MSc. Thesis

Understanding the schedule delay within design-construction interface

(In an infrastructure mega-project)

by

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In partial fulfillment for the degree of
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at

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In collaboration with

A Dutch construction company

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Colophon

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NOTE: This summary report is specifically drafted for the repository to address the graduation research and to discuss the original objectives and main results, while keeping the confidentiality required by the company.

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Preface

This report has been submitted in partial fulfillment of the course, CME2001 Master Thesis Preparation (2019/20), and CME2000 Master Thesis (2019/20) of the master construction management and engineering at the Delft University of Technology.

While interning with a construction company in the Netherlands, I observed that large-scale projects suffer from delays followed by cost escalation in the design-construction interface. Based on these findings and many discussions with the office supervisor and other team members, I found that the problem of delay is heightened during the design-construction interface, a period within which the design and the construction team start overlapping their activities. The research is focused on providing a profound understanding to developing mitigation measures for delays within design-construction interface. I believe that acknowledging these problems during the interface would directly reduce the probability and effect of risks leading to time and cost overruns in large-scale construction projects.

The research would not have been successful without the support of my supervisors. Firstly, I would like to thank my office supervisor for taking time from his busy schedule to help me with all my doubts and queries during these trouble times of COVID-19. My first supervisor, Yan Liu, who supported and guided me from the start. Without his feedback and friendly advice, it would have been challenging to complete the research on time. Dr. Erik-Jan Houwing, whose critical reviews and explicit comments on scientific writing helped better structure the study, and Prof. dr. PW. Chan, for always giving me constructive advice to improve the findings and results of the research.

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On a personal note, I am heartily grateful to my parents for their love and support during the entire two years. My brother and sister-in-law, with whom I discussed every hurdle and conflicts I faced, and lastly, my friends who directly or indirectly supported me during the entire masters.

Shreya Srivastava

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Summary

The construction sector is one of the world's largest economies, with more than $10 trillion construction-related spendings globally every year (Institute, 2017). Practitioners and experts have always considered these investments in construction projects, pivotal for boosting growth and increasing the opportunity to sustain a better life (Amann et al., 2016). The construction of large-scale projects covers a massive part of this investment. These large-scale projects contribute to changing society's traits (Flyvbjerg, 2018), and they are commonly known as mega-projects. There has been an escalating demand for these mega-projects worldwide for economic and societal benefits in recent years. However, the size, amount of investment, limited budget & time, and organizational & technical complexities have led towards making these projects extremely susceptible to high risks not just for the client and the contractor but also for the whole economy (Altshuler & Luberoff, 2003; Flyvbjerg et al., 2003; Merrow, 2011). The construction industry has suffered for decades from poor productivity worldwide (Institute, 2017), primarily due to cost escalation and schedule delays (Flyvbjerg et al., 2003; Ismail et al., 2013; Love & Ahiaga-Dagbui, 2018). And infrastructure mega-projects are not any different from these projects (Love et al., 2014).

For a long time, researchers have tried to investigate delays and time overrun in construction projects worldwide. Most have concentrated their studies on identifying causes and measures. None has focused on developing measures to minimize delays. These scholars also failed to consider the interface period, which is observed as one of the most critical project phases in innovative contracts (such as DBFM and DBM). Thus, the problem statement formulated for the research was:

“there is a lack of practical recommendations on developing mitigation measures for delays within the design-construction interface in infrastructure mega-projects.”

Based on the above problem statement, this research attempts to provide the first detailed study on developing measures to minimize schedule delay within the design-construction interface in an infrastructure mega-project by learning from practitioners' knowledge and experience. The construction project analyzed in the research is one of the most complex infrastructure mega-projects in the Netherlands. The mega-project studied experienced more than a year of schedule delay in design-construction interface (in UO milestone). Even though a few delays were present in the earlier phases, most of them were discovered in the overlapping phase or the design-construction interface. Therefore, parallel to the above problem statement, the main objective of the research was:

“The research's main objective is to minimize schedule delays within the design-construction interface in infrastructure mega-projects by identifying key issues and developing the measures.”

For achieving the above objective, the main and sub-questions were formulated as under:

“How to develop measures to minimize schedule delays within the design-construction interface in the Dutch infrastructure mega-project?”

The main question was answered based on the following sub-research questions.

1) *According to existing literature, what are the most common delay factors and measures present within the design-construction interface in construction projects?*
2) *What measures are adopted for key issues behind schedule delay within the design-construction interface in the selected infrastructure mega-project?*
3) *What measures can be recommended to minimize delays within the design-construction interface in the selected infrastructure mega-project and future projects?*

The research first conducted an extensive literature review on delays within the design-construction interface to answer the first sub research question. The literature review helped define the terminology for delays and design-construction interface. However, no research was found that combined the topic of delays and design-construction interface through literature study. Therefore, the first sub-question was answered by combining the factors and measures from studying the two topics separately (refer to Table **i**). It was also observed that most of the studies focused on identifying factors, and only a few provided mitigation measures (Al-Saggaf, 1998; Assaf et al., 1995; Chai et al., 2015; Chan & Kumaraswamy, 1997; De Saram et al., 2004; Enshassi et al., 2010; Mahamid, 2013; Odeh & Battaineh, 2002; Tumi et al., 2009) (Assaf & Al-Hejji, 2006; Chai et al., 2015; Gündüz et al., 2013; Le-Hoai et al., 2008; Ogunlana et al., 1996; Olawale & Sun, 2010). The studies' mitigation measures were vague and lacked practical implementation (Arantes & Ferreira, 2020). However, at the beginning of 2020, a study by Amilcar Arantes and Luis Miguel D. F. Ferreira focused on developing delay measures based on different project life cycle phases (Arantes & Ferreira, 2020). The research used a survey to identify the causes of delays and focus group discussion on developing mitigation measures. The causes and measures were divided into four stages: planning, design, procurement, and construction. Although the research gave new insights, it did not consider the design-construction interface period.

Table i. Identified delay factors for the design-construction interface

Number	Factors
1	Problem with finance and payments of completed work from client
2	Owner Interface
3	Unrealistic contract duration and requirements imposed
4	Poor provision of information
5	Excessive bureaucracy in project
6	The client-initiated change orders
7	Delay in approval of finished work
8	Type of project bidding and award (negotiation, lowest price, etc.)
9	Mistakes and discrepancies in contract documents
10	Uncompromising disputes between parties or with opponents
11	Time limitation in the design phase
12	Communication and coordination problems between parties
13	Problems with subcontractor or suppliers
14	Environmental concerns and public resistance
15	Slow permits by Govt. agencies
16	Changes in government regulations and laws (Building codes)
17	Economic situation
18	Necessary variation of works
19	Weather condition
20	Unforeseen ground conditions
21	Slowness in decision making

22	Design complexity
23	Managerial & co-ordination challenges
24	Delay in the contractor's progress
25	Lack of buildability
26	Problems with finance and payments to suppliers and sub-contractors
27	Inadequate/improper planning and scheduling of project
28	Delay in inspection and approval of completed works
29	Inappropriate overall organizational structure
30	Incompetence/inadequacies knowledge and experience
31	Lack of buildability (constructability)
32	Poor procurement programming of materials by contractor
33	Slow information flow between project team members
34	Changes in design/design error
35	Delay in design drawings
36	Fast-track (phased) construction
37	Poor site management and supervision
38	Conflict due to cultural differences and nationalities of participants
39	Mistakes during construction
40	Improper construction methods
41	The low productivity level of labors
42	Skilled labor shortage
43	Misuse/Poor handling of resource
44	Equipment/Tools availability and failure
45	Late delivery and shortage of Material
46	Quality of Material and Equipment

Because no studies elaborated on delays within the design-construction interface, the research conducted an explorative structured survey within the Dutch construction industry to validate the selected mega-projects earlier observation. The survey was sent to 45 participants, among which only 28 people responded to the survey. The survey results confirmed that the problem is more significant than one project and concluded that the frequency and severity of delays were higher in the design-construction interface than in other project life-cycle phases. Even though the survey sampling was small, it provided a base for future study on delays within the design-construction interface.

The research methodology was shaped to analyze the design-construction interface delays in the selected infrastructure mega-project in the next phase. The methodology selected for data collection and analysis was the ‘Critical Incident Technique’ (CIT). CIT was adopted to focus on the practitioner’s behavior missing in earlier studies and gain in-depth information on the critical events that led to the design-construction interface's delays. The CIT framework was used in the research as it provided a range of responding options to the participants, which is well suited for explorative studies (Flanagan, 1954). For the collection of the data, eight experts within the selected infrastructure mega-project organization were selected. These experts were interviewed in two rounds: The first round was conducted to get a general idea of the critical incidents; in contrast, the second round was conducted to gain more detailed insights.

The interviews provided in-depth knowledge of six critical incidents that experienced delays within the design-construction interface in the selected infrastructure mega-project. Based on the descriptions of critical incidents, the key-issues and their measures were identified. Following the bottom-up approach, each of these key-issues was divided into categories and

then levels. The categories were Organizational team, External Authority, Organizational management, Client. These categories were further divided into levels: external level and internal level. The Categorization of these key-issues into the two levels was based on the type of source (internal or external). Based on the discussion on critical incidences, the delay key issues and their measures for the selected infrastructure mega-project within the design-construction interface are represented in Table ii. The different colors in the table represent the acceptance level by the interviewees for the measure. Moreover, the level in the table indicates if the key-issue can be solved completely (internal) or partially (external).

- **Blue:** Best possible measure adopted by the selected organization to minimize the design-construction interface delay.
- **Red**: Measure proposed by project members to avoid delay within the design-construction interface.

The recommendations were made to develop the existing measures.

Table ii. Delay key-issues and measures within the design-construction interface in the selected mega-project in the Netherlands

Key-issues (Sub-category)	Category	Level	Measure
Delay in completion of DO design	Organizational team	Internal	Incorporating DO plus design phase to complete and finalize the DO designs. This phase should be treated as a phase-gate between the DO and UO design package.
Long Permit procedure	External Authority (Municipality)	External	Remarkable stakeholder management during the early phases leading to a reduction in permit approving duration. Practice transparency with the municipality for the beginning to avoid re-designs.
Initial coordination challenges	Organizational management	Internal	Integrate the design and construction team from the start of the project. Choose the right person at the right place and at the right time.
Poor provision of information by the client	Client	External	Based on the budget, procure a sufficient amount of extra material for emergency external level issues.
Delay in environment study	Organizational management	Internal	Conduct the Environmental study much early in the project to avoid last-minute changes. Based on the budget, procure a sufficient amount of extra material for emergency external level issues.
Change in norm	External Authority (Netherlands Standardization Institute)	External	Based on the budget, procure a sufficient amount of extra material for emergency external level issues.
Internal changes in design	Organizational team	Internal	Stick to the original plan and avoid making changes unless extremely necessary.

Conflicting responsibility within the team	Organizational team	Internal	Incorporating DO plus design phase to complete and finalize the DO designs. This phase should be treated as a phase-gate between the DO and UO design package. Divide the design team and construction into groups with short-term and long-term visions.
Trust issues	External Authority (Consultant)	External	Involve the authorities from the early phases to include their comments and practice transparency. Incorporating DO plus (+) design phase to complete and finalize the DO designs. This phase should be treated as a phase-gate between the DO and UO design package.
Understaffed approving authority	External Authority (Consultant)	External	A request is made at a higher level to increase the number of staff members. Involve the authorities from the early phases to include their comments to avoid intense discussions later, leading to delay in design approval.

Based on these findings and analysis, the research proposed preventive measures and a corrective measure framework in the last phase, as shown in Figure **i** and Figure ii. The research recommends following the preventive measures during the planning phase, while the corrective measure framework is recommended to be used when an unforeseen delay occurs. The preventive measures were divided based on the Dutch project life cycle phases (VO design phase, DO design phase, UO design phase, and design-construction interface). In contrast, the corrective measure framework was proposed to ensure the development of measures throughout the process. It consists of six steps: Identifying the root cause, research measure, verify measure, implement the measure, monitor, transfer the experience and knowledge. These steps are further explained below.

- Identifying the root cause: The first step is to identify the root cause behind the delay.
- Research the measure: Research for possible mitigation measures. The team impacted by the delay conducts the research.
- Verify the measure: Verify and validate the measure with other organizational teams and external authority/clients.
- Implement the measure: Implement the validated measure.
- Monitor: Closely monitor the progress of the measures. At this stage, in the case of any deviation, go back to step two.
- Transfer the experience and knowledge: Transfer the experience and knowledge of the success or failure of adopted measures to the next phase and next project.

The research will help the company and the project reflect on the adopted mitigation measures and develop them for future delays on the company level. The research also analyzes key issues and measures to develop them for future situations. Lastly, there is no one solution for all projects as every project is different, but the proposed measure can be used as a starting point to improve future project success.
Following the section on the problem definition, it is already known that the study of delay is not a newly found area of research for scholars. For years, researchers have tried to identify factors leading to delays in building and infrastructure projects; however, only identifying these

factors has not helped practitioners develop the measures to minimize the delays. Therefore, since the research will be one of the first explorative studies on developing practical measures within the design-construction interface, it will provide insights into the problem. Lastly, the research will also provide a base for future studies on delays within the design-construction interface.

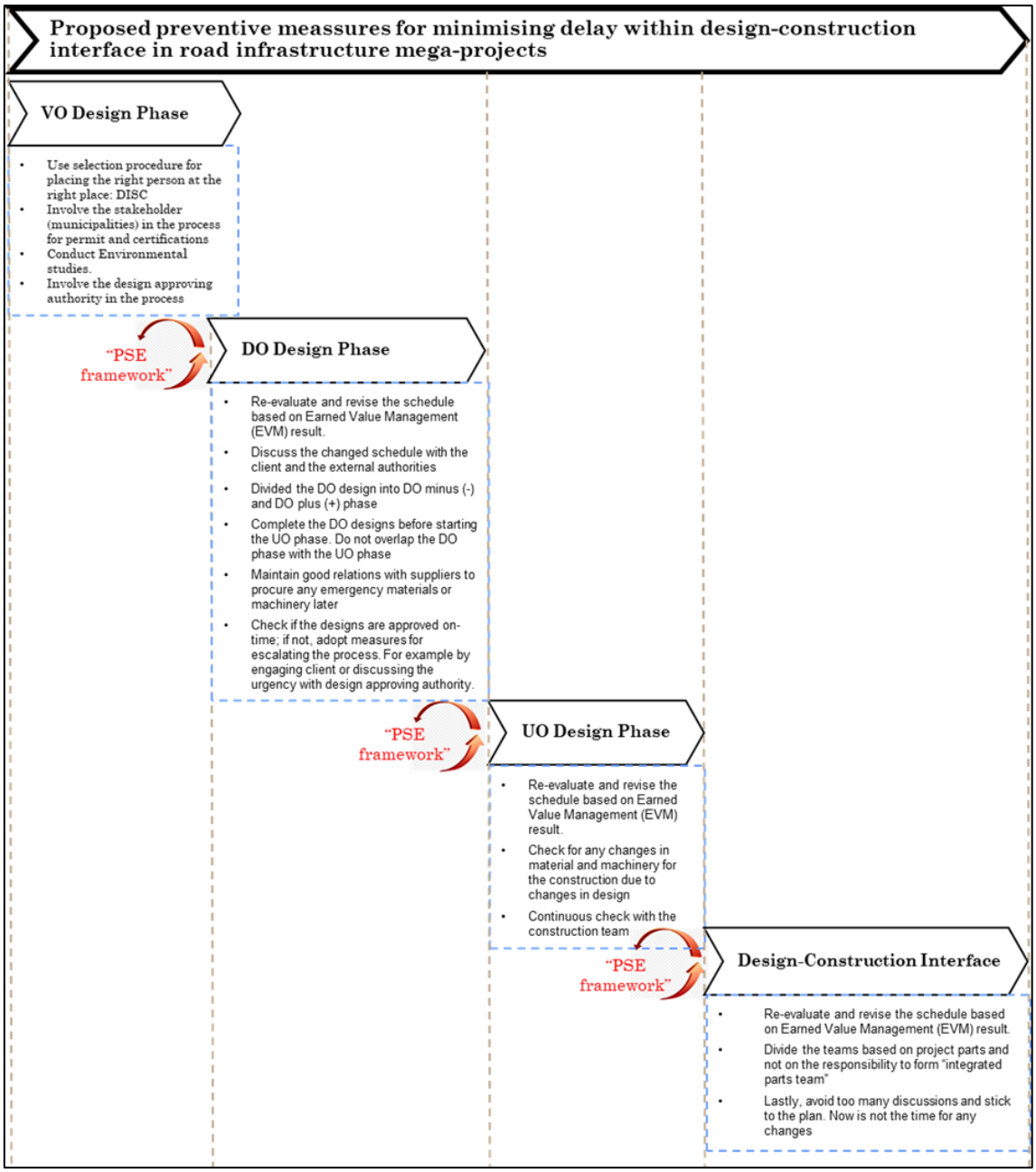
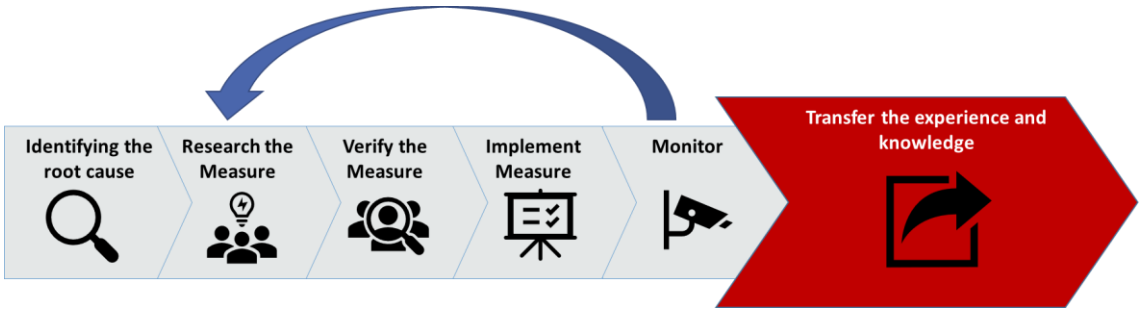


Figure i. Proposed preventive measure and corrective measure framework for delays within the design-construction interface



- Figure ii. Proposed corrective measure framework for delays within the design-construction interface

Research limitations

Like every research, this research also has some limitations due to the time constraint, chosen research approach and methodology, and the unfortunate situation of COVID-19.

Limitations of the literature review

- Due to the unavailability of the literature on delays within the design-construction interface, the list of common factors and measures was formulated by combining the literature on the two topics separately. Therefore, due to a lack of research on delays within the design-construction interface, the list of factors and literature measures might not be completely reliable.
- The research only includes a limited number of literature studies for identifying factors and mitigating measures. In the study, the literature review was discontinued after finding the same factors repeatedly. Therefore, the research might not have considered a few critical factors and measures not present in the reviewed studies.

Limitations of research methodology

- As already mentioned, the research methodology did not consider the 'why' aspect; instead, it focused on the 'what and how.' The limitation is recommended to be reflected in future research.
- According to CIT methodology, the critical incidents that are not discussed by the majority of participants are excluded from the study. Therefore, the critical incidents considered for the research might not be all the delay events present in the case study within the design-construction interface as the research only considered the outstanding events.
- Most of the meetings and interviews were conducted online with limited access to the on-site office because of the COVID-19 pandemic; this does not imply that the research findings are not reliable, but the interactive sessions could have been made more productive in a physical meeting.
- The research only considered the contractor's perspective to evaluate the key-issues for delays. More insights from other parties like the client and the external authority would have provided more insight into the problem. Their perspectives would also have helped to develop the measures further.

Limitations of research results

- Because the research results are based on one case study and a few interviews within an infrastructure mega-project, the research's generalizability is restricted. The

outcome would have been made more generic by conducting more in-depth case studies with more interviews.

- The proposed preventive measures and framework were generalized to the extent that they could be implemented in the project. However, since the measures and framework are only based on the identified key-issues, a few changes might be needed before implementing it in a new project. These changes will be made based on accepted practices.
- The research result depends on the interviews' results; therefore, the result might be biased based on the organization's members' opinions.

Recommendations

The section provides recommendations for the company/practice, and recommendations for future researchers.

Recommendation for practice

- A total of 8 interviewees participated in the semi-structured interview conducted for the data collection. Even though a reasonable outcome was delivered from this sample size, it is advised that the company should engage more participants from the design and construction team for future research. The involvement of more participants will provide more authenticity to the result.
- The methodology used in the research does not help in transforming the standard processes and practices. Therefore, it is recommended to conduct research that helps the organization change by learning through the process. The research suggests using Activity Theory to achieve the aim of learning from analyzing the process.
- It is recommended to explore other groups' views like the asset team and QA/QC within the PBO. The involvement of these teams will help give more perspective to the analyzed problem.
- More research is suggested for the application of the conceptual framework created in this research. Because the proposed measures were not tested due to the time constraint, it is advisable to conduct a pilot test and then implement it within the organization and future projects.
- Because of the Covid-19 pandemic, the site-visits were limited. In the future, it is recommended to research more on the organizational culture as an insider to provide more in-depth research on the findings.

Recommendation for researchers (future research)

- As already mentioned in the section on limitations, the research highly recommends focusing on the process's developmental transformation by concentrating on the 'why' aspect rather than 'what' or 'how.' This will provide more in-depth detailed analysis to change the inefficient standard procedures that have been used since long within the organization.
- The study focuses on understanding the contractor's perspective on learning to minimize schedule delay. Future research is recommended to include other parties' views like the client, the design approving authority, and the municipalities. Understanding these stakeholders' perspectives might open ways by which they can help each other.

- The research was limited to analyzing a single case to conduct an in-depth study on delays within the design-construction interface. Although the approach helped understand the problem in detail, future research can compare two or more projects' findings.

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