionnaire!

If you have questions regarding the research, please contact me at: j.boeters@student.tue.nl
The results of the research will be published at: http://repository.tue.nl/

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Appendix F – FDM: Rejected factors Questionnaire (I)

Table 33: Client rank rejected factors on the basis of the single derived numbers

No.	Factors	Sj (%)	Accepted/ Rejected
21*	Type of construction contract (Turnkey, building team, DBFMO)	57.1	Rejected
	Slowness in the decision-making process	57.1	Rejected
	Late in revising and approving design documents	57.1	Rejected
	Lack of experience of the contractor	57.1	Rejected
	Contractors' financial difficulties for the project	57.1	Rejected
	Conflicts between the contractor and other parties	57.1	Rejected
	Poor qualification of the technical staff	57.1	Rejected
	Delay in providing services from utilities (such as water, electricity)	57.1	Rejected
29	Poor contract management	50.0	Rejected
	Delay in progress payments from the client	50.0	Rejected
	Poor site management and supervision	50.0	Rejected
	Lack of experience of the consultant	50.0	Rejected
	Incomplete and unclear drawings	50.0	Rejected
	Problems with the procurement of materials	50.0	Rejected
35	Complexity of the project (e.g. Location, project size, etc.)	42.9	Rejected
	Poor risk management	42.9	Rejected
	Not familiar with the condition of the contract	42.9	Rejected
	Non-availability of drawing/design on time	42.9	Rejected
	New instructions to additional work	42.9	Rejected
	Ineffective planning and scheduling	42.9	Rejected
	Unreliable sub-contractors/suppliers	42.9	Rejected
	Low quality of material(s)	42.9	Rejected
	Equipment(s) shortage or breakdown(s)	42.9	Rejected
	Shortage of (un)skilled labour	42.9	Rejected
	Organisational structure (e.g. Bureaucracy)	42.9	Rejected
	Accident during construction	42.9	Rejected
	Environmental restrictions (Flora and Fauna)	42.9	Rejected
48	Unsafe practice on site	35.7	Rejected
	Unfavourable weather conditions	35.7	Rejected
50	Mistakes or discrepancies in the contract document(s)	28.6	Rejected
	Conflicts in sub-contractor's schedule in execution of project	28.6	Rejected
	Delay in performing inspection and testing	28.6	Rejected
	Fluctuation of material prices	28.6	Rejected
	Delay in material delivery	28.6	Rejected
	Shortage of construction materials	28.6	Rejected
	Improper equipment	28.6	Rejected
57	Mistakes or discrepancies in document(s) or specifications	21.4	Rejected
	Low productivity of labours	21.4	Rejected
	Changes in government regulations and laws	21.4	Rejected

* When factors have the same Single derived number (S_j) they are ranked at the same number

Table 34: Contractor rank rejected factors on the basis of the single derived numbers

No.	Factors	Sj (%)	Accepted/ Rejected
22*	Poor communication and coordination	68.0	Rejected
	Legal dispute(s) between various parts	68.0	Rejected
	Contractors' financial difficulties for the project	68.0	Rejected
	Conflicts in sub-contractor's schedule in execution of project	68.0	Rejected
	Delay in obtaining permits from authorities	68.0	Rejected
27	New instructions to additional work	65.4	Rejected
28	Clients' financial difficulties for the project	64.1	Rejected
29	Incomplete and unclear drawings	62.8	Rejected
30	State of market conditions	61.5	Rejected
31	Poor project management	60.3	Rejected
	Poor contract management	60.3	Rejected
	Low productivity of labours	60.3	Rejected
34	Poor risk management	59.0	Rejected
	Lack/increase of scope definition	59.0	Rejected
	Problems with the procurement of materials	59.0	Rejected
37	Poor site management and supervision	57.7	Rejected
	Inaccurate time and cost estimations	57.7	Rejected
	Poor qualification of the technical staff	57.7	Rejected
	Lack of experience of the consultant	57.7	Rejected
	Organisational structure (e.g. Bureaucracy)	57.7	Rejected
42	Not familiar with the condition of the contract	55.1	Rejected
43	Changes in government regulations and laws	53.9	Rejected
44	Type of construction contract (Turnkey, building team, DBFMO)	51.3	Rejected
45	Accident during construction	50.0	Rejected
46	Equipment(s) shortage or breakdown(s)	48.7	Rejected
	Improper equipment	48.7	Rejected
	Environmental restrictions (Flora and Fauna)	48.7	Rejected
49	Complexity of the project (e.g. Location, project size, etc.)	46.2	Rejected
50	Delay to furnish and deliver the site on time	44.9	Rejected
	Delay in performing inspection and testing	44.9	Rejected
52	Unfavourable weather conditions	43.6	Rejected
53	Unsafe practice on site	42.3	Rejected
54	Fluctuation of material prices	41.0	Rejected
55	Mistakes or discrepancies in the contract document(s)	39.7	Rejected
	Ineffective planning and scheduling	39.7	Rejected
	Low quality of material(s)	39.7	Rejected
58	Delay in progress payments from the client	33.3	Rejected
59	Problem with nearby neighbours, structure or facilities	32.1	Rejected

* When factors have the same Single derived number (S_j) they are ranked at the same number

Table 35: Consultant rank rejected factors on the basis of the single derived numbers

No.	Factors	Sj (%)	Accepted/ Rejected
19*	Legal dispute(s) between various parts	63.0	Rejected
	Ineffective planning and scheduling	63.0	Rejected
	Rework due to errors	63.0	Rejected
	Discrepancy between design specification and construction	63.0	Rejected
	Unreliable sub-contractors/suppliers	63.0	Rejected
	Unsafe practice on site	63.0	Rejected
25	Poor site management and supervision	60.9	Rejected
	Poor qualification of the technical staff	60.9	Rejected
	Organisational structure (e.g. Bureaucracy)	60.9	Rejected
28	Mistakes or discrepancies in the contract document(s)	58.7	Rejected
	Conflicts in sub-contractor’s schedule in execution of project	58.7	Rejected
	Shortage of (un)skilled labour	58.7	Rejected
	Delay in obtaining permits from authorities	58.7	Rejected
32	Poor contract management	56.5	Rejected
	Problems with the procurement of materials	56.5	Rejected
34	Not familiar with the condition of the contract	54.4	Rejected
	Late in revising and approving design documents	54.4	Rejected
	Lack/increase of scope definition	54.4	Rejected
	Unfavourable weather conditions	54.4	Rejected
	Accident during construction	54.4	Rejected
	Problem with nearby neighbours, structure or facilities	54.4	Rejected
40	Delay to furnish and deliver the site on time	52.2	Rejected
	Mistakes or discrepancies in document(s) or specifications	52.2	Rejected
42	Complexity of the project (e.g. Location, project size, etc.)	50.0	Rejected
	Poor risk management	50.0	Rejected
44	Poor project management	47.8	Rejected
	Low quality of material(s)	47.8	Rejected
	Improper equipment	47.8	Rejected
47	Equipment(s) shortage or breakdown(s)	45.7	Rejected
	Low productivity of labours	45.7	Rejected
49	New instructions to additional work	43.5	Rejected
50	Delay in providing services from utilities (such as water, electricity)	43.5	Rejected
51	Improper feasibility study	41.3	Rejected
	Clients' financial difficulties for the project	41.3	Rejected
	State of market conditions	41.3	Rejected
	Environmental restrictions (Flora and Fauna)	41.3	Rejected
55	Change orders	37.0	Rejected
56	Type of construction contract (Turnkey, building team, DBFMO)	32.6	Rejected
	Fluctuation of material prices	32.6	Rejected
	Changes in government regulations and laws	32.6	Rejected
59	Delay in performing inspection and testing	30.4	Rejected

* When factors have the same Single derived number (S_j) they are ranked at the same number

Table 36: Overall rank rejected factors on the basis of the single derived numbers

No.	Factors	Sj (%)	Accepted/ Rejected
21	Legal dispute(s) between various parts	65.9	Rejected
	Contractors' financial difficulties for the project	65.9	Rejected
23	Conflicts in sub-contractor's schedule in execution of project	65.2	Rejected
24*	Mistakes or discrepancies in the contract document(s)	64.5	Rejected
	Shortage of (un)skilled labour	64.5	Rejected
	Delay in obtaining permits from authorities	64.5	Rejected
	Problem with nearby neighbours, structure or facilities	64.5	Rejected
28	Inaccurate time and cost estimations	63.0	Rejected
29	Mistakes or discrepancies in document(s) or specifications	62.3	Rejected
30	Low quality of material(s)	61.6	Rejected
31	Improper feasibility study	60.1	Rejected
	Lack/increase of scope definition	60.1	Rejected
33	Delay in providing services from utilities (such as water, electricity)	59.4	Rejected
34	Poor risk management	58.7	Rejected
	Poor qualification of the technical staff	58.7	Rejected
36	Poor contract management	58.0	Rejected
37	Problems with the procurement of materials	57.3	Rejected
38	Poor project management	56.5	Rejected
	Clients' financial difficulties for the project	56.5	Rejected
40	New instructions to additional work	55.8	Rejected
41	State of market conditions	55.1	Rejected
42	Not familiar with the condition of the contract	53.6	Rejected
43	Lack of experience of the consultant	52.2	Rejected
44	Low productivity of labours	51.5	Rejected
45	Poor site management and supervision	49.3	Rejected
46	Organisational structure (e.g. Bureaucracy)	48.6	Rejected
47	Complexity of the project (e.g. Location, project size, etc.)	47.1	Rejected
48	Type of construction contract (Turnkey, building team, DBFMO)	45.7	Rejected
	Environmental restrictions (Flora and Fauna)	45.7	Rejected
50	Changes in government regulations and laws	43.5	Rejected
51	Accident during construction	42.8	Rejected
52	Equipment(s) shortage or breakdown(s)	40.6	Rejected
53	Improper equipment	39.1	Rejected
54	Delay in performing inspection and testing	38.4	Rejected
	Unfavourable weather conditions	38.4	Rejected
56	Fluctuation of material prices	37.0	Rejected
57	Delay to furnish and deliver the site on time	36.2	Rejected
	Unsafe practice on site	36.2	Rejected
59	Delay in progress payments from the client	33.3	Rejected

* When factors have the same Single derived number (S_j) they are ranked at the same number

Appendix G – BBN: Set-up Questionnaire (II)

1. Section - Start

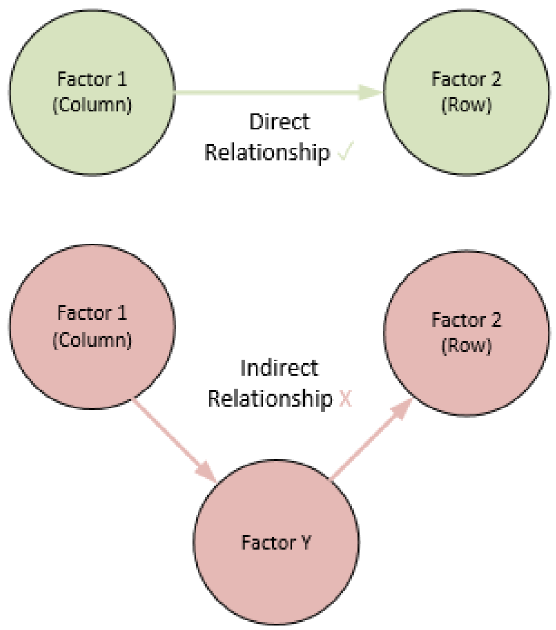
Relationships between the critical factors that cause delays and affect the execution phase of UCP in the Netherlands

Thank you very much for taking time and effort to fill in the questionnaire! It was not possible to design this questionnaire in an online survey system; therefore, this questionnaire is held through to use of Excel. The purpose of the questionnaire is to identify the relationships between the critical factors in the execution phase of UCP in the Netherlands. On the basis of questionnaire (I) it was determined which factors are accepted as critical during the execution phase of UCP in the Netherlands. In order to determine the relationships between these factors, you are asked to assess the cause-effect relationships between the identified critical factors.

The questionnaire consists of 2 parts:
1. General questions (2 minutes)
2. Assessment of the relationships (±25 minutes – Advised to complete in two stages)

Below you find an example to clarify what is expected of you when assessing the relationships. This part of the questionnaire starts on section 3 “Cause-effect relationships”!

The question of the questionnaire; What are the cause-effect relationships between the following critical factors in the execution phase of UCP in the Netherlands? *
** You indicate whether there is a **direct cause-effect relationship** between the factors in the column (Factor 1) and the row (Factor 2)*
(The collared cells contain the list with options to select from)



		Effect			
		Factor 1	Factor 2	Factor 3	Factor 4
Cause	Factor 1		Strong relationship*		No relationship
	Factor 2	No relationship**		Weak relationship	Strong relationship
	Factor 3	Strong relationship	Weak relationship		
	Factor 4	No relationship	Weak relationship		

* Example 1: Factor 1 have caused a delay what is the relationship with Factor 2? (→ Strong relationship)

** Example 2: Factor 2 have caused a delay what is the relationship with Factor 1? (→ No relationship)

In section 2 “Demographic questions” a number of general questions are asked. This will take about 2 minutes!

2. Section – Demographic Questions

What is your gender?
☐ Male
☐ Female
What is your age?
☐ 20 - 29 years
☐ 30 - 39 years
☐ 40 - 49 years
☐ > 50 years
What is your level of education?
☐ Intermediate vocational education (MBO)
☐ University of applied science (HBO)
☐ University of science (WO)
How many years of work experience do you have?
☐ < 10 years
☐ 11 – 15 years
☐ 16 – 20 years
☐ > 20 years
What is the average size of your projects?
☐ < 5 million
☐ 6 – 20 million
☐ 21 – 50 million
☐ > 50 million
How are you involved in the UCP?
☐ Contractor
☐ Consultant
☐ Client

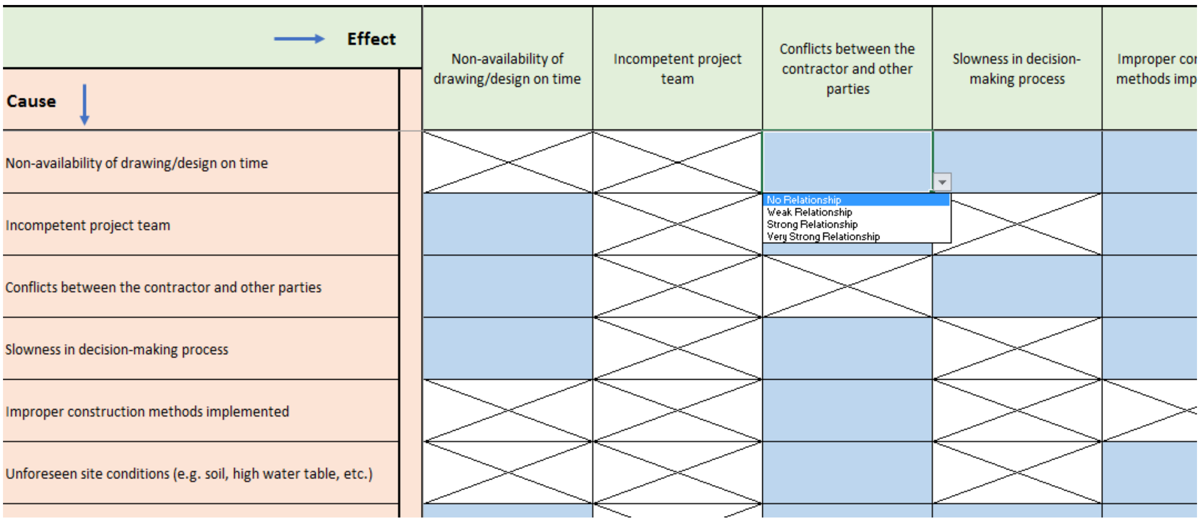
In which part of the Netherlands you work?

☐ West of the Netherlands (Noord-Holland, Utrecht, Zuid-Holland)
☐ South of the Netherlands (Limburg, Noord-Brabant, Zeeland)
☐ East of the Netherlands (Flevoland, Gelderland, Overijssel)
☐ North of the Netherlands (Drenthe, Friesland, Groningen)

In section 3 “Cause-effect relationships” it is expected to assess the relationships between certain factors. This will take about 15 minutes!

3. Section – Cause-effect relationships

I want to ask you to give an assessment on the relationships between the following factors! (Only fill in the collared cells, these cells contain a list of options)
You can choose from the following options:
1 = No relationship
2 = Weak relationship
3 = Strong relationship
4 = Very strong relationship



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Appendix H – BBN: Preselection deleted factors Questionnaire (II)

The cause-effect relationships between the important critical factors are reviewed to identify the preliminary relationships among the accepted critical factors. Reasons for removing factors are:

I. The relationship in the other direction is accepted and more logical (A → B; B → A);
II. No relationship from both directions (A X B);
III. Overlap between two critical factors that are selected looking at the relationship (A=B).

	Cause (Factor)	Effect (Factor)	Label	Reason
1	Non-availability of drawing/design on time	Incompetent project team	A → B B → A	Reason I
2	Non-availability of drawing/design on time	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
3	Non-availability of drawing/design on time	Change orders	A → B B → A	Reason I
4	Non-availability of drawing/design on time	Late in revising and approving design documents	A → B B → A	Reason I
5	Non-availability of drawing/design on time	Lack of experience of the contractor	A → B B → A	Reason I
6	Incompetent project team	Slowness in decision-making process	A X B	Reason II
7	Incompetent project team	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
8	Incompetent project team	Lack of experience of the contractor	A → B B → A	Reason I
9	Conflicts between the contractor and other parties	Incompetent project team	A → B B → A	Reason I
10	Conflicts between the contractor and other parties	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
11	Conflicts between the contractor and other parties	Change orders	A → B B → A	Reason I
12	Conflicts between the contractor and other parties	Lack of experience of the contractor	A → B B → A	Reason I
13	Slowness in the decision-making process	Incompetent project team	A X B	Reason II
14	Slowness in the decision-making process	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
15	Slowness in the decision-making process	Change orders	A = B	Reason III
16	Slowness in the decision-making process	Lack of experience of the contractor	A → B B → A	Reason I
17	Improper construction methods implemented	Non-availability of drawing/design on time	A → B B → A	Reason I
18	Improper construction methods implemented	Incompetent project team	A → B B → A	Reason I
19	Improper construction methods implemented	Slowness in the decision-making process	A → B B → A	Reason I
20	Improper construction methods implemented	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I

	Cause (Factor)	Effect (Factor)	Label	Reason
21	Improper construction methods implemented	Incomplete and unclear drawings	A → B B → A	Reason I
22	Improper construction methods implemented	Late in revising and approving design documents	A → B B → A	Reason I
23	Improper construction methods implemented	Unreliable sub-contractors/suppliers	A → B B → A	Reason I
24	Improper construction methods implemented	Lack of experience of the contractor	A → B B → A	Reason I
25	Improper construction methods implemented	Delay in material delivery	A → B B → A	Reason I
26	Improper construction methods implemented	Information delays and lack of information exchange between the parties	A → B B → A	Reason I
27	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Non-availability of drawing/design on time	A X B	Reason II
28	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Incompetent project team	A X B	Reason II
29	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Slowness in the decision-making process	A X B	Reason II
30	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Incomplete and unclear drawings	A X B	Reason II
31	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Late in revising and approving design documents	A X B	Reason II
32	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Unreliable sub-contractors/suppliers	A X B	Reason II
33	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Lack of experience of the contractor	A → B B → A	Reason I
34	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Poor communication and coordination	A X B	Reason II
35	Unforeseen site conditions (e.g. Soil, high water table, etc.)	Information delays and lack of information exchange between the parties	A X B	Reason II
36	Discrepancy between design specification and construction	Incompetent project team	A → B B → A	Reason I
37	Discrepancy between design specification and construction	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
38	Discrepancy between design specification and construction	Unreliable sub-contractors/suppliers	A → B B → A	Reason I
39	Discrepancy between design specification and construction	Lack of experience of the contractor	A → B B → A	Reason I
40	Discrepancy between design specification and construction	Shortage of construction materials	A → B B → A	Reason I
41	Discrepancy between design specification and construction	Information delays and lack of information exchange between the parties	A → B B → A	Reason I
42	Unrealistic enforced contract duration	Incompetent project team	A → B B → A	Reason I
43	Unrealistic enforced contract duration	Slowness in the decision-making process	A → B B → A	Reason I

	Cause (Factor)	Effect (Factor)	Label	Reason
44	Unrealistic enforced contract duration	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
45	Unrealistic enforced contract duration	Change orders	A → B B → A	Reason I
46	Unrealistic enforced contract duration	Late in revising and approving design documents	A → B B → A	Reason I
47	Unrealistic enforced contract duration	Lack of experience of the contractor	A → B B → A	Reason I
48	Unrealistic enforced contract duration	Delay in material delivery	A → B B → A	Reason I
49	Change orders	Incompetent project team	A → B B → A	Reason I
50	Change orders	Slowness in the decision-making process	A = B	Reason III
51	Change orders	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
52	Change orders	Unreliable sub-contractors/suppliers	A → B B → A	Reason I
53	Change orders	Lack of experience of the contractor	A → B B → A	Reason I
54	Change orders	Poor communication and coordination	A X B	Reason II
55	Change orders	Information delays and lack of information exchange between the parties	A X B	Reason II
56	Incomplete and unclear drawings	Incompetent project team	A → B B → A	Reason I
57	Incomplete and unclear drawings	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
58	Incomplete and unclear drawings	Change orders	A → B B → A	Reason I
59	Incomplete and unclear drawings	Lack of experience of the contractor	A → B B → A	Reason I
60	Late in revising and approving design documents	Incompetent project team	A → B B → A	Reason I
61	Late in revising and approving design documents	Slowness in the decision-making process	A → B B → A	Reason I
62	Late in revising and approving design documents	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
63	Late in revising and approving design documents	Change orders	A → B B → A	Reason I
64	Late in revising and approving design documents	Lack of experience of the contractor	A → B B → A	Reason I
65	Unreliable sub-contractors/suppliers	Slowness in the decision-making process	A → B B → A	Reason I
66	Unreliable sub-contractors/suppliers	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
67	Unreliable sub-contractors/suppliers	Late in revising and approving design documents	A → B B → A	Reason I

	Cause (Factor)	Effect (Factor)	Label	Reason
68	Unreliable sub-contractors/suppliers	Lack of experience of the contractor	A → B B → A	Reason I
69	Shortage of construction materials	Incompetent project team	A → B B → A	Reason I
70	Shortage of construction materials	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
71	Shortage of construction materials	Incomplete and unclear drawings	A → B B → A	Reason I
72	Shortage of construction materials	Unreliable sub-contractors/suppliers	A → B B → A	Reason I
73	Shortage of construction materials	Shortage of construction materials	A → B B → A	Reason I
74	Shortage of construction materials	Poor communication and coordination	A → B B → A	Reason I
75	Shortage of construction materials	Information delays and lack of information exchange between the parties	A → B B → A	Reason I
76	Ineffective planning and scheduling	Slowness in the decision-making process	A → B B → A	Reason I
77	Ineffective planning and scheduling	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
78	Ineffective planning and scheduling	Late in revising and approving design documents	A → B B → A	Reason I
79	Ineffective planning and scheduling	Lack of experience of the contractor	A → B B → A	Reason I
80	Delays related to sub-contractors/supplier's work	Incompetent project team	A → B B → A	Reason I
81	Delays related to sub-contractors/supplier's work	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
82	Delays related to sub-contractors/supplier's work	Discrepancy between design specification and construction	A → B B → A	Reason I
83	Delays related to sub-contractors/supplier's work	Late in revising and approving design documents	A → B B → A	Reason I
84	Delays related to sub-contractors/supplier's work	Lack of experience of the contractor	A → B B → A	Reason I
85	Delays related to sub-contractors/supplier's work	Rework due to errors	A → B B → A	Reason I
86	Delay in material delivery	Non-availability of drawing/design on time	A → B B → A	Reason I
87	Delay in material delivery	Incompetent project team	A → B B → A	Reason I
88	Delay in material delivery	Slowness in the decision-making process	A → B B → A	Reason I
89	Delay in material delivery	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
90	Delay in material delivery	Incomplete and unclear drawings	A → B B → A	
91	Delay in material delivery	Late in revising and approving design documents	A → B B → A	Reason I

	Cause (Factor)	Effect (Factor)	Label	Reason
92	Delay in material delivery	Lack of experience of the contractor	A → B B → A	Reason I
93	Delay in material delivery	Poor communication and coordination	A → B B → A	Reason I
94	Delay in material delivery	Information delays and lack of information exchange between the parties	A → B B → A	Reason I
95	Delay in material delivery	Rework due to errors	A → B B → A	Reason I
96	Poor communication and coordination	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
97	Poor communication and coordination	Change orders	A X B	Reason II
98	Poor communication and coordination	Lack of experience of the contractor	A → B B → A	Reason I
99	Information delays and lack of information exchange between the parties	Incompetent project team	A → B B → A	Reason I
100	Information delays and lack of information exchange between the parties	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A X B	Reason II
101	Information delays and lack of information exchange between the parties	Change orders	A X B	Reason II
102	Information delays and lack of information exchange between the parties	Lack of experience of the contractor	A → B B → A	Reason I
103	Rework due to errors	Non-availability of drawing/design on time	A → B B → A	Reason I
104	Rework due to errors	Incompetent project team	A → B B → A	Reason I
105	Rework due to errors	Improper construction methods implemented	A → B B → A	Reason I
106	Rework due to errors	Unforeseen site conditions (e.g. Soil, high water table, etc.)	A → B B → A	Reason I
107	Rework due to errors	Incomplete and unclear drawings	A → B B → A	Reason I
108	Rework due to errors	Late in revising and approving design documents	A → B B → A	Reason I
109	Rework due to errors	Unreliable sub-contractors/suppliers	A → B B → A	Reason I
110	Rework due to errors	Lack of experience of the contractor	A → B B → A	Reason I
111	Rework due to errors	Shortage of construction materials	A → B B → A	Reason I
112	Rework due to errors	Poor communication and coordination	A → B B → A	Reason I
113	Rework due to errors	Information delays and lack of information exchange between the parties	A → B B → A	Reason I

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Appendix I – BBN: Results Questionnaire (II)

No.	Cause	Effect	Average	0	1	2	3	Skewness
1	Late in revising and approving design documents	Non-availability of drawing/design on time	2.64	0	1	12	26	-1.140
2	Slowness in the decision-making process	Late in revising and approving design documents	2.62	0	2	11	26	-1.285
3	Shortage of construction materials	Delay in material delivery	2.56	0	3	11	25	-1.202
4	Delay in material delivery	Shortage of construction materials	2.55	2	2	7	27	-1.983
5	Poor communication and coordination	Information delays and lack of information exchange between the parties	2.53	0	2	14	22	-0.885
6	Incompetent project team	Poor communication and coordination	2.50	0	1	17	20	-0.494
7	Unreliable sub-contractors/suppliers	Delays related to sub-contractors/supplier's work	2.46	0	4	12	21	-0.915
8	Poor communication and coordination	Conflicts between the contractor and other parties	2.46	0	1	19	19	-0.329
9	Non-availability of drawing/design on time	Information delays and lack of information exchange between the parties	2.45	0	1	19	18	-0.283
10	Lack of experience of the contractor	Rework due to errors	2.45	0	4	13	21	-0.863
11	Information delays and lack of information exchange between the parties	Poor communication and coordination	2.45	0	2	17	19	-0.574
12	Lack of experience of the contractor	Ineffective planning and scheduling	2.44	0	2	18	19	-0.519
13	Incomplete and unclear drawings	Discrepancy between design specification and construction	2.41	2	1	15	21	-1.577
14	Lack of experience of the contractor	Improper construction methods implemented	2.41	1	1	18	19	-1.263
15	Unreliable sub-contractors/suppliers	Delay in material delivery	2.38	0	5	13	19	-0.724
16	Lack of experience of the contractor	Incompetent project team	2.38	1	1	19	18	-1.190
17	Poor communication and coordination	Incomplete and unclear drawings	2.38	1	3	15	20	-1.177

No.	Cause	Effect	Average	0	1	2	3	Skewness
18	Incompetent project team	Information delays and lack of information exchange between the parties	2.37	0	1	22	15	0.021
19	Slowness in the decision-making process	Non-availability of drawing/design on time	2.37	1	3	15	19	-1.143
20	Improper construction methods implemented	Rework due to errors	2.37	0	6	12	20	-0.738
21	Lack of experience of the contractor	Delays related to sub-contractors/supplier's work	2.37	0	2	20	16	-0.292
22	Non-availability of drawing/design on time	Incomplete and unclear drawings	2.36	1	5	13	20	-1.094
23	Change orders	Late in revising and approving design documents	2.34	0	5	15	18	-0.608
24	Ineffective planning and scheduling	Delays related to sub-contractors/supplier's work	2.34	0	2	21	15	-0.203
25	Information delays and lack of information exchange between the parties	Incomplete and unclear drawings	2.33	0	4	18	17	-0.488
26	Poor communication and coordination	Delays related to sub-contractors/supplier's work	2.32	0	1	24	13	0.222
27	Improper construction methods implemented	Ineffective planning and scheduling	2.31	1	4	16	18	-0.970
28	Discrepancy between design specification and construction	Incomplete and unclear drawings	2.31	1	2	20	16	-0.998
29	Unrealistic enforced contract duration	Conflicts between the contractor and other parties	2.31	1	1	22	15	-1.005
30	Information delays and lack of information exchange between the parties	Conflicts between the contractor and other parties	2.30	0	5	18	17	-0.470
31	Unrealistic enforced contract duration	Delays related to sub-contractors/supplier's work	2.29	1	3	18	16	-0.956
32	Incomplete and unclear drawings	Information delays and lack of information exchange between the parties	2.29	0	5	17	16	-0.461

No.	Cause	Effect	Average	0	1	2	3	Skewness
33	Delays related to sub-contractors/supplier's work	Conflicts between the contractor and other parties	2.28	1	3	20	16	-0.907
34	Information delays and lack of information exchange between the parties	Non-availability of drawing/design on time	2.28	1	2	22	15	-0.920
35	Conflicts between the contractor and other parties	Delays related to sub-contractors/supplier's work	2.27	0	4	19	14	-0.332
36	Slowness in the decision-making process	Information delays and lack of information exchange between the parties	2.26	0	6	16	16	-0.451
37	Change orders	Non-availability of drawing/design on time	2.26	1	5	15	17	-0.861
38	Conflicts between the contractor and other parties	Poor communication and coordination	2.24	0	4	20	13	-0.260
39	Unreliable sub-contractors/suppliers	Conflicts between the contractor and other parties	2.24	1	3	20	14	-0.855
40	Lack of experience of the contractor	Conflicts between the contractor and other parties	2.23	0	3	24	12	-0.060
41	Delays related to sub-contractors/supplier's work	Delay in material delivery	2.23	0	5	20	14	-0.298
42	Discrepancy between design specification and construction	Non-availability of drawing/design on time	2.21	2	4	17	16	-0.987
43	Incomplete and unclear drawings	Non-availability of drawing/design on time	2.21	5	2	12	20	-1.195
44	Late in revising and approving design documents	Information delays and lack of information exchange between the parties	2.21	0	5	20	13	-0.259
45	Incompetent project team	Conflicts between the contractor and other parties	2.18	0	5	22	12	-0.177
46	Lack of experience of the contractor	Poor communication and coordination	2.18	0	1	29	8	0.750

No.	Cause	Effect	Average	0	1	2	3	Skewness
47	Ineffective planning and scheduling	Conflicts between the contractor and other parties	2.18	0	6	20	13	-0.242
48	Delay in material delivery	Delays related to sub-contractors/supplier's work	2.18	0	3	25	10	0.047
49	Conflicts between the contractor and other parties	Information delays and lack of information exchange between the parties	2.14	0	5	22	10	-0.105
50	Incompetent project team	Delays related to sub-contractors/supplier's work	2.05	0	7	22	9	-0.052
51	Incomplete and unclear drawings	Delays related to sub-contractors/supplier's work	2.05	0	6	24	8	-0.025
52	Lack of experience of the contractor	Information delays and lack of information exchange between the parties	2.05	0	6	24	8	-0.025
53	Incomplete and unclear drawings	Poor communication and coordination	1.97	0	10	19	9	0.039
54	Conflicts between the contractor and other parties	Delay in material delivery	1.95	0	10	19	8	0.076
55	Incomplete and unclear drawings	Conflicts between the contractor and other parties	1.95	0	9	23	7	0.046
56	Discrepancy between design specification and construction	Improper construction methods implemented	1.69	0	20	11	8	0.628

Appendix J – BBN: Development DG

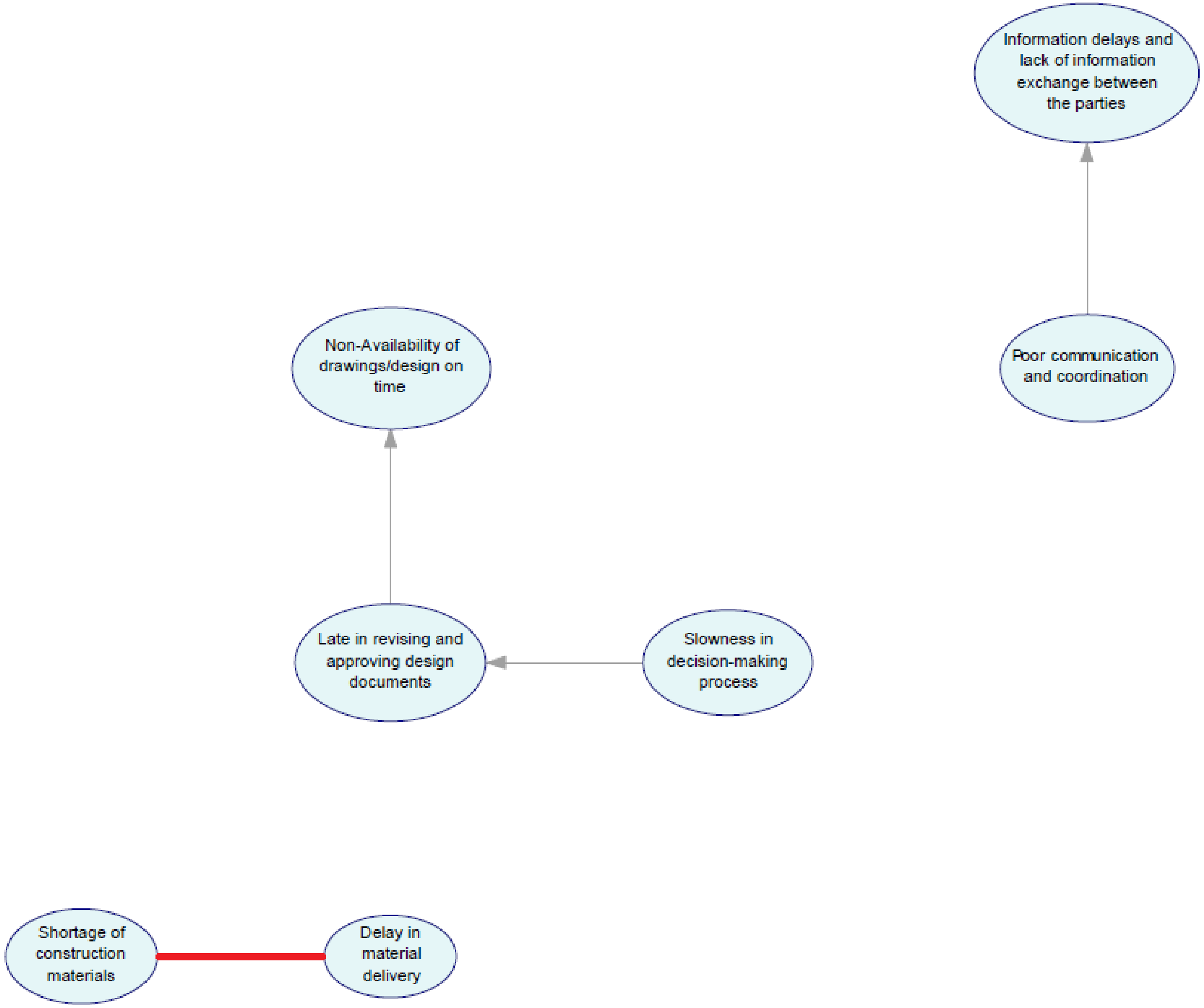

Figure 18: Step 1 - Development Directed graph (5 relationships included)

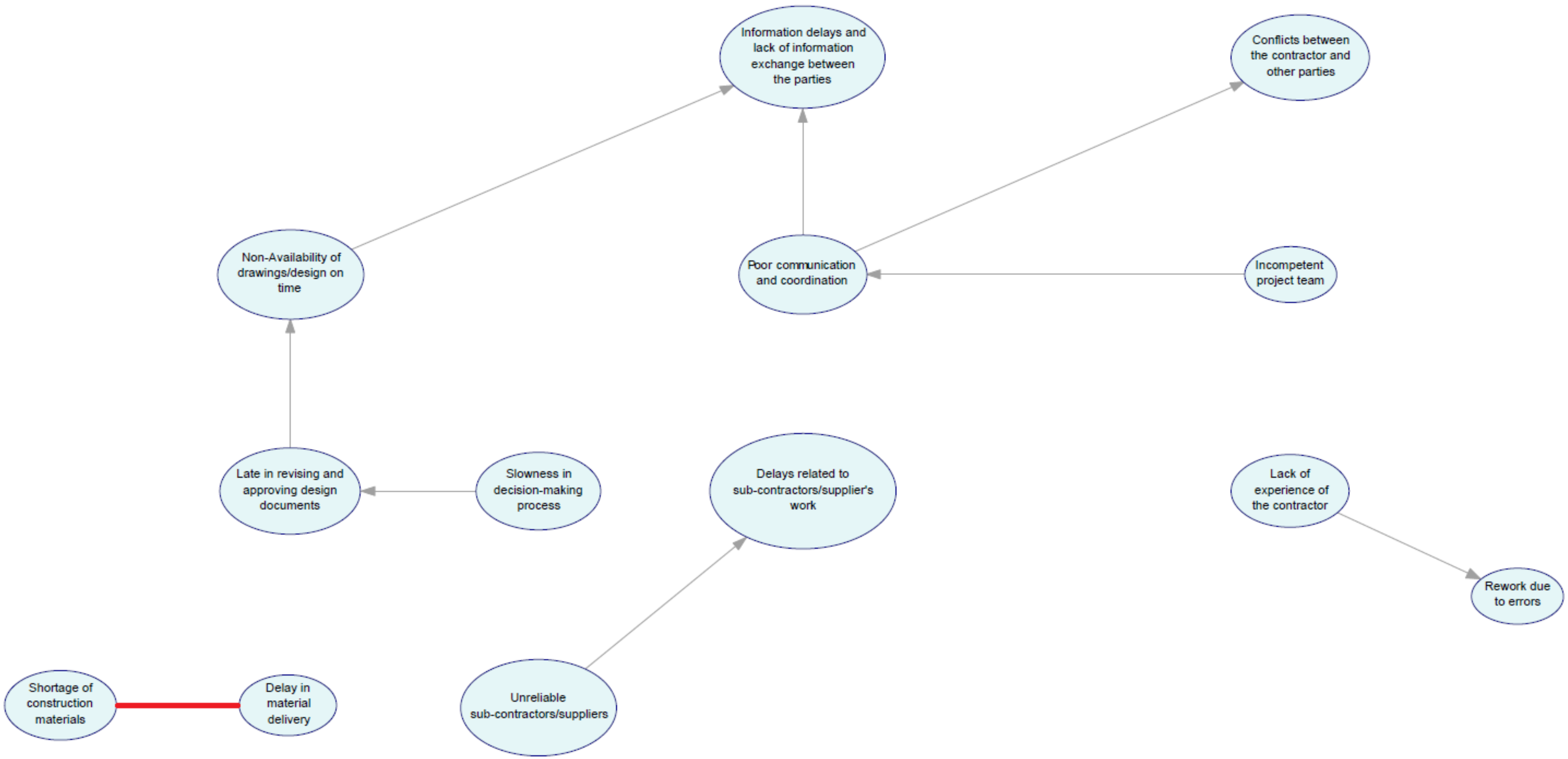

Figure 19: Step 2 - Development Directed graph (10 relationships included)

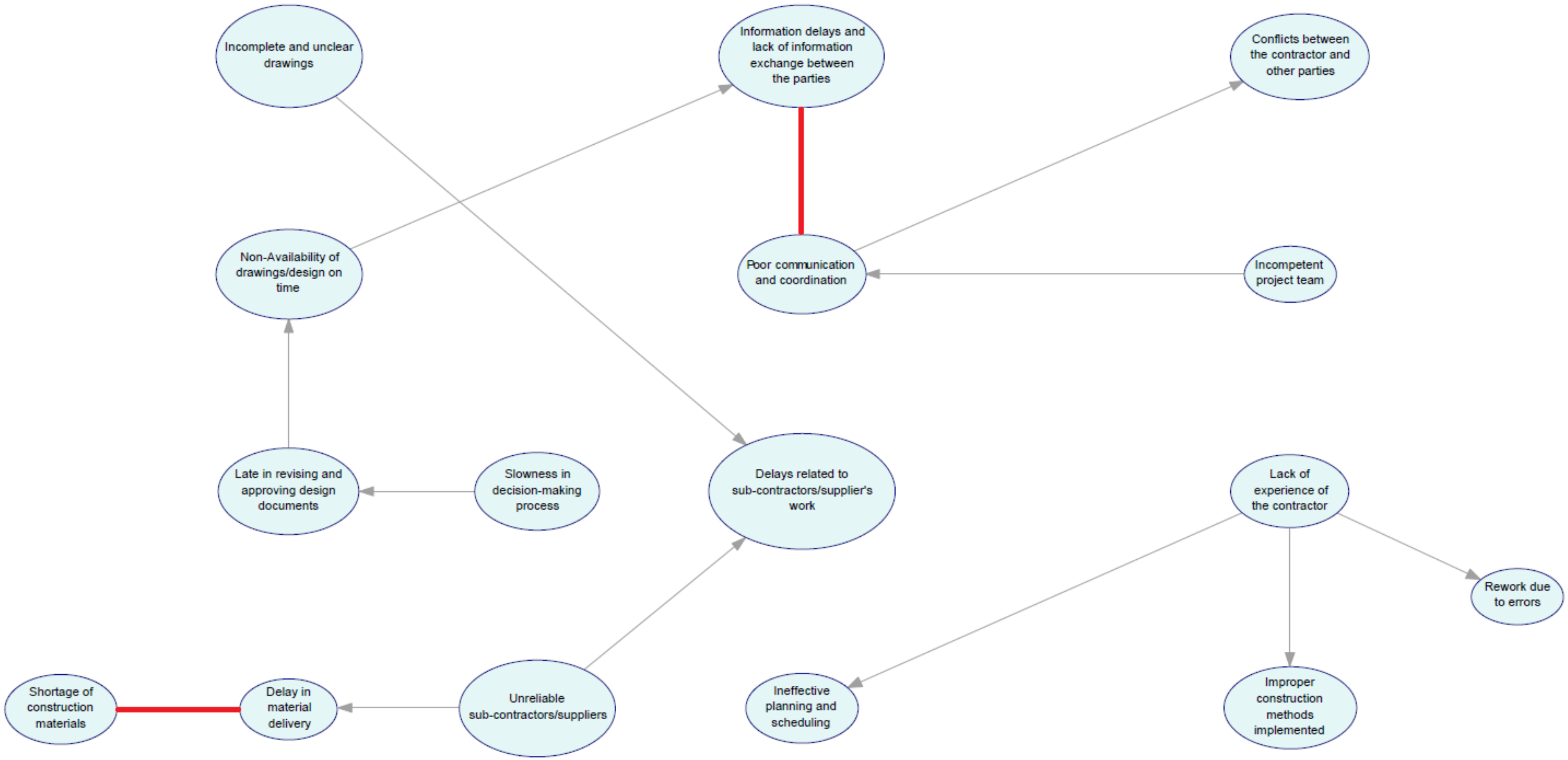

Figure 20: Step 3 - Development Directed graph (15 relationships included)

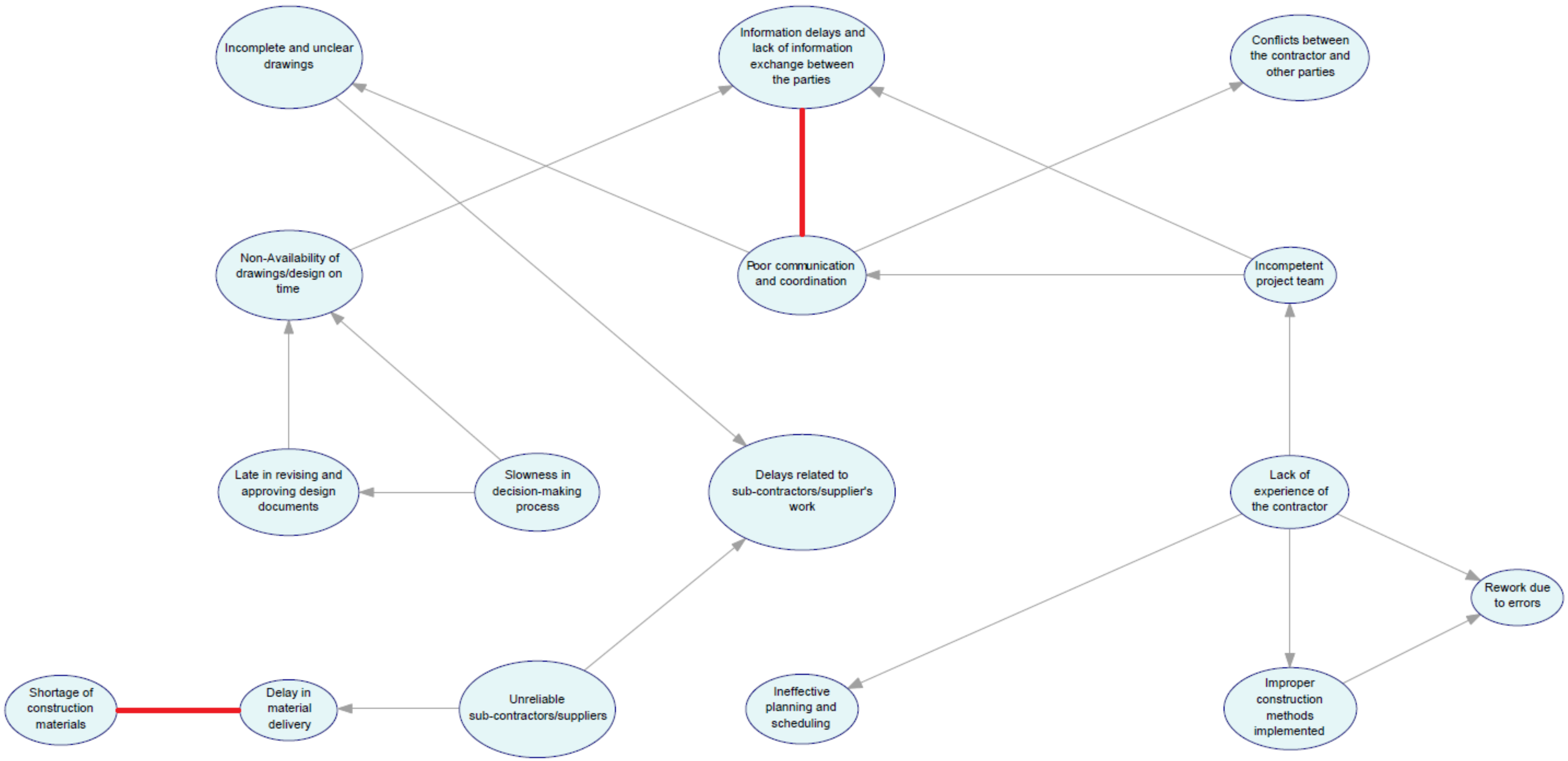

Figure 21: Step 4 - Development Directed graph (20 relationships included)

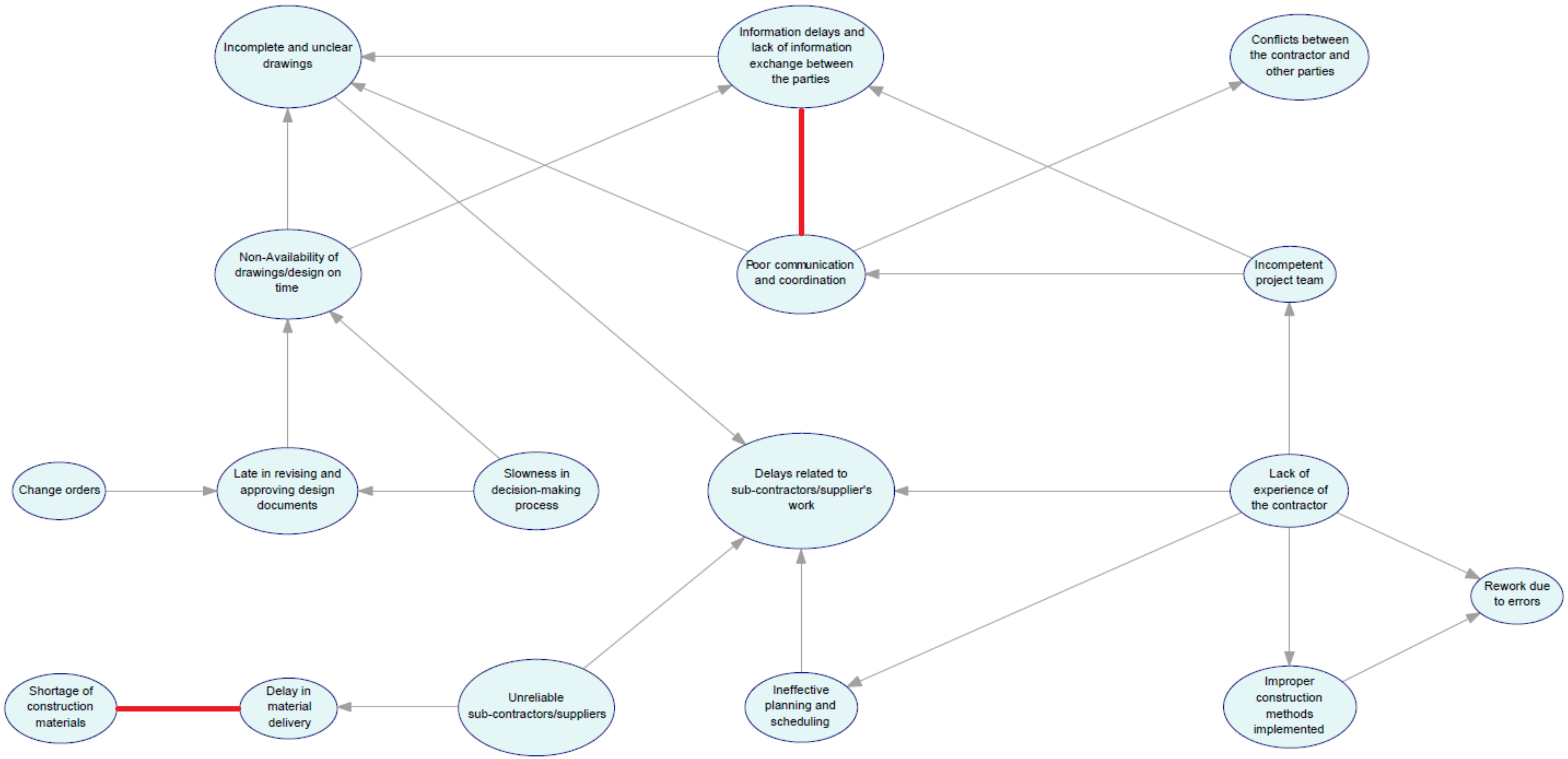

Figure 22: Step 5 - Development Directed graph (25 relationships included)

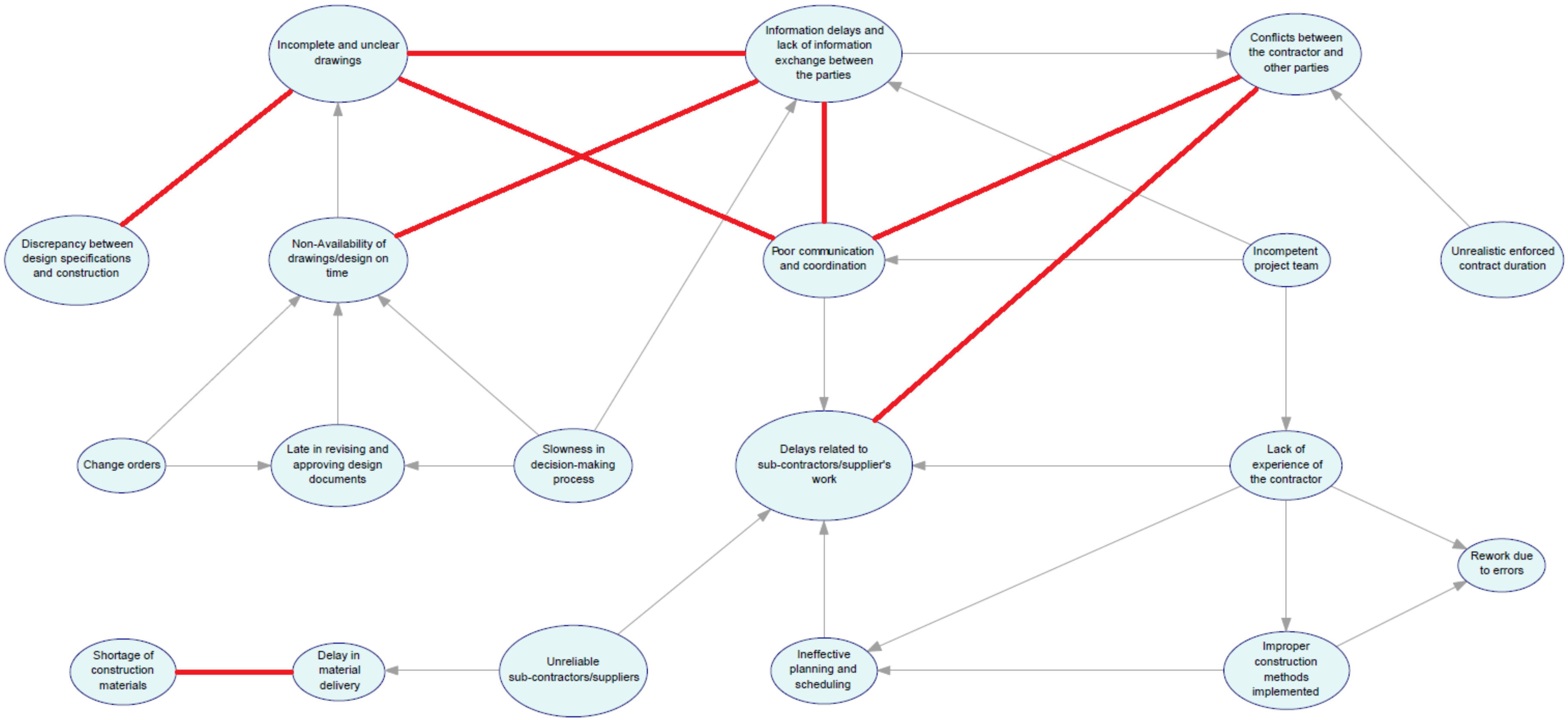

Figure 23: Step 6 - Development Directed graph (30 relationships included)

Appendix K – Expert Discussion: Set-up

Demographical questions:	
Name interviewee	
Gender	☐ Male ☐ Female
Age	☐ < 29 years ☐ 30 – 39 years ☐ 40 – 49 years ☐ 50 > years
Level of education	☐ Intermediate vocational education (MBO) or lower ☐ University of applied science (HBO) ☐ University of science (WO)
Work experience	☐ < 10 years ☐ 10 – 15 years ☐ 16 – 20 years ☐ > 20 years
Average project size	☐ < 5 million euros ☐ 6 – 20 million euros ☐ 21 – 50 million euros ☐ > 50 million euros

1. Which relationship is "most logical" in order of time? (A → B, B → A)
   Please place an X in the column with your choice (only 1 answer)

	Cause	Effect	Choice
1	Shortage of construction materials	Delay in material delivery	
	Delay in material delivery	Shortage of construction materials	

	Cause	Effect	Choice
2	Poor communication and coordination	Information delays and lack of information exchange between the parties	
	Information delays and lack of information exchange between the parties	Poor communication and coordination	

	Cause	Effect	Choice
3	Poor communication and coordination	Conflicts between the contractor and other parties	
	Conflicts between the contractor and other parties	Poor communication and coordination	

	Cause	Effect	Choice
4	Non-availability of drawings/design on time	Information delays and lack of information exchange between the parties	
	Information delays and lack of information exchange between the parties	Non-availability of drawings/design on time	

	Cause	Effect	Choice
5	Incomplete and unclear drawings	Discrepancy between design specifications and construction	
	Discrepancy between design specifications and construction	Incomplete and unclear drawings	

	Cause	Effect	Choice
6	Incomplete and unclear drawings	Information delays and lack of information exchange between the parties	
	Information delays and lack of information exchange between the parties	Incomplete and unclear drawings	

	Cause	Effect	Choice
7	Conflicts between the contractor and other parties	Information delays and lack of information exchange between the parties	
	Information delays and lack of information exchange between the parties	Conflicts between the contractor and other parties	

	Cause	Effect	Choice
8	Delays related to sub-contractors/supplier's work	Conflicts between the contractor and other parties	
	Conflicts between the contractor and other parties	Delays related to sub-contractors/supplier's work	

2. What are the chances that the factors below "Directly" cause delays in the execution phase of UCP?
   Please place an X in the column with your choice (only 1 answer)

No.	Factor	Low	Moderate	High
1	Non-availability of drawing/design on time			
2	Poor communication and coordination			
3	Incompetent project team			
4	Rework due to errors			
5	Conflicts between the contractor and other parties			
6	Information delays and lack of information exchange between the parties			
7	Delays related to sub-contractors/supplier's work			
8	Late in revising and approving design documents			
9	Incomplete and unclear drawings			
10	Improper construction methods implemented			
11	Ineffective planning and scheduling			
12	Delay in material delivery			

3. Are there any additions to the presented DG?
   Think about strange relationships in the DG, directions of arrows that are wrong, missing relationships in the DG or the readability of the network.

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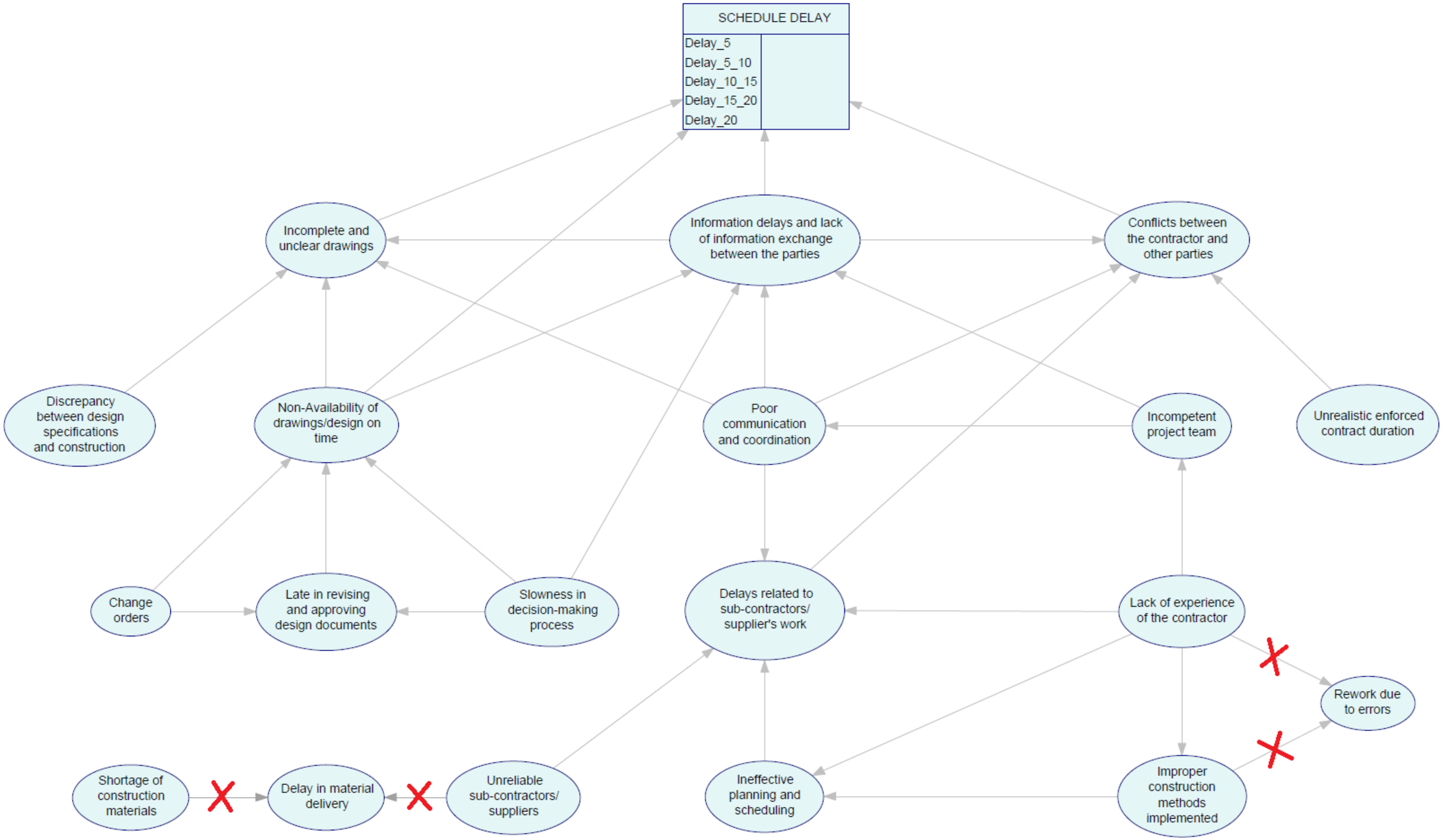
Appendix L – Expert Discussion: DG



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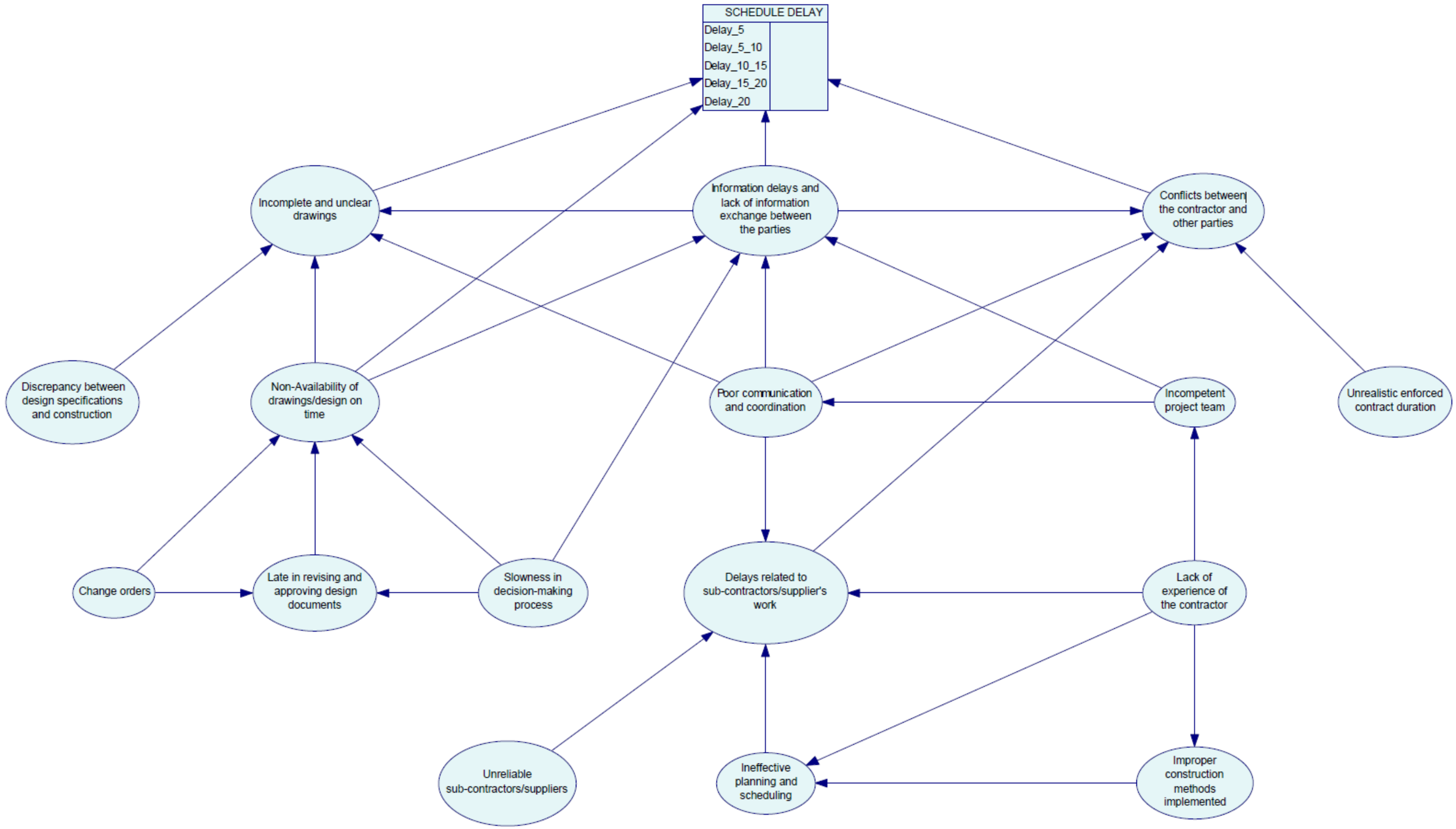
Appendix M – BBN: Final DG



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Appendix N – BBN: Set-up questionnaire (III)

What are the conditional probabilities of the critical factors that cause delays in the execution phase of UCP in the Netherlands?

Thank you very much for taking time and effort to fill in the questionnaire! The purpose of the questionnaire is to estimate the conditional probabilities of critical factors that cause delays in the execution phase of UCP. On the basis of questionnaire (II) it was determined which cause-effect relationships between the critical factors are accepted. These cause-effect relationships are included in this questionnaire to determine the conditional probabilities of these factors cause delays in the execution phase of UCP in the Netherlands. In order to determine the conditional probabilities between these factors, you are asked to assess the chance of occurrence the critical factors cause delays.

The questionnaire consists of 3 parts:
1. General questions (2 minutes)
2. Assessment effects: Factors that cause delays (±5 minutes)
3. Assessment probabilities: Occurrence factors (±10 minutes)

Part 2 and 3 is introduced with an example to make sure what is expected of you in the assessment of effects and probabilities!

1. General questions (2 minutes)

Please indicate what applies to you (Please note only 1 answer).

Demographic questions:		
1	Gender	☐ Male ☐ Female
2	Age	☐ < 29 years ☐ 30 – 39 years ☐ 40 – 49 years ☐ 50 > years
3	Level of education	☐ Intermediate vocational education (MBO) ☐ University of applied science (HBO) ☐ University of science (WO)
4	Work experience	☐ < 10 years ☐ 10 – 15 years ☐ 16 – 20 years ☐ > 20 years
5	Average project size	☐ < 5 million euros ☐ 6 – 20 million euros ☐ 21 – 50 million euros ☐ > 50 million euros

2. Assessment effects: Factors that cause delays (±5 minutes)

What is the effect on the project when the following factors occurred during the execution phase of UCP? (Delay in percentage of total project duration)

Example:

Direct schedule delay								
Non-availability of drawing/design on time	*Information delays and lack of information exchange between the parties*	*Incomplete and unclear drawings*	*Conflicts between the contractor and other parties*	*<5%*	*5 – 10%*	*10 – 15%*	*15 – 20%*	*>20%*
Yes	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
No	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐

Example of the red frameworks:

'Non-availability of drawing/design on time' **(YES)** occurred in the project, 'Information delays and lack of information exchange between the parties' **(NO)** not occurred in the project, 'Incomplete and unclear drawings' **(YES)** occurred in the project, 'Conflicts between the contractor and other parties' **(NO)** not occurred in the project → What is the effect to the project? → ANSWER POSIBILITIES: Delay <5% of the total project duration, 5-10% of the total project duration, 10-15% of the total project duration, 15-20% of the total project duration or >20% of the total project duration.

Direct schedule delay								
Non-availability of drawing/design on time	*Information delays and lack of information exchange between the parties*	*Incomplete and unclear drawings*	*Conflicts between the contractor and other parties*	*<5%*	*5 – 10%*	*10 – 15%*	*15 – 20%*	*>20%*
Yes	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
No	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐

Example of the Blue frameworks:

'Non-availability of drawing/design on time' **(NO)** not occurred in the project, 'Information delays and lack of information exchange between the parties' **(YES)** occurred in the project, 'Incomplete and unclear drawings' **(YES)** occurred in the project, 'Conflicts between the contractor and other parties' **(YES)** occurred in the project → What is the effect to the project? → ANSWER POSIBILITIES: Delay <5% of the total project duration, 5-10% of the total project duration, 10-15% of the total project duration, 15-20% of the total project duration or >20% of the total project duration.

Fill in (±5 minutes):
Question:
What is the effect in the project when the following factors occurred during the execution phase of UCP? (Delay in percentage of total project duration) → *Please indicate what applies (Please note only 1 answer).*

Direct schedule delay								
Non-availability of drawing/design on time	***Information delays and lack of information exchange between the parties***	***Incomplete and unclear drawings***	***Conflicts between the contractor and other parties***	***<5%***	***5 – 10%***	***10 – 15%***	***15 – 20%***	***>20%***
Yes	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
No	Yes	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
	No	Yes	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐
		No	Yes	☐	☐	☐	☐	☐
			No	☐	☐	☐	☐	☐

3. Assessment probabilities: Occurrence factors (±10 minutes)

What is the probability that the following factors occurred during the execution phase of UCP when other factors are applicable in the project?

Example:

What is the probability that the factor ‘Non-availability of drawing/design on time’ occur when the following factors are applicable in the project?

Non-availability of drawing/design on time				
Late in revising and approving design documents	***Slowness in decision-making process***	***Change orders***	***Yes***	***No***
Yes	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐
No	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐

Example of the red frameworks:

‘Late in revising and approving design documents’ **(YES)** occurred in the project, ‘Slowness in the decision-making process’ **(NO)** not occurred in the project, ‘Change orders’ **(NO)** not occurred in the project → Does ‘Non-availability of drawing/design on time’ occur? → ANSWER POSIBILITIES: Chance of occurrence likely (Yes) or unlikely (No)

Non-availability of drawing/design on time				
Late in revising and approving design documents	***Slowness in decision-making process***	***Change orders***	***Yes***	***No***
Yes	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐
No	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐

Example of the blue frameworks:

‘Late in revising and approving design documents’ **(NO)** not occurred in the project, ‘Slowness in the decision-making process’ **(YES)** occurred in the project, ‘Change orders’ **(NO)** not occurred in the project → Does ‘Non-availability of drawing/design on time’ occur? → ANSWER POSIBILITIES: Chance of occurrence likely (Yes) or unlikely (No)

Fill in (±10 – 15 minutes):
Question:
What is the probability that the factor 'Incomplete and unclear drawings' occurred during the execution phase of UCP, when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Incomplete and unclear drawings					
Poor communication and coordination	***Non-availability of drawing/design on time***	***Information delays and lack of information exchange between the parties***	***Discrepancy between design specification and construction***	***Yes***	***No***
Yes	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
No	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐

Question:
What is the probability that the factor 'Non-availability of drawing/design on time' occurred during the execution phase of UCP when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Non-availability of drawing/design on time				
Late in revising and approving design documents	***Slowness in the decision-making process***	***Change orders***	***Yes***	***No***
Yes	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐
No	Yes	Yes	☐	☐
		No	☐	☐
	No	Yes	☐	☐
		No	☐	☐

Question:
What is the probability that the factor 'Late in revising and approving design documents' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Late in revising and approving design documents			
Slowness in the decision-making process	***Change orders***	***Yes***	***No***
Yes	Yes	☐	☐
	No	☐	☐
No	Yes	☐	☐
	No	☐	☐

Question:
What is the probability that the factor 'Incompetent project team' occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Incompetent project team		
Lack of experience of the contractor	***Yes***	***No***
Yes	☐	☐
No	☐	☐

Question:
What is the probability that the factor 'Information delays and lack of information exchange between the parties' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Information delays and lack of information exchange between the parties					
Poor communication and coordination	***Non-availability of drawing/design on time***	***Incompetent project team***	***Slowness in the decision-making process***	***Yes***	***No***
Yes	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
No	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐

Question:
What is the probability that the factor 'Ineffective planning and scheduling' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Ineffective planning and scheduling			
Lack of experience of the contractor	***Improper construction methods implemented***	***Yes***	***No***
Yes	Yes	☐	☐
	No	☐	☐
No	Yes	☐	☐
	No	☐	☐

Question:
What is the probability that the factor 'Poor communication and coordination' occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Poor communication and coordination		
Incompetent project team	***Yes***	***No***
Yes	☐	☐
No	☐	☐

Question:
What is the probability that the factor 'Improper construction methods implemented' occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Improper construction methods implemented		
Lack of experience of the contractor	***Yes***	***No***
Yes	☐	☐
No	☐	☐

Question:
What is the probability that the factor 'Conflicts between the contractor and other parties' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Conflicts between the contractor and other parties					
Poor communication and coordination	***Unrealistic enforced contract duration***	***Information delays and lack of information exchange between the parties***	***Delays related to sub-contractors/supplier's work***	***Yes***	***No***
Yes	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
No	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐

Question:

What is the probability that the factor 'Delays related to sub-contractors/supplier's work ' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Delays related to sub-contractors/supplier's work					
Unreliable sub-contractors/ suppliers	***Lack of experience of the contractor***	***Ineffective planning and scheduling***	***Poor communication and coordination***	***Yes***	***No***
Yes	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
No	Yes	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐
	No	Yes	Yes	☐	☐
			No	☐	☐
		No	Yes	☐	☐
			No	☐	☐

Question:
What is the probability that the factor 'Discrepancy between design specification and construction' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Discrepancy between design specification and construction		
	Yes	***No***
	☐	☐

Question:
What is the probability that the factor 'Slowness in the decision-making process' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Slowness in the decision-making process		
	Yes	***No***
	☐	☐

Question:
What is the probability that the factor 'Unrealistic enforced contract duration' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Unrealistic enforced contract duration		
	Yes	***No***
	☐	☐

Question:
What is the probability that the factor 'Change orders' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Change orders		
	Yes	***No***
	☐	☐

Question:
What is the probability that the factor 'Unreliable sub-contractors/ suppliers' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Unreliable sub-contractors/ suppliers		
	Yes	***No***
	☐	☐

Question:
What is the probability that the factor 'Lack of experience of the contractor' occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Lack of experience of the contractor		
	Yes	***No***
	☐	☐

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Appendix O – BBN: Results questionnaire (III)

2. Results – Assessment effects: Factors that cause delays

What is the effect on the project when the following factors occurred during the execution phase of UCP? (Delay in percentage of total project duration)

Direct schedule delay								
Non-availability of drawing/design on time	***Information delays and lack of information exchange between the parties***	***Incomplete and unclear drawings***	***Conflicts between the contractor and other parties***	***<5%***	***5 – 10%***	***10 – 15%***	***15 – 20%***	***>20%***
Yes	Yes	Yes	Yes	0%	0%	0%	30%	70%
			No	10%	0%	20%	50%	20%
		No	Yes	0%	30%	40%	20%	10%
			No	30%	20%	30%	20%	0%
	No	Yes	Yes	0%	20%	60%	20%	0%
			No	10%	50%	40%	0%	0%
		No	Yes	20%	50%	30%	0%	0%
			No	50%	50%	0%	0%	0%
No	Yes	Yes	Yes	0%	20%	20%	50%	10%
			No	30%	30%	10%	30%	0%
		No	Yes	0%	60%	30%	10%	0%
			No	30%	40%	30%	0%	0%
	No	Yes	Yes	0%	70%	30%	0%	0%
			No	30%	70%	0%	0%	0%
		No	Yes	20%	80%	0%	0%	0%
			No	80%	20%	0%	0%	0%

Results of respondents expressed in percentage (%) of the total weighting results

3. Results – Assessment probabilities: Occurrence factors

What is the probability that the factor 'Incomplete and unclear drawings' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Incomplete and unclear drawings					
Poor communication and coordination	***Non-availability of drawing/design on time***	***Information delays and lack of information exchange between the parties***	***Discrepancy between design specification and construction***	***Yes*** (%)	***No*** (%)
Yes	Yes	Yes	Yes	100	0
			No	80	20
		No	Yes	100	0
			No	100	0
	No	Yes	Yes	80	20
			No	90	10
		No	Yes	100	0
			No	40	60
No	Yes	Yes	Yes	100	0
			No	90	10
		No	Yes	100	0
			No	20	80
	No	Yes	Yes	100	0
			No	80	20
		No	Yes	50	50
			No	30	70

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Non-availability of drawing/design on time' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Non-availability of drawing/design on time				
Late in revising and approving design documents	***Slowness in the decision-making process***	***Change orders***	***Yes*** (%)	***No*** (%)
Yes	Yes	Yes	100	0
		No	90	10
	No	Yes	70	30
		No	50	50
No	Yes	Yes	100	0
		No	50	50
	No	Yes	60	40
		No	20	80

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Late in revising and approving design documents' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Late in revising and approving design documents			
Slowness in the decision-making process	***Change orders***	***Yes*** (%)	***No*** (%)
Yes	Yes	100	0
	No	60	40
No	Yes	60	40
	No	0	100

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Poor communication and coordination' occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Poor communication and coordination		
Incompetent project team	***Yes*** (%)	***No*** (%)
Yes	100	0
No	10	90

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Information delays and lack of information exchange between the parties' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Information delays and lack of information exchange between the parties					
Poor communication and coordination	***Non-availability of drawing/design on time***	***Incompetent project team***	***Slowness in the decision-making process***	***Yes*** (%)	***No*** (%)
Yes	Yes	Yes	Yes	100	0
			No	100	0
		No	Yes	100	0
			No	70	30
	No	Yes	Yes	100	0
			No	90	10
		No	Yes	60	40
			No	60	40
No	Yes	Yes	Yes	100	0
			No	90	10
		No	Yes	80	20
			No	60	40
	No	Yes	Yes	90	10
			No	20	80
		No	Yes	30	70
			No	0	100

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Ineffective planning and scheduling' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Ineffective planning and scheduling			
Lack of experience of the contractor	***Improper construction methods implemented***	***Yes*** (%)	***No*** (%)
Yes	Yes	100	0
	No	70	30
No	Yes	70	30
	No	0	100

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Conflicts between the contractor and other parties’ occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Conflicts between the contractor and other parties					
Poor communication and coordination	***Unrealistic enforced contract duration***	***Information delays and lack of information exchange between the parties***	***Delays related to sub-contractors/supplier’s work***	***Yes*** (%)	***No*** (%)
Yes	Yes	Yes	Yes	100	0
			No	100	0
		No	Yes	100	0
			No	80	20
	No	Yes	Yes	100	0
			No	90	10
		No	Yes	90	10
			No	40	60
No	Yes	Yes	Yes	100	0
			No	80	20
		No	Yes	100	0
			No	40	60
	No	Yes	Yes	100	0
			No	40	60
		No	Yes	50	50
			No	0	100

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Improper construction methods implemented’ occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Improper construction methods implemented		
Lack of experience of the contractor	***Yes*** (%)	***No*** (%)
Yes	100	0
No	40	60

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Delays related to sub-contractors/supplier's work ' occur when the following factors are applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Delays related to sub-contractors/supplier's work					
Unreliable sub-contractors/ suppliers	***Lack of experience of the contractor***	***Ineffective planning and scheduling***	***Poor communication and coordination***	***Yes*** (%)	***No*** (%)
Yes	Yes	Yes	Yes	100	0
			No	80	20
		No	Yes	100	0
			No	90	10
	No	Yes	Yes	100	0
			No	70	30
		No	Yes	70	30
			No	50	50
No	Yes	Yes	Yes	80	20
			No	70	30
		No	Yes	80	20
			No	0	100
	No	Yes	Yes	60	40
			No	30	70
		No	Yes	40	60
			No	20	80

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor 'Incompetent project team' occur when the following factor is applicable in the project? → *Chance of occurrence likely (Yes) or unlikely (No)*

Incompetent project team		
Lack of experience of the contractor	***Yes*** (%)	***No*** (%)
Yes	100	0
No	10	90

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Discrepancy between design specification and construction’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Discrepancy between design specification and construction		
	Yes (%)	***No*** (%)
	90	10

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Slowness in the decision-making process’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Slowness in the decision-making process		
	Yes (%)	***No*** (%)
	80	20

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Unrealistic enforced contract duration’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Unrealistic enforced contract duration		
	Yes (%)	***No*** (%)
	60	40

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Change orders’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Change orders		
	Yes (%)	***No*** (%)
	80	20

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Unreliable sub-contractors/ suppliers’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Unreliable sub-contractors/ suppliers		
	Yes (%)	***No*** (%)
	20	80

Result of respondents expressed in percentage (%) of the total weighting results

What is the probability that the factor ‘Lack of experience of the contractor’ occur? → *Chance of occurrence likely (Yes) or unlikely (No)*

Lack of experience of the contractor		
	Yes (%)	***No*** (%)
	20	80

Result of respondents expressed in percentage (%) of the total weighting results

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Appendix P – BBN: Results testing BBN

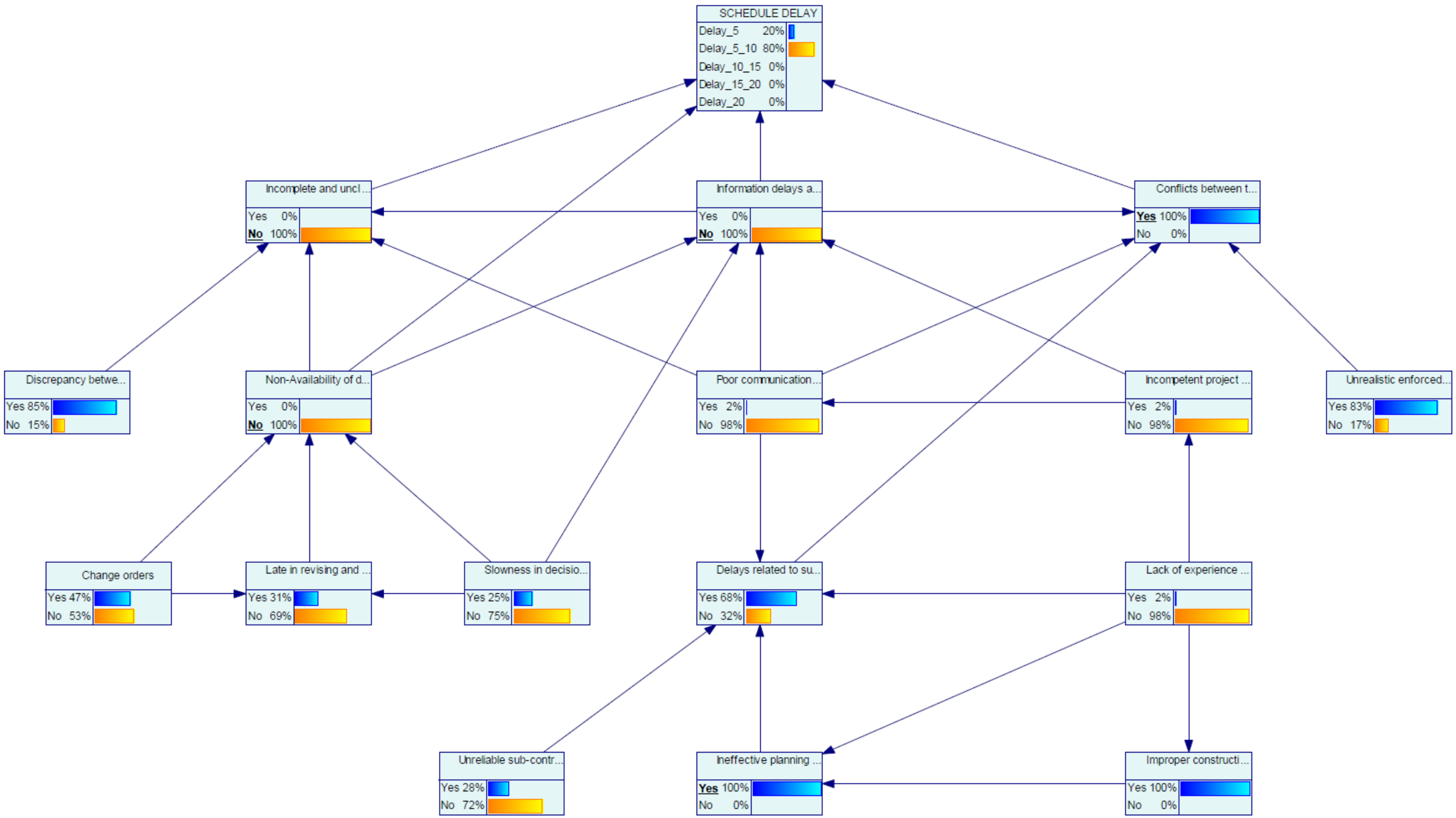

Figure 24: Results of test BBN - Project A

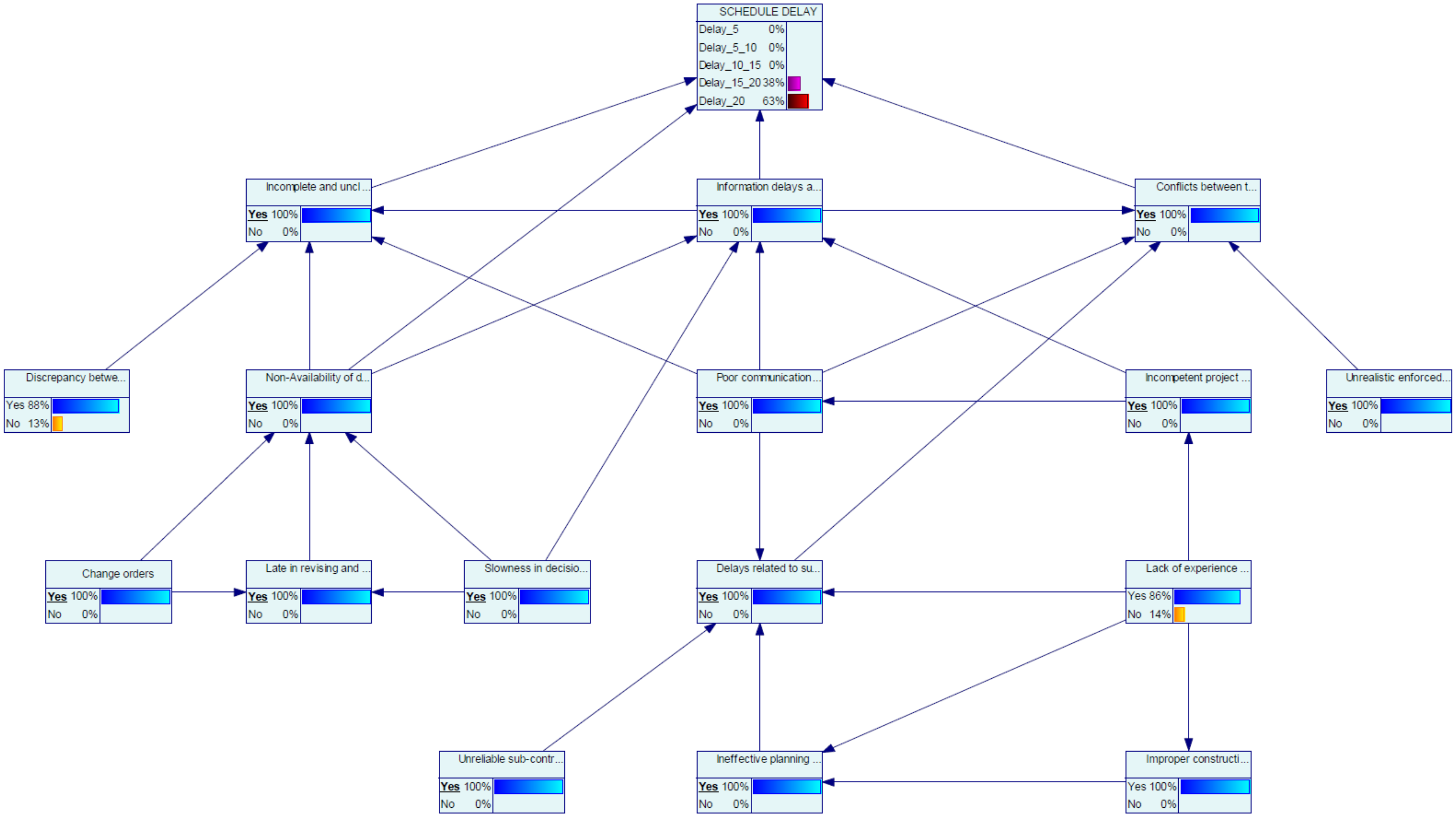

Figure 25: Results of test BBN - Project B