Short-cyclic scheduling in construction projects

An exploratory study on finding the critical project factors for determining the appropriateness of projects for short-cyclic scheduling during the realization phase

May 13, 2019
Master thesis
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by
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In partial fulfilment of the requirements
for the degree of Master of Science
in Construction Management and Engineering
at the Delft University of Technology

Delft, 13-05-2019
to be defended publicly on 23-05-2019

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Project duration	8 months	
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an electronic version of this graduation research report is available on https://repository.tudelft.nl

Acknowledgements

This research gave me the opportunity to combine practical insights with the theory that I have learned in the past two years following the master's program Construction Management and Engineering. It was an interesting learning experience to enter two complex construction projects and to see the differences between the organizations.

It was interesting to see that even with all the knowledge about procedures and collaboration in construction projects it remains difficult to manage construction projects. One of the most interesting personal insights is that people tend to behave counterproductive when the pressure on the organization increases. Less collaboration, lacking professionality and decreasing commitment were observed in the case that was under high pressure and needed those factors the most.

Furthermore, I learned what scientific research entails. During this process I learned to write more structurally, concise and critically. This could not have been possible without the guidance of my graduation committee. I am thankful that they had the time and patience to teach me to write my report and show me what it meant to do research.

I would like to thank Marian for the frequent sessions and the constant critical view on my report. You were constantly critical on my research questions and approach, which in the end helped me a lot to structure my report. Thank you, Louis for translating much of the feedback. During the meetings I really appreciated your calmness. You rephrased the feedback, which made it comprehensible, which reassured me when I felt stressed. Barthelemy thank you for the mental support and the guidance. You were the one that helped me get back the trust that I could do it after the sessions with the entire commission. Also thank you for the opportunity to arrange the case studies. Hans, you impressed me by the thoroughness of your assessments of my report. I appreciated the feedback, because it really helped me taking this report to the next level. I especially enjoyed the discussion about the theoretical conditions.

A big thanks to all the interviewees and project members that helped me showing their projects. Thank you to Dirk and Ton that validated the research results.

Last but not least, I would like to thank my friends, family, fellow students and colleagues for their support and good advice! Especially, Iwan and Marc for helping me with the structure of my report and keeping me critical on my writing. Leonie, Moritz and Arjan for checking my texts spelling and grammar.

Maarten van der Kaaij

Rotterdam, May 13, 2019

Executive summary

To cope with the current problems in the construction industry, project managers and scholars seek new methods to turn the tide. Many scholars blame traditional management approaches for cost overruns and delays occurring in current projects. To find solutions, project managers introduce tools from various sectors that have coped with similar problems before, such as the IT and manufacturing sectors.

Scheduling has been found to be a main reason for delays and cost overruns. Traditionally, scheduling is done before projects start. Predictions are made for durations, costs and required resources. Project managers impose schedules on subcontractors and apply pressure to prevent delays or cost overruns. This method is characterized by a reactive approach to problems.

Short-cyclic scheduling is more appropriate for complex projects than traditional scheduling. Short-cyclic scheduling tools allow operational personnel to schedule their own tasks. This gives them the flexibility to detect problems quickly and act proactively. Besides, recent knowledge from the work floor is applied directly to the schedule. Furthermore, A benefit of short-cyclic scheduling is the possibility to proactively cope with changing top-down requirements and circumstances.

Most short-cyclic scheduling tools originate from the IT and manufacturing sectors. However, construction projects during the realization phase differ from IT and manufacturing projects. Which raises the question if construction projects during the realization phase are appropriate for short-cyclic scheduling. Scholars have investigated implementations of such tools but have not clearly formulated criteria for short-cyclic scheduling in ongoing projects. To find these criteria the following research question is formulated:
What determines the appropriateness for short-cyclic scheduling of construction projects in the realization phase?

The determination of a project's appropriateness started with a literature study on short-cyclic implementation in construction projects. The literature study resulted in theoretical conditions for appropriate short-cyclic implementation. The theoretical conditions were used as a framework to observe scheduling sessions and to interview project members in two construction projects. The theoretical conditions were a means to structurally investigate problems and success factors in the two projects.

The case studies resulted in a list of critical project factors for appropriateness, depicted in Figure 1. These critical factors can be considered the tipping point for a project's appropriateness. If a project does not possess these factors it is unrealistic to expect a successful short-cyclic implementation.

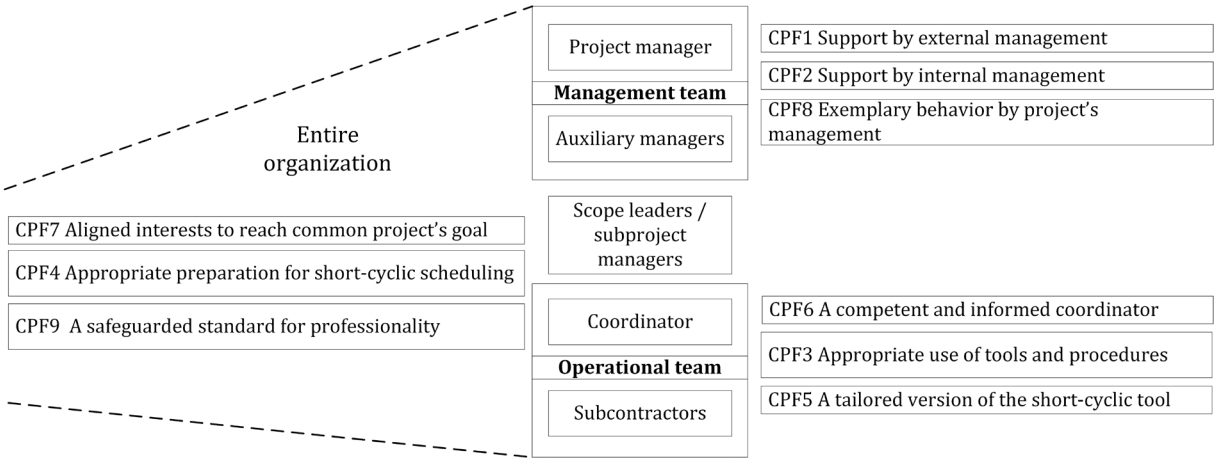


Figure 1 Critical project factors that influence the appropriateness of construction projects for short-cyclic scheduling

CPF7, 4 and 9 on the left side of Figure 1 apply to the entire organization. Aligned interests to reach common project's goal (CPF7) is necessary to ensure effective top-down and bottom-up communication. This means that the information that is shared and the interaction between management and the operational team contributes to meeting the project's goal.

A basic level of professionality is a prerequisite for collaboration and scheduling. If project members fail to share information effectively and if conflicts are not resolved, short-cyclic scheduling is ineffective. Appropriate preparation is necessary for all project members (CPF4). Project members must be aware of the procedures and the reasons for using short-cyclic scheduling. This prevents reversion to old habits and resistance against the used short-cyclic tool. New project members must also be prepared on project entry to ensure the appropriate qualifications and competences for short-cyclic scheduling.

CPF1, 2, and 8 relate to managers. Support by internal management (CPF2) is required for the operational layer to have the freedom to schedule their tasks. Internal management must support the use of short-cyclic scheduling. Internal management must also facilitate horizontal collaboration, which is established by preventing isolation, organizing collaboration meetings and setting communication standards. Support by external management is essential for project members originating from external companies that are not used to short-cyclic scheduling. The project's management must create support from those companies for short-cyclic scheduling.

The project's management must lead by example. Short-cyclic implementation and following procedures are likely to fail when management does not behave as an example.

CPF3, 5 and 6 relate to scheduling procedures and tools that operational teams use, see Figure 1. A coordinator ensures that information is shared effectively between organizational layers. The coordinator's role is guiding and coaching inexperienced schedulers.

Implementation of short-cyclic scheduling should be complete and tailored. Coexisting tools lead to inefficiencies that harm a project's progress. Construction projects are different from IT and manufacturing projects. Therefore, it is required to tailor the derived short-cyclic tools to the characteristics of the construction project.

Two cases were investigated to establish the critical project factors that were described above. One of the cases implemented short-cyclic scheduling. This case succeeded in meeting milestones. This project was not completely appropriate for short-cyclic scheduling. Which resulted in ineffective discussions and lost information between management and the operational team. The project was however capable of following most of their procedures and the role of the coordinator

proved to be essential for compensating for ineffective information flows, unaligned interests and a lack of experience with short-cyclic scheduling.

The second case did not implement short-cyclic scheduling. This case did not comply with any of the critical project factors. This project was characterized by unprofessional behavior, unclear project goals and ad-hoc behavior. Management did not behave exemplary and did not create support from external management and did not support the other project members, which had a negative effect on the project's performance. No milestones were met, and delays increased during the observation period.

It is recommended to use the model depicted in Figure 1 for assessing future projects' appropriateness for short-cyclic scheduling. Project managers can hire advisors for assessing their projects. The assessment results in an overview of critical project factors already appropriate and factors that need improvement.

Recommendations for project managers and advisors are creating understanding by workshops, coaching sessions and courses. Making sure that people at key positions in the organization are fully committed and competent to use short-cyclic scheduling reduces the risk of coexisting procedures and tools and reversion to old habits.

It is advisable to hire consultants as change managers to introduce short-cyclic scheduling tools in ongoing projects. They are not biased by previous experiences in the project and can take a neutral stand towards the project members. In the first case the hired consultant fulfilled an essential role in coordinating the short-cyclic sessions and maintaining the procedures, which led to meeting the milestone.

Alignment of interests can be done using contractual incentives or by reducing the amount of parties involved in the project. In any case it is important to agree on using the procedures and tools and to set rules for safeguarding these tools and procedures. This can start by selecting the right subcontractors that understand short-cyclic scheduling.

An important note for project managers is that short-cyclic scheduling does not solve problems that already exist such as coexisting procedures, collaboration problems, ineffective communication and conflicts. First solve these problems, before implementing short-cyclic scheduling.

Contents (concise)

Table of contents

List of figures

List of tables

1 Introduction

This chapters introduces the research context in Section 1.1. The problem statement and contribution to literature are discussed in Section 1.2. a Research design has been set up to answer the research question, which is discussed in Section 1.3. A reading guide in Section 1.4 helps the reader to know what can be expected in the following chapters.

1.1 Research context

Large construction projects have been coping with time and cost overruns for many years (Bosch-Rekveldt, Jongkind, Mooi, Bakker, & Verbraeck, 2011; Flyvbjerg, B., Bruzelius, N., Rothengatter, 2003). One of the reasons for overruns and delays is the increasing complexity of construction projects (Blom, Bosch-Rekveldt et al. , 2016; Bosch-Rekveldt et al., 2011; Hertogh & Westerveld, 2010). Without appropriate management approaches this increasing complexity cannot be coped with (Hertogh & Westerveld, 2010).

Delays and cost overruns lead to unsatisfied clients and reduced profits or even losses for stakeholders. Recent figures of the construction sector in The Netherlands show that the orders are increasing, but yields are dropping (Cobouw.nl, 2018). A small amount of parties has managed to increase their yields. However, most large Dutch construction firms are confronted with disappointing figures.

Several scholars consider poor project management to be the main cause for cost and time overruns in the construction industry (Hertogh & Westerveld, 2010; Olawale & Sun, 2010; Trost & Oberlender, 2003). Traditional project management tools have proven to be inadequate to reduce construction projects' delays and cost overruns.

Cost overruns can largely be attributed to a project's scheduling and planning activities. Lacking project specific knowledge is considered a large impediment for making realistic schedules and cost estimates. In other words, the construction sector has difficulty with predicting the future (Doloi, 2013; Love, Ahiaga-Dagbui, & Irani, 2016).

This research's context is the implementation of new scheduling tools in ongoing construction projects. Scheduling has not been a problem for the construction industry only. The IT and manufacturing sectors are examples of industries that have improved their management methods, including scheduling. This enabled them to cope with changing requirements and circumstances (Blom, 2014; Owen & Koskela, 2006b). Some of these new tools have found their way into construction projects but little is known about their implementation in ongoing projects.

1.1.1 Traditional scheduling

Traditionally project's milestones are high level goals that are often scheduled months or years in advance. By scheduling project milestones in advance there is a risk of under- or overestimating the durations of activities due to a lack of specific knowledge about the future project situation (Dallasega, Rauch, & Frosolini, 2018; Koppenjan, Veeneman, Van Der Voort, Ten Heuvelhof, & Leijten, 2011; Priemus & Wee, 2014). This forces the schedulers to make assumptions about task durations. This is a reactive approach. From the moment the predicted schedules are imposed on operational teams, deviations arise. (Ballard, 2000, p. 2-6).

The traditional scheduling approach as described above is considered inappropriate to cope with various uncertainties in construction projects (Hertogh & Westerveld, 2010). Examples of uncertainties are a changing project environment, changing client requirements or changing legislation. A complex project's context is ever changing. A changing context requires a flexible

schedule (Bosch-Rekveldt et al., 2011). An elaboration on traditional scheduling can be found in Section 2.1.

1.1.2 Short-cyclic scheduling

Short-cyclic scheduling, also called iterative scheduling is an example of such a flexible scheduling method. Short-cyclic scheduling enables the performers of tasks to schedule their own work within the limits of their resources and the project's milestones. By having short feedback loops between management and operations, expectations are managed and problems can be solved proactively. (H. G. Ballard, 2000).

Common short-cyclic tools are derived from Lean and Agile methodologies and Last Planner System™. Lean and Agile originate from the manufacturing and the IT industry. These methodologies describe tools for coping with complex project environments. Both Lean and Agile make use of short-cyclic scheduling tools that enable performers to schedule their own tasks (Beedle et al., 2001; Demir, Bryde, Dj, & Sertyesilisik, 2013; Owen & Koskela, 2006a).

Last Planner System is a known method in the construction sector, which implements short-cyclic scheduling to the operational layer similarly to the Agile and Lean methods. Last Planner has also been implemented to cope with known limitations of traditional scheduling tools (Dallasega et al., 2018; Gao & Low, 2014; Iqbal, 2015). An elaboration on short-cyclic tools can be found in Section 2.2.

1.2 Problem statement and contribution

Criticisms remain regarding implementing short-cyclic scheduling in construction projects during the realization phase (Iqbal, 2015; Owen, Koskela, Henrich, & Codinhoto, 2006). According to an extensive literature study it seems that many of the tools from Lean are yet to be implemented in the construction industry which is lagging decades behind in comparison to the manufacturing industry (Babalola, Ibem, & Ezema, 2019).

As a reaction to the slow development of project management in the construction sector much research has been done on scheduling tools that can improve current project management practice. However, little remains known about the implementation of short-cyclic scheduling tools during the realization phase of construction projects (Blom et al., 2016; Owen et al., 2006). Scholars indicate problems with the appropriateness of construction projects during the realization phase. However, no clear image can be given on how to assess projects' appropriateness for short-cyclic scheduling.

This research investigates how projects' appropriateness for short-cyclic scheduling can be determined. A set of critical project factors (CPFs) is established by comparing literature insights and findings from practice. The critical project factors can be used as an appropriateness check for construction projects in the realization phase. In order to find the set of critical project factors the following research question is answered.

What determines the appropriateness for short-cyclic scheduling of construction projects in the realization phase?

The following sub-questions are formulated:

1. What does current literature say on short-cyclic scheduling?
2. What are theoretical conditions for implementing short-cyclic scheduling?
3. How is short-cyclic scheduling currently implemented in the realization phase?
4. How appropriate are ongoing construction projects for short-cyclic scheduling?

1.3 Research design

Figure 2 depicts the research design related to the research questions and the chapters in this report. Chapter 2 presents the results of the literature study which is a summary of the common short-cyclic tools in the construction sector and theoretical conditions for appropriate implementation of short-cyclic scheduling tools.

Chapter 3 and 4 describe the case studies, see Figure 2. The theoretical conditions are used as a framework to categorize the findings from the case projects. The findings describe the use of the scheduling tools during the realization phase of construction projects, which answers research question 3, see Figure 2. Each case finding can yield critical project factors. Critical factors are generalizations of case findings. The factors influence the appropriateness of a project related to the theoretical conditions.

The case studies result in a list of critical project factors which are validated and compared to literature in Chapter 5. The method that is used for the case studies is described in Paragraph 1.3.2.

Chapter 5 contains the synthesis of the case studies, expert validation and literature. The result of the synthesis is a model that can be used for the determination of a projects' appropriateness for short-cyclic scheduling.

Combining the list of critical project factors is done by checking the factors on mutual exclusiveness and collective exhaustion. Being collectively exhaustive means covering all the findings' insights.

The expert validation is explained in Paragraph 1.3.4 is step two of the synthesis chapter, see Figure 2. The validation's result is a revised list of critical project factors that is considered applicable for practical use, according to experts. This revised list is compared to literature insights from the literature study to determine the added value of the research and the final model which answers the main research question.

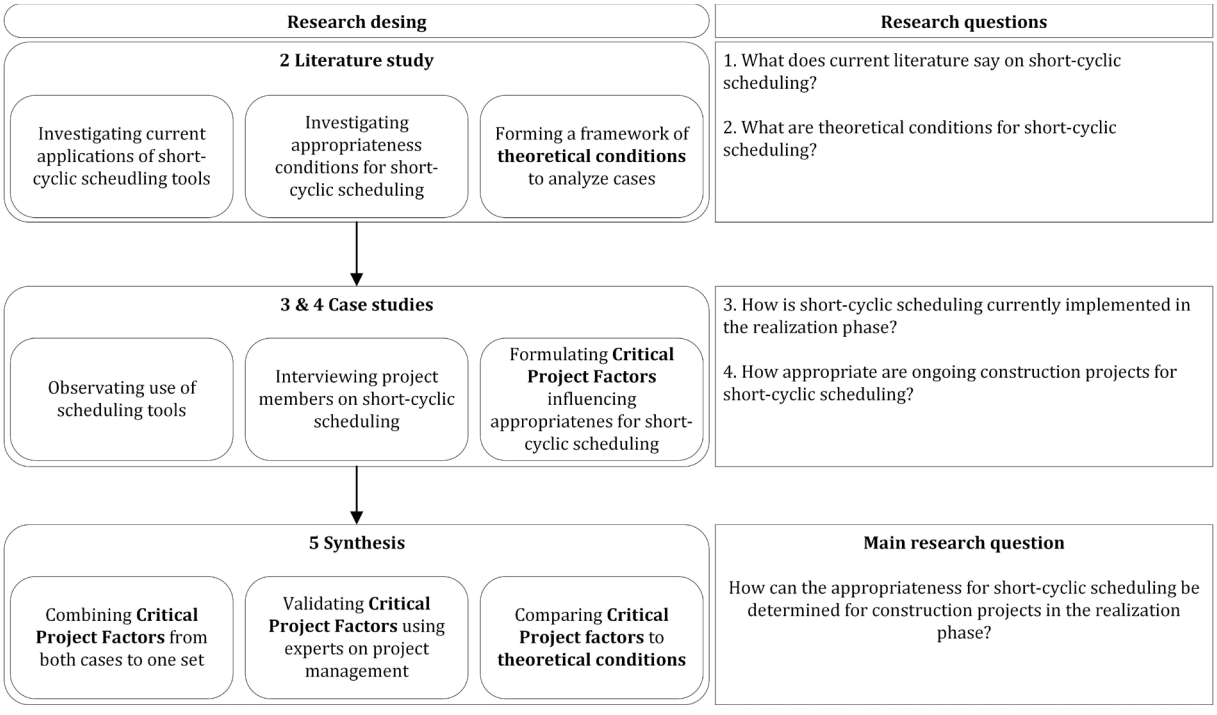


Figure 2 Research design per chapter related to research questions

1.3.1 Method: Literature Study

The literature study is performed using scientific articles and textbooks on project management. Literature on the implementation of short-cyclic tools in the construction was sought. The available literature consists mostly of textbooks for project management methods and scientific articles about the application of scheduling tools. The used sources are; the TU Delft library, Science Direct and Scopus for all scientific papers. The textbooks that are used are the prescribed textbooks for the project management courses of the Master study Construction Management and Engineering at the Delft University of Technology and textbooks that were found in the university's library.

The author used the following categorization in Mendeley:

- Agile scheduling general
- Agile in the construction sector
- New scheduling techniques in the construction sector (state-of-the-art)
- Project complexity and causes of delays and overruns
- Lean scheduling
- Scrum methodology
- Traditional scheduling
- Traditional project management in general

This categorization corresponds with the search entries and topics that were used for finding the literature.

1.3.2 Method: Case studies

The theory of (Yin, 2018) is used to determine that this research is appropriate for case studies. Table 1 is used as a checklist for choosing this method. First the main research question is a how question. Next, the researcher does not require control over the behavioral effect, because his purpose is to assess current instead of changing behavior. The case studies are done on contemporary events in current cases, which excludes a history study.

Methods	Form of research question	Requires control over behavioral effect?	Focuses on contemporary events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case study	How, why?	No	Yes

Table 1 Method criteria (Yin, 2018)

Case requirements

This research requires cases with an uncertain and large scope. A volatile project environment such as changing requirements, stakeholders and interfaces with the environment increase project complexity. This requirement relates to a degree of complexity that forces the project to

implement scheduling processes, because the entire project cannot be comprehended by the project members without tools to help them.

Scheduling activities take place during the period of observation. The researcher must have the possibility to observe short-cyclic scheduling activities during the realization phase of the construction projects. The accessibility to both the scheduling sessions and the interviewees is essential for gathering data.

To be able to compare the scheduling tools at least one of the projects is chosen that uses short-cyclic scheduling tools. One of the projects must have problems with implementing a short-cyclic scheduling tool. One of the projects must be under pressure. This gives the opportunity to compare the appropriateness of a project that is under control and a project that is experiencing pressure.

1.3.3 Case selection

Two cases were chosen from the projects that are being managed by the Consultant. This means that the access and facilities were arranged by the Consultant. The observations and interviews that are done in the case studies are from the perspective of the Consultant. Below the case selection related to the criteria is presented.

Case 1 Urban infrastructure project

The case complies with the relevance criteria and the data criteria, see Table 2 and Table 3 .

Table 2 Relevance criteria case 1 Urban infrastructure project

Criteria	Case description
Location	The project is in a large city in the Netherlands.
Change from the client	The client asks for many changes during the realization phase.
Change from the construction site	The conditions of the subsurface is uncertain because of the city's rich history. Remaining foundations of old structures are not mapped properly leading to uncertainty.
Scheduling activities	During the research, short-cyclic scheduling activities take place.
Phase	The project is in the realization phase

Table 3 Data criteria case 1 urban infrastructure project

Criteria	Case description
Accessibility observations	The project organization has agreed with the observer that all the meetings can be attended.
Accessibility interviews	Participants are introduced to the interviewer and are cooperative in scheduling meetings for interviews.
Use of non-traditional tools	This project uses stand-ups twice a week for scheduling the tasks. The performers of the tasks schedule their own tasks.
Problems with choosing tools	This project uses the same tools for a longer period already and did not have problems choosing these tools.

Case 2 Urban building project

Table 4 shows the relevance criteria of the second case. Table 5 shows the data criteria for case 2.

Table 4 Relevance criteria case 2 urban building project

Criteria	Case description
Location	The project is in a large city in the Netherlands.
Change from the client	The client asks for many changes.
Change from the construction site	The conditions of the subsurface are uncertain because of the rich history of the city. Remaining foundations of old structures are not mapped properly. Technical complexity leads to necessary changes concerning building methods to solve issues such as, lack of space or problems related to building sequence.
Scheduling activities	During the research scheduling activities take place.
Phase	The project is in the realization phase.

Table 5 Data criteria case 2 urban building project

Criteria	Case description
Accessibility observations	The project organization has agreed with the observer that all the meetings can be attended.
Accessibility interviews	Participants are introduced to the interviewer and are cooperative in scheduling meetings for interviews, however not all participants are available due to busy schedules or disinterest.
Use of non-traditional tools	This project uses stand-ups and Lean boards, which are considered non-traditional. However, the main scheduling process is traditional
Problems with choosing tools	This project organization changes the use of tools frequently. They remain coping with the same problems and try to solve this with changing their scheduling procedures (the Consultant has been hired to solve these problems).

Data collection

The data collection is done by observations and interviews. The observations are used to compare the activities with the procedures and to observe the behavior during these activities. The observations are made during scheduling sessions by writing down the observations during the activities. The collected data are grouped in Atlas.TI based on the relevance related to the characteristic categories that are derived from literature. This helps linking each quote and observation to a certain characteristic category which can be used to describe the projects' characteristics.

The participants of scheduling meetings use visual tools to depict schedules. These schedules are monitored to observe the actual progress of tasks compared to the scheduled duration of the tasks. The protocol for the observations can be found in Appendix C.

Interviews are used to explain observations that are made and to gain additional insight in the projects' scheduling activities. The interviews are an opportunity to get a more in-depth perspective of the scheduling activities including reasons for behavior and the points of improvement according to the interviewees. The interviewees are project members that either participate in scheduling activities, are dependent on the information from the scheduling activities or managers that are responsible for the assessed scope. In Appendix B, the protocol for the interviews can be found.

1.3.4 Method: Validation

The critical project factors are validated by using the opinion of experts in project management. The experts are asked to consider the critical project factors as a checklist for their projects. They

are asked if it is feasible to use this checklist. This gives insight in the appropriateness of changing projects towards a short-cyclic desirable state in an already established project environment. The validation protocol is explained in Appendix D.

1.3.5 Comparing critical project factors to theoretical conditions

The insights from the case studies and the validation are compared to the theoretical insights from the literature study. The goal of this step is to assess whether the critical project factors are categorized appropriately related to the used framework. Also, blind spots from the case studies are identified using this comparison.

1.4 Reading guide

To gather the insights to create a list of critical project factors that determine projects' appropriateness for short-cyclic scheduling, practical insights from two case studies are combined with theory and expert opinion. The thesis is structured in the following way:

Chapter 2 (Literature study, p9) presents the current use of scheduling tools and the theoretical conditions for appropriate implementation of short-cyclic tools. The current use of scheduling tools is presented for the traditional and the short-cyclic approach to show the difference between the two approaches and to present arguments for a transition towards short-cyclic scheduling. The framework that is used to categorize the practical findings and theoretical insights is presented in Section 2.4, p16 and Section 2.5, p19.

Chapter 3 (Case 1 Urban infrastructure project, p21) presents the findings from the first case. First the scope, the organization and the used scheduling process are introduced. Next the findings are presented based on interviews with project members and observations of the scheduling meetings, categorized according the framework of theoretical conditions. The result of Chapter 3 are summarized (Table 7, p31).

Chapter 4 (Case 2 Urban building project, p32) presents the findings from the second case. First the scope, the organization and the used scheduling process are introduced. Next the findings are presented based on interviews with project members and observations of the scheduling meetings. The findings are categorized using the framework of theoretical conditions. The results of Chapter 4 are summarized (Table 8, p41).

Chapter 5 (Synthesis, p43) combines and elaborates the critical project factors from the two case studies, Section 5.1. The critical project factors are validated to assess their practical applicability in the next section. Next these insights are compared to the literature insights leading to the final model presented (Table 15, p52).

2 Literature study

This chapter describes the literature on traditional scheduling and short-cyclic scheduling. First traditional scheduling is discussed in Section 2.1. This section entails the basic principles of scheduling, which explain basic concepts that are used in the entire report. Paragraph 2.1.1 discusses the state-of-the-art of traditional scheduling. Section 2.2 introduces short-cyclic scheduling principles and tools and explains the difference between traditional and short-cyclic scheduling. Section 2.3 elaborate on the state-of-the-art of short-cyclic scheduling. The theoretical conditions for implementation of short-cyclic scheduling are introduced in Section 2.4. Based on the findings in Section 2.5 a framework of theoretical basic conditions is established.

2.1 Traditional scheduling

Scheduling is an activity that can be done in all layers of a project organization. In most cases scheduling is done for some or all of the following reasons (Nagata, Manginelli, Lowe, & Trauner, 2018b):

- Assess the tasks that need to be performed
- Estimate the duration of those tasks
- Sequence tasks
- Assess the required parties for performing the scheduled tasks
- Assess the required and available resources for performing the scheduled tasks
- Determine physical interfaces on the construction site

Traditionally the scheduling process aims at predicting the future. High level future project goals are broken down to low level tasks that are scheduled in advance (Burke, 2003). Scheduling can be done for many reasons. Depending on the project's management preferences. Examples of preferences are a minimal project duration, minimal project costs, maximal project revenue or maximal quality (Vanhoucke, 2012). These preferences have an effect on the eventual schedule (Vanhoucke, 2012).

Two schedules that are commonly used in projects are the project schedule and the task schedule (Nicholas & Steyn, 2017). The project schedule is the highest schedule level that is used by project organizations. This schedule contains the important project milestones often divided in different project phases or important delivery moments (Burke, 2003; Nicholas & Steyn, 2017). The task schedule contains the activities that are to be performed by the (sub)contractor(s) in order to complete work packages (Nicholas & Steyn, 2017). Work packages are manageable parts of the project that can be completed by performing certain activities (tasks) but cannot be broken down further in sub-packages. Work packages are comprehensible and controllable for all project members (Nicholas & Steyn, 2017; Vanhoucke, 2012). Examples of work packages are a floor, a wall or a kitchen. Examples of tasks are pouring concrete, placing power cables in the wall or placing an oven.

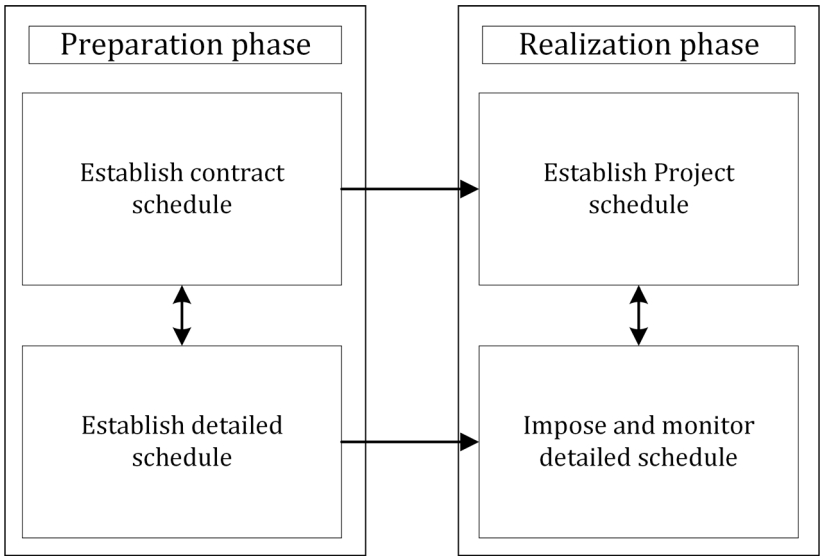


Figure 3 General process of traditional scheduling (Burke, 2003; Nagata et al., 2018b; Nicholas & Steyn, 2017)

Figure 3 depicts the general process of establishing traditional schedules. Scheduling starts in the project's preparation phase. Based on the client's requirements a contract schedule is established during the tender phase. This contract schedule contains the most important milestones and delivery dates, which are often linked to the payment of the contractor (H. G. Ballard, 2000; Nicholas & Steyn, 2017). The contract schedule and the detailed schedule in the preparation phase are linked. The estimations are done to predict the feasibility of the milestones, the required resources, costs and interfaces between parties and the project's environment (Nagata et al., 2018b; Nicholas & Steyn, 2017).

During the realization the project schedule is used. The project schedule is similar to the contract schedule. It entails all the important project milestones which are imposed organization's operational layer. The detailed schedule that is used in the realization phase is often somewhat adapted based on input from (sub)contractors and foremen to get a more realistic image of the coming works. This schedule is traditionally imposed on the (sub)contractors and foremen and monitored (Nicholas & Steyn, 2017; Owen & Koskela, 2006b). Based on progress (delay or gain) the project schedule's feasibility is monitored, hence the two sided arrow between the project schedule and the detailed schedule in Figure 3. When needed, project management exerts more pressure on the operational layer or allocates more resources to gain time (Burke, 2003; Martinelli & Milosevic, 2015; Nagata, Manginelli, Lowe, & Trauner, 2018a; Nicholas & Steyn, 2017).

Many researchers consider the project schedule and the detailed schedule a stand-alone product (Pellerin & Perrier, 2018). This is not appropriate for large complex projects that are dynamic (Blom et al., 2016; Pellerin & Perrier, 2018). The next paragraph describes how traditional scheduling has been adapted to cope with complex projects and changing schedules.

2.1.1 State of the art of traditional scheduling

The Critical Path Method (CPM) remains one of the most used scheduling methods. (Burke, 2003; Dallasega et al., 2018; Nicholas & Steyn, 2012). CPM is a method that summarize different activities to come from a Work Breakdown Structure to the critical path in a schedule. This critical path describes the activities in the detailed schedule that have a direct effect on meeting a milestone from the project schedule. The most used tool to visualize traditional schedules are Gantt charts (Dallasega et al., 2018), see Figure 4.

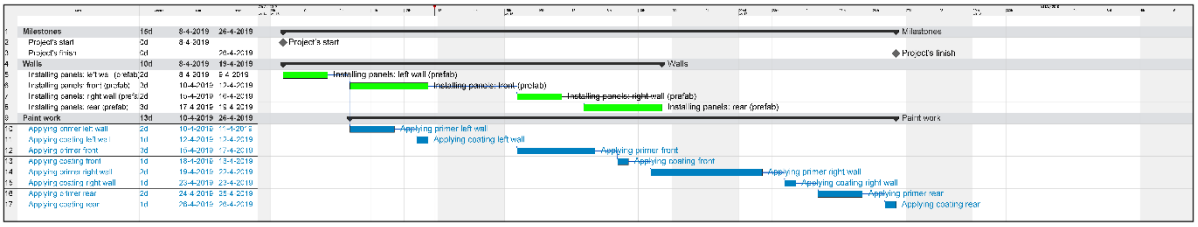


Figure 4 Example of a Gantt chart (own image)

Traditional scheduling has improved by implementing new estimation and control tools. These new tools were introduced to cope with changes and unrealistic estimations (Dallasega et al., 2018; Pellerin & Perrier, 2018). A combination of tools to cope with unrealistic estimations are the Rough-Cut Capacity Planning (RCCP) and Resource-Constrained Project Schedules (RCPS) (Pellerin & Perrier, 2018). This combination uses a rolling scheduling window which advances over time. The RCCP is used to schedule important milestones and dates approximately six months in advance periodically. These milestones are divided in work packages that can be scheduled within a weekly timeframe. At the moment these work packages are scheduled using RCPS there is enough knowledge about the project to schedule realistically, including the input of the concerned (sub)contractors (Pellerin & Perrier, 2018). The basic principle here is that the schedule horizon decreases as the level of detail increases (Pellerin & Perrier, 2018; Ponce de Leon, 2011).

To cope with the control of the traditional CPM schedules there are several tools to measure the progress and effectivity of the work force (Ellis, 2016b; Nagata et al., 2018a). Most of these tools represent some sort of measure of productivity related to the desired delivered work. Examples are Earned Value Management (Vanhoucke, 2012), burn charts or slippage charts (Nagata et al., 2018a). These tools enable project managers to make decisions to cope with gain or delays. Even though these tools have improved traditional scheduling, it remains inappropriate for contemporary large construction projects according to a review on scheduling in the construction sector, because it is unable to cope with the many changes that are certainly to occur (Collyer, Warren, Hemsley, & Stevens, 2010; Dallasega et al., 2018).

Another improvement for traditional scheduling is the use of Building Information Modelling (BIM). BIM facilitates the use of different software packages in one project. This enables project organizations to choose the package which is most efficient for their project (Liu, Al-Hussein, & Lu, 2015). BIM also enables the use of large amounts of data which can be used for analyses and estimations (Liu et al., 2015). In practice BIM is used to get more insight in the building process by using 3D models. However, the full potential of linking 3D models and components to scheduling optimization is not exploited yet. The potential is obvious and can be expected to gain ground in the future scheduling practice (Liu et al., 2015). Not only tools have been improved over time to cope with the increasing complexity of construction projects. The next Section explains the principles of short-cyclic scheduling.

2.2 Short-cyclic scheduling

The principle of short-cyclic scheduling is letting the performers of tasks schedule their own tasks (H. G. Ballard, 2000; Conforto, Salum, Amaral, Da Silva, & De Almeida, 2014; Ellis, 2016a). Progress on task level is maintained by same performers and frequently communicated towards project management who monitor the overall project's progress (Aziz & Hafez, 2013; H. G. Ballard, 2000; Owen et al., 2006). Short-cyclic scheduling is a part of larger methodologies which are called Agile or Lean. These methodologies use iterative production methods to minimize waste and produce

quick costumer value (Conforto et al., 2016). Figure 5 depicts the basic difference between traditional scheduling, which is discussed in the previous Section and short-cyclic scheduling which is discussed below.

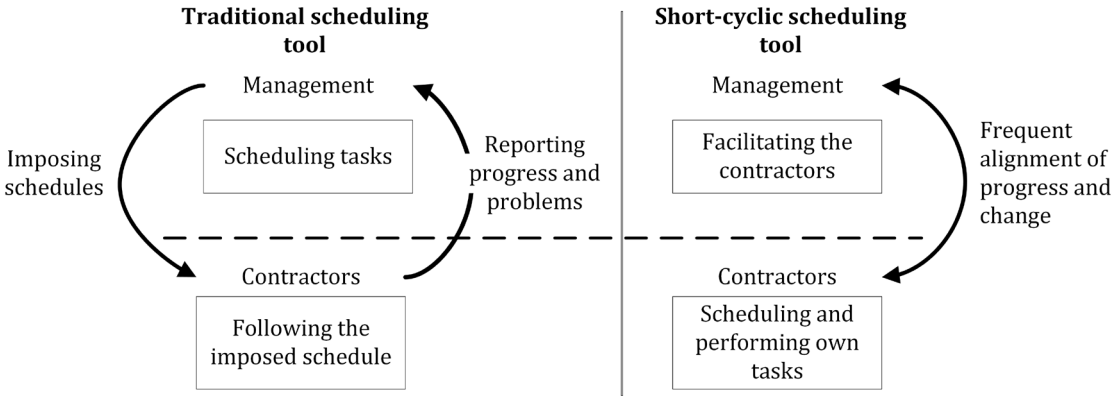


Figure 5 Difference between traditional and non-traditional scheduling tools (H. G. Ballard, 2000)

The management layer that is referred to in Figure 5 consists of the project manager, his auxiliary managers, such as a technical manager and a contract manager and scope leaders or managers (H. G. Ballard, 2000; Nicholas & Steyn, 2017; Owen & Koskela, 2006b). The contractors are considered the performing part of the organization. The persons in the organization that schedule the tasks are the foremen that are allocated by the contractors (H. G. Ballard, 2000; Owen & Koskela, 2006a). The big difference between the two approaches are the responsibilities of both parts of the organization. Traditionally the contractors are responsible for following orders and addressing problems, but they do not have limited room to decide on their own activities (Nicholas & Steyn, 2017). Management takes all the decisions. Using short-cyclic scheduling gives the responsibility to the teams on the construction site, within the boundaries of the project's milestones. Managers must take a more facilitating role to provide enough information and decisions to enable the contractors to perform their tasks. The other way around, the contractors must ask for information and decisions and must detect and communicate problems in an early stage (H. G. Ballard, 2000). The next Section discusses the state-of-the art of short-cyclic scheduling in the construction sector.

2.3 State-of-the art of short-cyclic scheduling in the construction sector

The success of Lean management in the manufacturing industry triggered the introduction of Lean tools in the construction industry (Dallasega et al., 2018). Lean tools that are used in the construction sector are referred to as Lean Construction. The purpose of introducing Lean Construction into construction project is to improve the project's performance for the customer. This is done by clarifying the delivery process, design, construction and controlling the entire project's life-cycle (Aziz & Hafez, 2013).

However, Lean Construction has limitations for coping with complex project environments (Blom et al., 2016). Therefore more attention has come for Agile construction methods to be added to the practice of Lean Construction as a complementary tool set (Blom et al., 2016). This attention for Agile tools originates from the self-organizing character of such tools, which is absent in the traditional scheduling approach (Blom et al., 2016), this difference is explained in the previous section related to Figure 6.

There is no clear evidence for the successful implementation of Agile tools during the realization phase of construction projects yet (Blom et al., 2016; Owen et al., 2006; Streule, Miserini, Bartlomé, Klippel, & De Soto, 2016). Scholars do believe that some Agile tools can be used during the realization phase (Owen et al., 2006; Streule et al., 2016). Especially day-to-day alignment which is a characteristic of Agile tools can be used on construction sites for progress updates, day-to-day scheduling and problem solving (Owen et al., 2006; Streule et al., 2016; Sutherland, 2009)

The Last Planner System™ (LPS) is the most obvious short-cyclic scheduling approach, which is widely adopted by the construction sector (Aziz & Hafez, 2013; Dallasega et al., 2018; Habchi, Cherradi, & Soulhi, 2016). LPS is used to enable collaboration between different disciplines on the construction site and "create a reliable work flow" (H. G. Ballard, 2000; Dallasega et al., 2018). However, there are little reports of the exclusive application of Agile tools in the construction sector (Blom et al., 2016; Serrador & Pinto, 2015). The state-of-the-art for short-cyclic scheduling consists of several implementations of LPS, as discussed in Paragraph 2.3.1.

2.3.1 Key principles of Last Planner System™

LPS is used for project scheduling, monitoring and control focused on improving the project's delivery process (H. G. Ballard, 2000; Habchi et al., 2016). Ballard (2000) refers to this delivery process as "workflow". LPS uses Lean principles to achieve a continuously improving work flow focused on collaboration within the entire organization (H. G. Ballard, 2000; Dallasega et al., 2018; Habchi et al., 2016). LPS uses tools to ensure proactive problem solving as opposed to the traditional reactive problem solving (Dallasega et al., 2018; Habchi et al., 2016).

LPS is unique for involving the "last planners" into the scheduling process. Last planners are the operational layer of the organization consisting of foremen, work planners and site managers. The last planners are responsible for scheduling their own work on a high level of detail, which creates more project involvement for operational teams (H. G. Ballard, 2000; Habchi et al., 2016). The process of establishing a schedule is depicted in Figure 6

.

The Master schedule or the contract schedule is processed to a milestone schedule in every project. This is regardless of the chosen scheduling technique. The master schedule consists of the most important project milestones which are connected to the contract. These are often linked to incentives or payment moments for the contractors (H. G. Ballard, 2000; Nicholas & Steyn, 2017).

These master schedules can be broken down in **phase schedules** which contain the major internal project's milestones (H. G. Ballard, 2000). Examples of phases are, building the hull or applying the furniture. The phases are not as detailed as work packages that can be broken down into tasks (H. G. Ballard, 2000; Nicholas & Steyn, 2017).

The next step, making a **lookahead plan** is necessary for rescheduling. Rescheduling can be necessary in case of changes or mistakes. The lookahead schedule is also used to be able to make week-to-week schedules (Dave, Hämäläinen, & Koskela, 2015; Iqbal, 2015). The lookahead schedule is made on a work package level of detail.

The Master schedule, the phase schedules and lookahead plans can all be made using traditional tools, such as Gantt charts from MS Projects using a Critical Path Method. These schedules are not made by the "last planners" but by management in cooperation with the client and (sub)contractors (H. G. Ballard, 2000; Dallasega et al., 2018; Iqbal, 2015; Nicholas & Steyn, 2012).

The bottom part of Figure 6 is comparable to the short-cyclic tools used in Lean methodologies and Agile methodologies such as Sprints or Standups with Sprint boards or Lean boards (Iqbal,

2015; Streule et al., 2016). The **weekly work plan** is made by the last planners. Progress is tracked by the coordinator assigned by management to assess the scheduled work and the reasons for delays, extra costs or quality issues. **This progress tracking** is used to quickly **learn** how to solve recurrent problems and give **feedback** to the foremen. This feedback back to the construction site can be rescheduling or proposing different production techniques (H. G. Ballard, 2000; Dave et al., 2015; Iqbal, 2015).

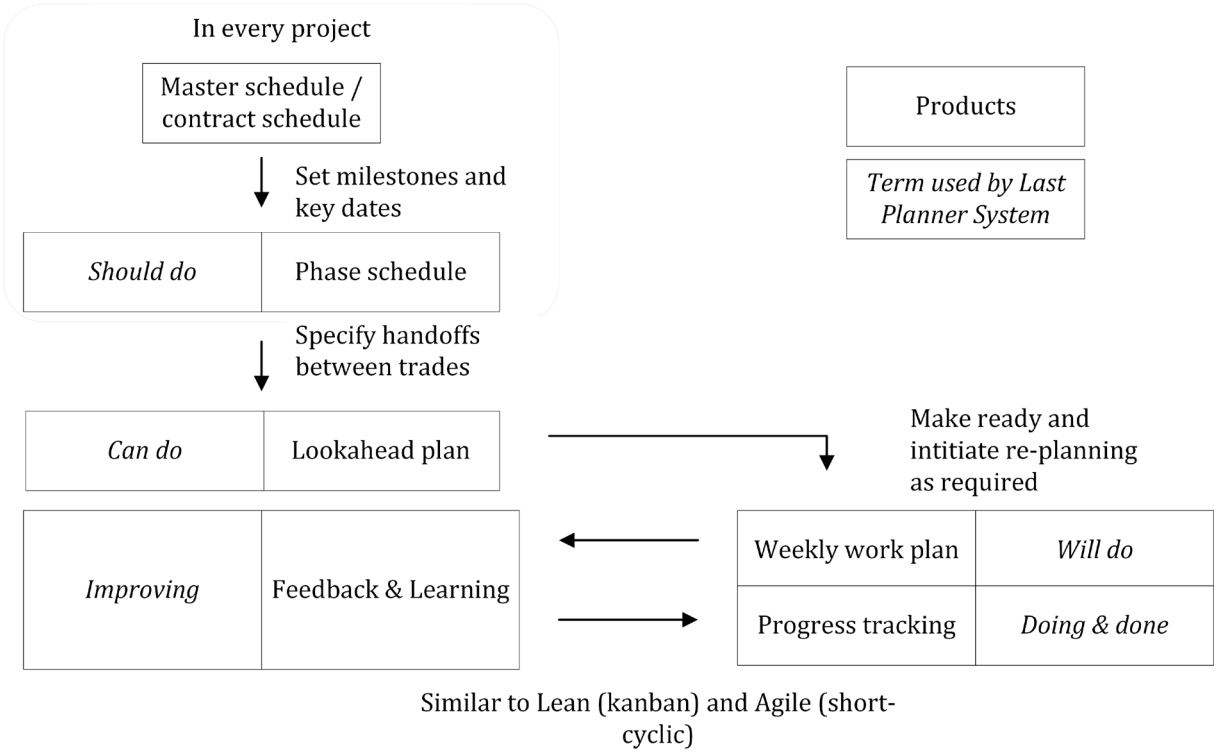


Figure 6 Last Planner System (H. G. Ballard, 2000; Iqbal, 2015)

2.3.2 Improving Last Planner System with Takt-Time-Planning

Since the introduction of Last Planner in 2000 some limitations were encountered in practice (Dallasega et al., 2018). These limitations were overcome by improving some of the processes in LPS (Dallasega et al., 2018). The most obvious improvement that was found in literature is adding Takt-Time Planning to LPS (Dallasega et al., 2018; Frandson, Berghede, & Tommelein, 2014). The monitoring of the construction pace can be achieved by implementing Takt-Time-Planning (Bølviken, Aslesen, Kalsaas, & Koskela, 2017; Frandson et al., 2014; Owen & Koskela, 2006a). Takt-Time-Planning is introduced to construction to create "flow" (Liker & Meier, 2006).

The principle of Takt-Time-Planning is dividing the work into batches of non-recurrent and recurrent works (Dallasega et al., 2018). The batches are completed with the same continuous rate (Takt in German) (Frandson et al., 2014). The Takt-Time is the amount of time all the recurrent elements are to take divided by the number of elements. If the completion of the recurrent items is quicker than the takt-time than progress goes faster than planned and vise-versa (Gao & Low, 2014).

In construction, the number of recurrent batches is less common. Therefore, so called takt-zones can be determined for batches of nonrepeating works, that are in sequence. Those takt-zones have a similar duration. The project's flow can be determined by assessing the difference

between the demanded rate and the actual rate for finishing the batches (Dallasega et al., 2018; Frandson et al., 2014).

2.3.3 Improving Last Planner System with Location Based Management System

LPS in construction mainly introduces procedures to cope with the more social aspects of project management. LPS focuses on collaboration between the project's organizations management layers (G. Ballard, Pesonen, & Seppänen, 2010). The scheduling process could be improved by a quantitative tool that helps making more reliable schedules (G. Ballard et al., 2010; Dallasega et al., 2018).

Scheduling with tools from the Location Based Management System (LBMS) helps making more reliable estimations of tasks durations and predictions of scheduling bottlenecks in the future (G. Ballard et al., 2010). This done by defining all the work that has to be done on a location before a team can move on to the next location. The exact quantity of works is established for each location using historical data and updated information from the continuous feedback on the different schedule levels (G. Ballard et al., 2010). The update of the forecasts is done based on the numerical information about the scheduled tasks and the actual progress (G. Ballard et al., 2010). The LBMS is especially useful for scheduling.

Based on research that has been done at US contractors by Ballard et al. (2010) it seems that LBMS is especially useful for scheduling the Phase and Lookahead plans, see Figure 6. The US contractors stress that the interaction between team members during meetings that focus on the day-to-day activities are essential. Putting this in a quantitative system that models the outcomes of these meetings would reduce the necessary communication, which is considered undesirable. Besides. The US contractors perceive scheduling in a system and scheduling during meetings concerning the same tasks a double activity (G. Ballard et al., 2010).

2.3.4 Lean and Agile tools used on the construction site by last planners

Kanban is used as a visualization tool for scheduling (Dallasega et al., 2018; Gao & Low, 2014). This is similar to the Sprint board used by Scrum methodology (Iqbal, 2015). The procedure for using these boards is to have frequent standups with multidisciplinary teams to add tasks to the schedule, monitor progress and discuss problems and solutions for finishing the most important tasks first (Owen & Koskela, 2006a; Streule et al., 2016).

The steps that are taken by the last planners is depicted on the bottom grey part of Figure 6. The foremen hold daily standups with their workers to discuss the weekly schedule and the day-to-day tasks. They make sure everything is prepared, with the help of the work planners. They measure progress and evaluate this with the weekly schedules using the standups at the Kanban or Sprint board or other visualization (Iqbal, 2015).

2.3.5 Conclusion state-of-the-art short-cyclic scheduling

For now, Last Planner System is the mostly used scheduling process that contains short-cyclic elements. Especially, the last planners that schedule their day-to-day activities use tools that are like the short-cyclic principles of both Lean and Agile methodologies. LPS has improved some of the aspects of project complexity that traditional project management could not overcome. However, challenges for the implementation of LPS remain (Iqbal, 2015). The next Section explains what theoretical conditions a project should comply with to successfully implement short-cyclic scheduling.

2.4 Theoretical conditions required for short-cyclic scheduling

Habchi et al. (2016) investigated the implementation of Last Planner System. They formulated 12 different challenges which were used as the starting point for investigating the literature that describes the most important theoretical conditions for implementing short-cyclic scheduling. Clustering the 12 challenges of Habchi et al. (2016) is depicted in Figure 15 in Appendix A. The found theoretical conditions are depicted in Figure 7. Paragraph 2.4.1 discusses the literature found on effective collaboration related to short-cyclic scheduling. Paragraph 2.4.2 explains the appropriate implementation of short-cyclic scheduling. Paragraph 2.4.3 describes literature on the effective communication between organization levels as a condition for short-cyclic scheduling. Paragraph 2.4.4 explains how the qualifications and competences of the project members relate to the implementation of short-cyclic scheduling. Paragraph 2.4.5 discusses literature on the appropriate culture and attitude towards short-cyclic scheduling.

The framework that is used for the case studies in Chapters 3 and 4 is presented in Table 6.

Figure 7 The initial theoretical conditions used for literature study

2.4.1 Effective collaboration

Collaboration within teams and between management layers are an important aspect of project management in general (Nicholas & Steyn, 2017). A responsibility of the management is to create a sense of commitment and responsibility towards the project (Nicholas & Steyn, 2017). Creating a common goal, which is known for all project members enhances collaboration and leads to more successful projects (Nicholas & Steyn, 2017). The role of management and the team chemistry appeared to be a big challenge for the implementation of Last Planner System (Habchi et al., 2016). This inhibits the appropriate implementation of LPS, because it's main function is a "collaborative planning process" (Habchi et al., 2016).

Based on research done on the challenges and success factors for large agile transformations a different point of view comes to light. The success factors related to collaboration and leadership are management support, leadership and team autonomy (Dikert, Paasivaara, & Lassenius, 2016). This emphasizes the management role in agile transformations to influence project members' behavior (Dikert et al., 2016). Management support should be constantly visible and adequate by educating management on agile (Dikert et al., 2016). Leadership is formulated as introducing managers that are specialized in change and transforming to agile. These "new" leaders should not be influenced by past experience in the projects and accepted by the current project organization (Dikert et al., 2016). Team autonomy focuses on giving the operational teams freedom of self-organization. This requires the management to refrain from a certain degree of imposing (Dikert et al., 2016).

The difficulty of achieving effective collaboration with LPS is a recurrent problem (Dave et al., 2015). An inhibiting factor for this effective collaboration is having ineffective meetings.

Teams spend too much time on information collection to be able to schedule appropriately (Ann, Brady, Tzortopoulos, & Rooke, 2011; Dave et al., 2015). This shows an important role for management to create the basic conditions for effective collaboration, including commitment, leadership, team mandate (self-organization) and information provision (Dave et al., 2015; Dikert et al., 2016). Visualizing the work that has to be done on the construction site could enhance the collaboration between construction workers (Ann et al., 2011). Visualizing the work and day-to-day alignment with the relevant parties enhances the commitment to the project and transparency between the construction workers (Ann et al., 2011)

2.4.2 Appropriate use of tools and procedures

Nicholas and Steyn (2017) describe the tendency of organizations to change their procedures when project conditions change. This leads to an increasing bureaucracy and unclear expectations for project members. Changing procedures and increasing bureaucracy influence the project performance negatively when applied excessively (Nicholas & Steyn, 2017).

One of the success factors for large-scale agile transformations is the customization of the agile approach. The transformation should be mirrored to the known way of working. This makes the implementation comprehensible for project members that are new to agile tools. The customization should be done with care and be limited to a "single approach" (Dikert et al., 2016). Integrating the new method in the entire organization and ensuring a single approach is a big challenge for agile transformations (Dikert et al., 2016). An option to ensure the appropriate implementation is piloting the new approach. This gains acceptance and insight in what the aimed change entails (Dikert et al., 2016).

Another aspect of for the appropriate implementation of short-cyclic tools is full implementation. A large challenge for the appropriate implementation of Last Planner System in construction projects was the full implementation (Dave et al., 2015). The appropriate implementation of Agile tools in the construction industry has especially been acknowledged for the design phase of construction projects (Blom et al., 2016; Owen & Koskela, 2006a). Implementing Agile tools in the realization phase is considered difficult and not fully discovered yet (Blom et al., 2016; Owen & Koskela, 2006a). This lack of guidelines from theory has also been identified as one of the challenges for implementing Agile in other sectors (Dikert et al., 2016).

The preparation should be done adequately to appropriately implement Last Planner in construction projects. This entails clear role and responsibility definitions. Also, decision making processes are defined during the preparation. These processes must prevent authoritative decisions, but ensure transparent process-based decisions (Ann et al., 2011). This preparation must ensure the full implementation of LPS, clearly for all involved project members (Ann et al., 2011), which is also acknowledged by Dave et al. (2015).

2.4.3 Effective communication between organization levels

Smooth information flows are a prerequisite for an effective scheduling process (Nicholas & Steyn, 2017). Without these smooth information flows decision making and information sharing is too slow, which delays the project (Nicholas & Steyn, 2017). The link between detailed and high-level plans is a basic condition for Last Planner System in construction projects. Sharing incomplete information top-down and problems bottom up is essential for a good implementation of LPS, but difficult to achieve (Ann et al., 2011; Dave et al., 2015).

The links between the scheduling levels are the essence of Last Planner. Discussing the higher level schedule with the project members responsible for the level below ensures information sharing and commitment for decisions (H. G. Ballard, 2000; Habchi et al., 2016).

Agile teams can teams prioritize their own goals over the organization's goals. Also, the response of the larger organization can be slower than the agility of the agile teams. So, when the agile teams need new information quickly based on day to day changes, this information can take a week to gather by the larger organization. This "slows down" the agile team. When working with different agile teams the technical interfaces can form a problem as well. The teams are working on different aspects of the same project. If the direction of these two teams diverge, this can lead to problems (Dikert et al., 2016).

A challenge that is also found in traditional projects is the increase in bureaucracy (Habchi et al., 2016; Nicholas & Steyn, 2017). The paper work and the meetings increase uncontrollably when the communication between the organization levels is not managed appropriately (Habchi et al., 2016; Nicholas & Steyn, 2017). This leads to more resources and time consumed by ineffective communication processes (Habchi et al., 2016).

2.4.4 Appropriate qualifications and competences

The success factors found by Dikert et al. (2016) that relate to the quality and competences for large-scale agile transformations are education of management on agile, provide training on agile methods, coach teams as they learn by doing and Include persons with agile experience. The challenges found in the same research show that persons have difficulty adapting to the new situation (Dikert et al., 2016). Skilled change managers and project members with previous agile experience can help recalibrating the organization when focus and clarity is lost (Dikert et al., 2016). Appropriate training is considered a critical success factor for implementing LPS as well (Ann et al., 2011; Cerveró-Romero, Napolitano, Reyes, & Teran, 2013).

Workforce competence has been introduced as an impediment the introduction of Agile tools into construction projects during the realization phase by Owen et al. (2006). The construction sector is characterized by a lowly educated workforce, not suitable for the more professional set of competences required for Agile tools (Owen et al., 2006). Another workforce related problem originates from the use of different external consultants and subcontractors. Each consultants and subcontractors have different backgrounds. Each party interprets and uses LPS differently. A lack of standardized textbooks for LPS implementations does not help tackling this problem shortly. Also companies that provide trainings and implementation guidance apply different interpretations of LPS (Dave et al., 2015).

The problems with the competences found in the literature above especially relate to the preparation of the project for short-cyclic scheduling. Only Dikert et al. (2016) have considered the transformation in current projects but stress the same issues with competences and qualifications. They propose introducing the right people into the project to cope with the knowledge gap on appropriate implementation.

2.4.5 Appropriate culture and attitude

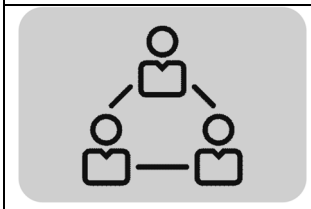
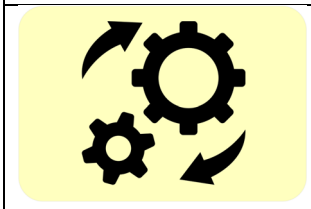
The construction sector is a traditionally conservative sector (Blom et al., 2016). Lack of commitment from management and the workforce and the resistance to change are challenges for the implementation of LPS, see Figure 15, Appendix A (Habchi et al., 2016). This resistance to change has also been observed in large-scale Agile transformations (Dikert et al., 2016).

Besides a lack of commitment, users had a negative attitude towards LPS (Habchi et al., 2016). Top management commitment to LPS is a critical success factor for implementation (Ann et al., 2011). Commitment and alignment towards the Agile values and change are success factors for large-scale Agile transformations (Dikert et al., 2016). Especially preventing managers to revert to old habits is important for Agile implementation. Behavior such as micromanaging,

remaining bureaucratic, keeping the traditional waterfall mode and remaining islands within the organization inhibit the successful introduction of agile (Dikert et al., 2016; Habchi et al., 2016).

2.5 Summary used framework for case studies

Table 6 Summarized descriptions of the theoretical conditions

Theoretical condition	Summarized description
 Effective collaboration	Effective collaboration relates to horizontal relations. It relates to collaboration between the project's managers and their counterparts from the client and external parties. Effective collaboration between scope managers, foremen and work planners are necessary for an effective implementation of short-cyclic scheduling.
 Appropriate use of tools and procedures	The appropriate use of tools and procedures relates to the ability to make decisions based on the right information. Complete implementation of chosen tools is considered an important factor to determine a project's appropriateness. Other aspects are division of responsibilities and roles, which need to be clear and respected. Appropriate use of tools means using uniform procedures and the prevention of coexisting procedures.
 Effective communication between organization levels	Effective communication between organization levels is a condition to ensure the project's goals. All organization levels should work on the most important tasks for the project. This entails safeguarding links between different scheduling levels. Another aspect is bureaucracy. Projects tend to become bureaucratic, which inhibits smooth vertical information flows.
 Appropriate qualifications and competences	The appropriate qualifications and competences relate to the project members. A degree of training and coaching is necessary to implement short-cyclic scheduling. The education level is lower in the operational level of construction organizations compared to IT and manufacturing projects. Operational layers in construction projects therefore need additional training and coaching to be prepared for short-cyclic scheduling.
 Appropriate culture and attitude	A certain degree of professionalism is required to be able to adapt to new tools. Resistance and a negative attitude towards change can be expected in any project that introduces new tools. A project organization must be able to cope with this resistance and must create commitment towards short-cyclic scheduling.

3 Case 1 Urban infrastructure project

The first case is a big reconstruction project of infrastructure near a Dutch city's central railway station which is executed for its municipality. The project was initiated to create a resilient infrastructure system to cope with an increase in tourism the coming years. Most of the tourists will arrive from the central station and move towards the touristic area using the new trams and roads.

In the first section the case context is described. This entails details about the project and the chosen short-cyclic scheduling tool. The case findings and discussion on the project's appropriateness are presented in Section 3.2. The last section summarizes the findings and appropriateness.

3.1 Case context and used scheduling tool

The entire project scope consists of several subprojects that are being executed over a timespan of five years. these subprojects consist of different parts of infrastructure around the central station. The subprojects are an underground cycling garage, new tram rails and new roadworks.

This research' focal scope consists of reorganizing the roadworks and replacing all the old subsurface infrastructure on a stretch of road next to hotels on the opposite site of the central train station. The subsurface infrastructure that is replaced consists of water distribution and transport pipes, sewer pipes and drains, gas pipes and power lines.

The observation period is three months from September until the end of December. This entails a major milestone concerning the roadworks. The deadline for this milestone is "before Christmas". This milestone is agreed upon with the client to facilitate access to the city's shopping center during Christmas time. The municipality expects many tourists to come to the city for their Christmas holidays. The site layout is depicted in Figure 8

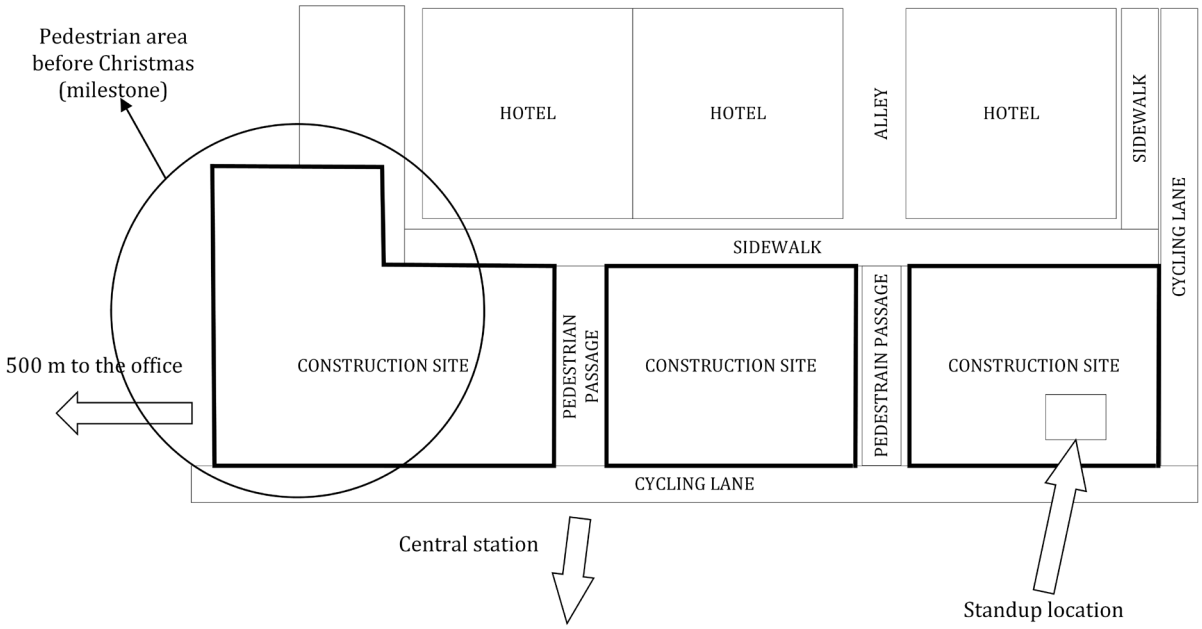


Figure 8 Construction site layout case 1

The organization consists of a main contractor, subcontractors and a consultancy company, which is referred to as: Consultant. The Consultant and the main contractor have formed a consortium. The main contractor and The Consultant assigned people to the management team. The management team is responsible for interaction with the client, safeguarding quality, complying with the requirements of the contract, mitigating nuisance for the surrounding stakeholders and ensuring project progress. The case project's organization structure is depicted in Figure 9.

Every scope or sub-project has a project leader. This project leader is responsible for the realization of his or her scope and answers to the management team. The project leader oversees an operational team that consists of foremen, work planners and coordinators originating from subcontractors, the main contractor and the Consultant.

Figure 9 depicts the participants of short-cyclic sessions. The subsurface foreman is assigned by the subcontractor that is responsible for the subsurface works. The process coordinator for subsurface works is assigned by the Consultant. The subsurface coordinator of work preparation is assigned by the main contractor. The foreman and the work planner of the surface works originate from the same surface contractor.

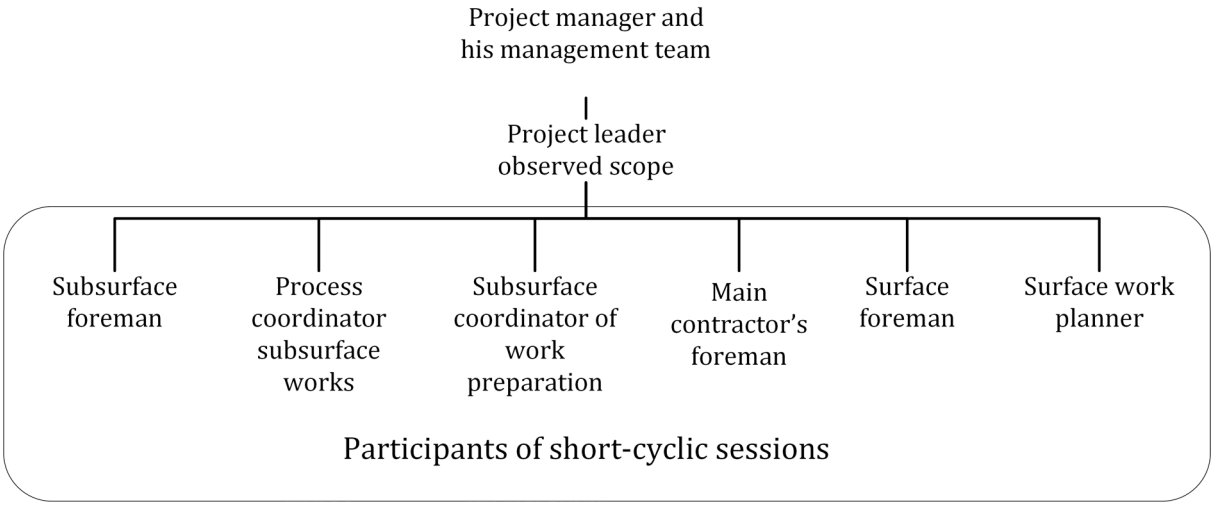


Figure 9 Case 1 project's organization structure

Figure 10 depicts the project's scheduling process. The highest schedule, the milestone schedule is linked to the contract with the client. Adaptations in this schedule are done in consent with the client and the management team (A and B). The management team meets every two weeks, the meeting rate with the client is unknown. Progress of the milestones is monitored with software called Microsoft Projects. This software is a tool that uses traditional Gantt charts to depict schedules. It can calculate the critical tasks. The information derived from the MS projects schedule is used as input for the weekly progress and problems meetings with the operational and the management team. These meetings address top-down changes in the schedule and bottom up problems that need solving by the scope leader or the management team.

The standups from Figure 10 are the focal activities of this research. The standups are the meetings with the operational team that is depicted in Figure 9. The standups take on average 45 minutes and are held twice a week in a construction shack on the construction site with a clear view on the works that are discussed. It is important to note that this is a different location than where the rest of the project organization is located. The organization's office is located 500

meters from the construction site, with no clear view on the works. During the standups the two subcontractors and the foreman of the main contractor schedule their own tasks.

A standup is led by the coordinator of the subsurface works. He asks the participants to stick sticky notes on a sheet of paper on the wall. Each sheet of paper is a grid with squares with the size of the sticky notes. Each note represents a day and each sheet represents a week (7 columns). The standups have a lookahead window of 5 weeks, therefore 5 sheets are pinned to the wall containing sticky notes of all the participants. The participants write the name of the tasks on a sticky note and place it on the square that represents the starting date. Next, the participants add as many sticky notes as the amount of days the task is expected to take.

During each standup the tasks' progress that is represented on the sheets is discussed and adapted if need be. New tasks are added and the impact of the schedule's change on the other participants' tasks is discussed. When all participants agree on the schedule, one of the participants takes a picture of the new schedule. This picture is processed into the MS projects software which automatically updates the schedules on all levels of detail, see Figure 10. The chosen scheduling tool is similar to Last Planner System that is described in Section 2.3.

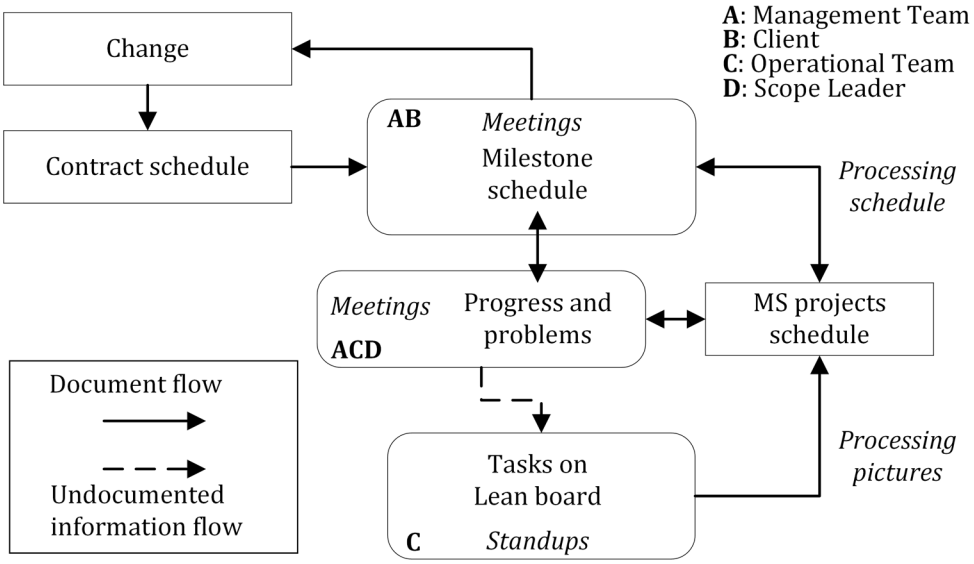


Figure 10 Scheduling process case 1 during observation period

3.2 Findings case 1 Urban infrastructure project

This Section presents the case findings from the first case using the framework that is described in Table 6. This Section is divided according to that framework, which consists of four theoretical conditions. Each Paragraph presents the case findings (C1F#) from observations and interviews related to the theoretical conditions. Each Paragraph is concluded with a discussion on the appropriateness of the case related to the framework.

Critical project factors (CPF) are formulated to generalize the findings into factors that influence the appropriateness, nonspecific for the case. The found critical project factors from case 1 and 2 are used in the Synthesis Chapter 5 to validate the applicability of the factors to evaluate a project's appropriateness for short-cyclic scheduling and to compare these factors with the established knowledge from the literature study.

The findings can be found in the following order:

3.2.1 Effective collaboration

C1F1: Lacking management support from subcontractors

C1F3: Freedom to make decisions
C1F9: Ineffective discussions

3.2.2 Appropriate use of tools and procedures

C1F5: Little preparation time and slow client's decision making
C1F6: Having meetings on the construction site
C1F7: Important role of the coordinator

3.2.3 Effective communication between organization layers

C1F2: Management support from project's management team
C1F4: No documented link between progress meetings and standups
C1F12: Common milestones

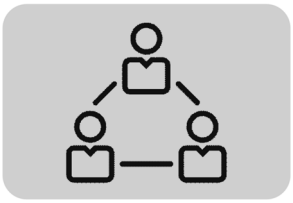
3.2.4 Appropriate qualifications and competences

C1F8: No observed training for short-cyclic scheduling

3.2.5 Appropriate culture and attitude

C1F10: Strategic behavior during standups
C1F11: Settling differences before standups
C1F13: Reverting to old habits

3.2.1 Effective collaboration



C1F1 Lacking management support from subcontractors

The surface contractor is highly dependent on the subsurface works. The inevitable sequence of subsurface works and roadworks demands an adaptive attitude from the subsurface subcontractor when the subsurface works experience change. The subsurface work planner and foreman can adapt their plans during the standups. However, in some cases this requires extra work force or material to solve or prevent future problems.

According to the work planner and the foreman this is often not received well by their managers. The subcontractor's managers make estimates for assigning work force, money and durations based on incomplete information. The work planner says that important factors such as the construction site's size are not considered, which leads to a discrepancy of expectations. The foreman indicates that he experiences stress for losing his position when he addresses problems to his management.

It was observed that the surface contractor experienced pressure. Especially when subsurface works were delayed, the surface foreman tended to react obstinately. The foreman refrained from actively participating in the standup and made remarks such as; "it does not matter what I say, because everything changes anyways".

C1F3 Freedom to make decisions

Many activities such as replacing gas lines or waterpipes require help of the utility parties that own the infrastructure. The subsurface contractor communicates directly with a representative to align activities, such as closing valves or cutting of power. One of the milestones was finishing a part of the roadworks before Christmas. This was dependent on the progress on the waterpipe below. In order to complete this waterpipe, the water utility party had to close some valves on different locations in the city.

The utility party was not able to give a definitive answer about when these valves were going to be closed. Every standup the status of the information about the valves was discussed. Management was informed about the problem, but the standup participants had the freedom to decide what actions were necessary to complete the milestone. No solution was imposed.

Ultimately the participants reached an agreement on a date to make the definitive choice between closing the hole without the new water pipe or finishing the pipe.

This forced the subsurface contractor to gain all the necessary information from the utility party and to ask help at the project's management. In other words, horizontal collaboration between the utility parties and the subsurface subcontractor was reached. This agreement gave the surface contractor the security that he could finish his work in time for the milestone. The other milestones during the observation period were met as well.

C1F9 Ineffective discussions

Many topics were discussed multiple times. Both during the meeting itself and between meetings. No one took notes of agreements or discussions, which can be an explanation for the repeating discussions. The participants also had difficulty with accepting the input of the main contractor's foreman. Often the main contractor's foreman challenged the statements of the subcontractors. This led to a certain degree of irritation, often because the topic that was being addressed by the main contractor's foreman was not entirely relevant for that moment. However, it still led to irritated discussions. Afterwards when the topic was relevant, the discussion was repeated with the same outcome.

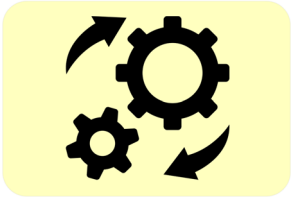
Critical project factors and appropriateness for short-cyclic scheduling

From the findings C1F1 and C1F3 two critical project factors (CPF) can be derived: CPF1 *Support by external management* and CPF2 *Support by internal management*. The theoretical condition Effective collaboration that is explained in Paragraph 2.4.1 stresses the importance of horizontal collaboration. This explains why the freedom of decision-making works in terms of the freedom to make decisions, without much management interference. If the participants did not have this freedom, they would have not aligned this much with the utility party.

The appropriateness of this project regarding the theoretical condition management support is not perfect. Even though the internal organization supports the short-cyclic scheduling process and decisions that are made by the participants, there is a disturbing effect caused by the subcontractors' managers. The subcontractors' management did not show understanding for the freedom of scheduling tasks during standups and took a traditional stand towards the project. This is the reason for the distinction between internal and external management support. Both these factors are considered influential on the effectivity of the collaboration during the standups.

Ineffective discussion (C1F9) did not contribute to the collaboration during the standups as well. Irritation and repetition influenced the group dynamic. However, it can be counterproductive to structure the standups more to solve this problem of ineffective discussions. The participants should also have a degree of freedom to create their own group dynamics. The critical project factor related to C1F9 is: CPF8: *Effective communication between project members.*

3.2.2 Appropriate use of tools and procedures



C1F5 Little preparation time and slow client's decision making

According to the project manager and the main contractor's company leader the project had little preparation time for making definitive designs and schedules. This has caused uncertainty about what was to be executed, especially in the beginning of the project.

Besides an unclear design, the client took much time for deciding on change. This shows that the client was not prepared to process much change quickly. However, the participants of the

standups were dependent on those decisions. This is an indication of a lacking preparation of responsibilities, also at the client.

C1F6 Having meetings on the construction site

The location of the meeting contributed to making decisions together and quickly. Some decisions required looking at the works and making measurements on the spot to discuss the feasibility of decisions. An example of a feasibility problem relates to the construction site's size. If the subsurface and surface contractors wanted to work simultaneously there was risk that the side was too small. If there were such doubts, the participants discussed these matters outside, whilst looking at the works.

According to the project manager this dynamic of solving problems on site, was the reason to implement short-cyclic scheduling. The subcontractors were indeed capable of aligning their tasks and making decisions based on changing circumstances on the construction site.

Another benefit of the standups' location is the reluctance of the foremen to leave their activities on the construction site. Often when making rounds on the construction site and during the standups the foremen said that they'd rather continue working than having meetings. It would have been difficult to motivate the foremen to attend meetings in the project's office 500 meters from the construction site.

C1F7 Important role of coordinator

The chairman of the standups was the process coordinator for subsurface works, assigned by the Consultant. He led the meetings and interfered when discussions took too long or were not about the right subject. The chairman was not responsible for any task that was performed on the construction side, I.E. he did not own tasks on the sheets.
As introduced with finding C1F4 there was no list of prioritized tasks. The coordinator played an important role in trying to achieve a complete schedule on the sheets. He asked all the participants if they had tasks to add or change and repeated this question multiple times during the standups. He was aware of all the important tasks to meet the milestones. He could therefore detect missing tasks and ask the subcontractors or contractor to add them.

The attitude of the participants changed every meeting. The participants actively took part in one meeting and were passive in the next. This required the coordinator to be adaptive. During the passive meeting he was actively asking people to stick their sticky notes on the sheets and in case of extreme passiveness he would do it for them. Once a task was added or changed, he repeatedly asked the other participants to evaluate the adaption related to interfaces between their own tasks. Sometimes he asked the same participant a question four times before an answer was given.

Critical project factors and appropriateness for short-cyclic scheduling

Figure 10 shows a feedback loop between standups, MS projects and meetings about progress and problems. The meetings about progress and problems are weekly meetings. The results of these meetings are not visible during the standups (C1F5) through a list or another type of document. A list of tasks from these weekly progress meetings could be compared to the weekly workplan that is applied in Last Planner System, see Paragraph 2.3.1. Since LPS is the mostly used short-cyclic tool in the construction industry and comparable with the chosen tool in this case, the missing weekly work plan indicates incomplete implementation of the tool. CPF3: *Appropriate use of procedures i*s the critical project factor that follows from the findings.

The project had difficulty making up for the lack of preparation time (C1F5). This was both visible in the procedures that coped with change and the information that was shared with the operational team.

C1F6 shows that there is added value to the location of the meetings. With meeting on another location, the participants would not have succeeded to align tasks with the same accuracy. Besides, the participants' workplace is on the construction site and they would have been reluctant to meet somewhere else. This leads to the following critical project factor: CPF5 *A tailored version of the short-cyclic scheduling tool.*

C1F7 shows that the coordinator is essential for the standup's success. The participants are not able to organize themselves in a way that a chairman is unnecessary. CPF6 is therefore: *A competent and informed coordinator.* The coordinator must have the right competences to cope with management as well as the operational team and he must be informed on the project to detect gaps in the schedules, problems with changes in the schedules and a feeling for the quality of information that is given by the participants.

Moreover, his position is part of the appropriate implementation of the short-cyclic tool in this project. The compensating role of the competent coordinator ensured collaboration and information flows between organizational layers.

3.2.3 Appropriate qualifications and competences

C1F8 No observed training for short-cyclic scheduling

Not all interviewees that participated in the standups had training for short-cyclic scheduling. Others indicated some experience, but no elaborate training and one of the participants had an actual certificate for Lean methods. None of the interviewees mentioned training or a lack of training. The lack of management support (C1F1) from the subcontractors supports observation that knowledge on short-cyclic scheduling was limited. Without management support for the tools it can be expected that the subcontractors did not provide in training.

Critical project factors and appropriateness for short-cyclic scheduling

The lack of observed training (C1F8) can also be ascribed to the absent preparation for short-cyclic scheduling (C1F5). If the project had prepared the all involved parties appropriately, they would have been trained in the short-cyclic tool that is applied. Therefore, C1F8 is also translated in the CPF4 *Appropriate preparation for short-cyclic scheduling*

The project is not considered appropriate when it comes to the qualifications and competences of the project's members. The lack of training and the importance of the coordinator is a risk when the scales are tipped in the wrong direction. Especially with the lack support by external management there is a risk of not having the appropriate people for standups.

3.2.4 Appropriate culture and attitude

C1F10 Strategic behavior during standups

The subcontractors displayed several examples of strategic behavior during the standups. The first example of this behavior relates to the estimation of task durations. The subsurface contractor had the tendency to estimate more tasks than he could finish. When the schedules were reviewed over a period of three months tasks were disappearing without them being finished. This sometimes had a direct effect on the surface contractor that was not considered by the subsurface contractor.

The surface contractor estimated the tasks differently, yet still strategically. All estimated tasks took 10 to 50 percent less time than indicated on the sheets. According to the foreman of the surface contractor these strategic estimations were necessary to cope with the unpredictability of the subsurface contractor.

The main contractor's foreman and the work planner for surface works ascribe this behavior to the lack of pressure on the schedule. They say that it is better to impose some pressure or tasks to maintain pressure.

Another example of strategic behavior related to the interface between the preparation of the subsurface for the road works. The subsurface contractor did not adequately compact the sand when excavations were filled. There were strict guidelines in place to do this, but the quality of the compacted ground layers was difficult to check. However, sinking streets were the responsibility of the surface contractor. This resulted in the subsurface contractor saving time and the surface contractor taking a risk.

The surface contractor's foreman described that this behavior had harmed the trust between the contractors. He admitted that this harmed trust was a reason for not participating actively during the standups. The coordinator insisted that the surface foreman delivered his input in which he succeeded eventually. So, this dynamic had a negative influence on the trust relation but did not directly harm to the effectivity of the standups.

C1F11 Settling differences before standups

The strategic behavior that is described above related to the quality of the subsurface led to a small fight between the foremen of the subsurface and surface subcontractors. One of the foremen had left the standup angrily, without returning afterwards to finish the standup. However, during the next standup they settled their differences. They told the other participants that they had settled their differences and agreed on working together during the standups. The consensus between both foremen was that with a fight even more problems would arise, which would make the standups fruitless.

C1F13 Reverting to old habits

The foreman of the main contractor made a statement against the use of short-cyclic scheduling during the interviews. He stated that in times of pressure on the schedule, short-cyclic scheduling does not work and that the project manager or scope leader should apply pressure on the operational layer. He explained that the way to exert this pressure is to use imposed schedules. He agreed that imposing schedules is a traditional method. This indicates a lack of commitment at one of the participants.

However, when asked the other participants on how they would design the scheduling process they indicate that the current process is the way to go. They say that they would not have introduced a different scheduling tool and that the standups are very useful. Therefore, in this project the risks of reverting to old habits was relatively small, since one of the participants was negative about the short-cyclic approach. But they were also unable to explicitly point out the added value of short-cyclic scheduling.

Critical project factors and appropriateness for short-cyclic scheduling

Strategic behavior has shown to be a risk for the feasibility of short-cyclic scheduling. The participants managed to settle their differences and the coordinator managed to safeguard the milestone, but this was not without the risk of an escalation between the subcontractors. Still, it can be expected of subcontractors that are not bound by a contract between each other that they

serve their own interests. The critical project factor is therefore related limiting the strategic behavior to prevent the risk of failing short-cyclic scheduling. Again, the importance of the coordinator (CPF6) is clear to cope with the strategic behavior and the settling of differences (C1F10) was crucial for continuing with short-cyclic scheduling.

Combine limiting strategic behavior (C1F9) and settling differences (C1F10) it can be concluded that if a mutual interest for meeting the common milestone exists, short-cyclic scheduling can work. Therefore, the critical project factor is: CPF7 *Aligned interests to reach common project's goal.*

The project is not completely committed to short-cyclic scheduling, based on the strategic behavior and the risk of reversion for the main contractor's foreman. C1F13 shows that not all participants can name the benefits of short-cyclic scheduling, besides not having negative experiences. Proper preparation of the involved parties for short-cyclic scheduling can contribute to this understanding. Therefore, the critical project factor that is derived from C1F13 is CPF4 *Appropriate preparation for short-cyclic scheduling.*

3.2.5 Effective communication between organization layers

C1F2 Management support from project's management team

The project manager and technical manager were interviewed. Both persons were responsible for the progress of the observed scope. The project manager on a milestone level of detail and the technical manager on a work package level. Both managers described their dependency on the bottom-up information from the standups. They experienced an active pull of information and valued the importance of their decision-making process.

Both managers stressed the importance of their work to facilitate the operational team. By making well considered decisions, before imposing change to the operational team prevented unexpected problems. The managers also stressed their inability to schedule tasks into detail, because they lack the specific information of the works on the construction site. They indicated that the process of short-cyclic scheduling should be safeguarded to ensure commitment to the schedule, alignment and to prevent cost of failure.

Both managers were critical on using short-cyclic scheduling for schedules on lower levels of detail (work package and milestone level). Because the managers must make indications of costs, necessary resources, space, time and nuisance they require lookahead schedules for the entire project duration. This forces them to make detailed schedules, which lead to the estimation of work package and milestone durations. The project manager states contract types force project organizations to schedule traditionally.

C1F4 No documented link between progress meetings and standups

Figure 10 shows an undocumented information flow. This refers to the tasks that are put on the sheets during the standups. No clear (prioritized) list of tasks was observed. It seemed to the observer that the collective memory of all the participants was enough. Problems with this lacking list of tasks occurred concerning specialistic tasks. At some point the subsurface contractor indicated delay for finishing works on sewer drains. This delay was caused by a task that had to be executed for every drain. This task was however not visible on the sheets, which surprised the other participants. This led to a discussion about the intentions of the subsurface contractor and irritation between the participants.

The surface contractor's work planner stated during his interview that this part of project's scope was not very complex. During more complex parts of the project, tools to comprehend and know the tasks are necessary. He gave examples of using 3D models and drawings to discuss the tasks, combined with the schedule on the sheets.

The coordinator of the subsurface work preparation and the main contractor's foreman indicated a missing work package schedule with a lookahead window of three months. They both agreed on the fact that there was unclarity about the tasks that needed to be done, because a schedule in between the milestones and the tasks was not available. They both indicated that the lack of this schedule made it hard to assess when their works were done. This was supported by the surface contractor's foreman and the technical manager that stated that there was no definitive design for the works. This definitive design is necessary to assess the quality requirements of the delivered works.

C1F12 Common milestones

Towards the end of the observation period, near Christmas, the pressure on the milestone increased. Many tasks became critical for meeting the milestone, but not all tasks required full days of work. This meant that workforces could be shared between the subcontractors. More alignment between the subcontractors was observed as the pressure on the schedule increased.

The observations that support the reason for the commitment for the common milestones are twofold. First, the coordinator repeated the critical tasks for the milestone every standup. This sometimes led to adapting the tasks' order or the tasks' durations for both subcontractors. The second reason for the commitment was the start of another part of the project in the new year. Both subcontractors repeated that they had other works in the new year and that any task that was delayed related to this Christmas milestone would delay their following works.

Critical project factors and appropriateness for short-cyclic scheduling

The project is appropriate related to communicating high level decisions towards the construction site (C1F2). The managers are aware of their facilitative responsibility to provide the necessary information to the construction workers. Besides, the managers support the use of short-cyclic scheduling to use the real time information from the construction site and the constructors' experience. Summarized in a critical project factor: CPF1: *Support by internal management*.

The link between the detailed schedules and the short-cyclic sessions has not been documented (C1F4). This is inappropriate, because there is a risk that information is lost between the office and the construction site. The critical project factor for short-cyclic scheduling based on this finding is CPF3: *Appropriate use of procedures.*

The common milestones (C1F12) relate to communication of top-down goals towards the construction site. This has been done appropriately in this project. Everyone was aware of and working on the Christmas milestone. The participants all had an interest in meeting this milestone, leading to the following critical project factor; CPF7 *Aligned interests to reach common project's goal.*

3.3 Summary of findings and appropriateness for short-cyclic scheduling

Overall the project has met its milestone during the observation period. This can be perceived as proof for a successful implementation of the tool but does not fully support the appropriateness of this implementation. Still some findings challenge the appropriateness of the short-cyclic implementation in this project which are indicated with the red color in Table 7.

When referring to the framework that is used, the project does not comply with any of the theoretical conditions completely. However, still this project was successful. An explanation for this can be the common milestone and the role of the coordinator. The coordinator has compensated for the lack of participation and documentation during all the standups. The common milestone has forced the participants to work together to prevent losses that had otherwise occurred.

Table 7 The case 1 findings linked to the critical project factors

C1F#	Case 1 findings	CPF#	Critical project factors
Effective collaboration			
C1F1	Lacking management support from subcontractors	CPF1	Support by external management
		CPF4	Appropriate preparation for short-cyclic scheduling
C1F3	Freedom to make decisions	CPF2	Support by internal management
C1F9	Ineffective discussions	CPF6	A competent and informed coordinator
Appropriate use of tools and procedures			
C1F5	Little preparation time and slow client's decision making	CPF4	Appropriate preparation for short-cyclic scheduling
C1F6	Having meetings on the construction site	CPF5	A tailored version of the short-cyclic tool
C1F7	Important role of coordinator	CPF6	A competent and informed coordinator
Effective communication between organization layers			
C1F2	Management support from project's management	CPF2	Support by internal management
C1F4	No documented link between progress meetings and standups	CPF3	Appropriate use of procedures
C1F12	Common milestones	CPF7	Aligned interests to reach common project's goal
Appropriate qualifications and competences			
C1F8	No observed training for short-cyclic scheduling	CPF4	Appropriate preparation for short-cyclic scheduling
Appropriate culture and attitude			
C1F10	Strategic behavior during standups	CPF7	Aligned interests to reach common project's goal
C1F11	Settling differences before standups		
C1F13	Reverting to old habits	CPF4	Appropriate preparation for short-cyclic scheduling

The critical project factors (Table 7)can be overlapping with the CPFs found in the next case. Chapter 5 elaborates on the CPFs, which are validated by experts afterwards. The validated CPFs are combined with the insights from literature which results in a definitive list of critical project factors.

4 Case 2 Urban building project

Case 2 entails a large urban building project in a large Dutch city. A large real estate company initiated the project and is the client of the project organization that builds it. The project's goal is to transform one of the most central points in the shopping area of this city into an iconic piece of architecture. A large department store will be located here, multiple restaurants, brand stores and apartments looking out over the city.

Case 2 is a traditional project. The appropriateness of this project is assessed using the framework from Section 2.5 but no statements about the success of short-cyclic scheduling can be expected from this case. The goal of this case study is to show what findings influence the appropriateness for short-cyclic scheduling and how these can be translated to critical project factors.

Section 4.1 starts with describing the project's context and the used scheduling tool. The next Section 4.2 discusses the case findings and introduces the critical project factors based on these findings. The last Section gives a summary of the findings and the case's appropriateness for short-cyclic scheduling.

4.1 Case context and used scheduling tool

The scope of the project that is observed during a period of three months from September until the end of December consists of three parts. The residential tower, a basement and brand stores, see Figure 11. The research focuses on the scheduling of tasks that concerned the interfaces between these subprojects and progress meetings. The construction site itself is relatively small compared to the amount of work that must be performed. There is little room for storage and equipment.

The meetings were held in the monument (Figure 11). Different teams from the main contractor such as, work preparation, realization and management had their own office in the monument. Subcontractors were also assigned to their own office. During the three months of observation, renovation works were realized in the Monument by another contractor. This forced the teams and subcontractors to close their doors to heat their offices with electrical heaters.

During the observation period the largest milestone was building a large elevator for trucks in the basements. This elevator was needed to provide the supplies for all the stores and restaurants in the complex. When the observations started, there was little insight in the interfaces between the truck project and the surrounding projects, there was also the risk of delay.

The meetings that were observed concern scheduling the project's parts that encountered problems, such as interface problems between parties, capacity problems caused by the limited room on the construction site or the limited capacity of the cranes and delays.

Except for the consultant all persons in Figure 12 are employees of the main contractor. The organizational structure is hierarchical. The project leaders that are responsible for the subprojects and the project leader for work preparation are supervised by the project manager. The project manager reports to the project director and the client directly or through the project director, depending on the subject. Technical and progress related subjects are discussed between the client and the project manager directly.

The project leaders for the residential tower, the basement and the brand stores supervise their foremen and work planners. However, the work planners are also supervised by a project leader for work preparation which is under direct supervision of the project manager.

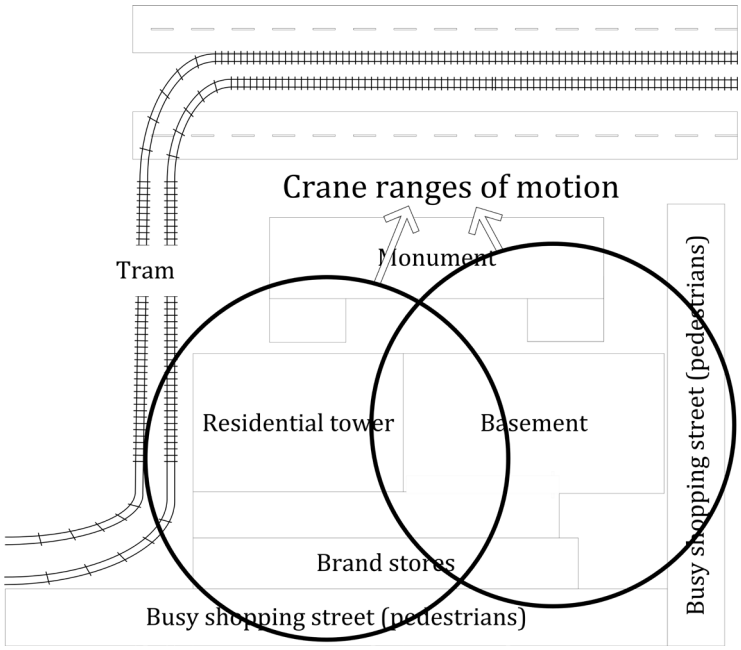


Figure 11 Site layout case 2

The Consultant and the project coordinator for technical complexities, see Figure 12 are auxiliary functions for the project manager. The project coordinator for technical complexities prepares documents, drawings and information related to the building process of technical complex parts. He does this for all subprojects. These prepared documents are presented to the client for approval.

The Consultant is responsible for making the schedules after meetings and sharing this with the relevant persons. The Consultant also maintains a 4D (3D and time) model of the project and processes the progress into this model. The Consultants advices the project manager on which meetings to set up and leads these meetings on behalf of the main contractor. The Consultant is represented by three or two persons in the project's office.

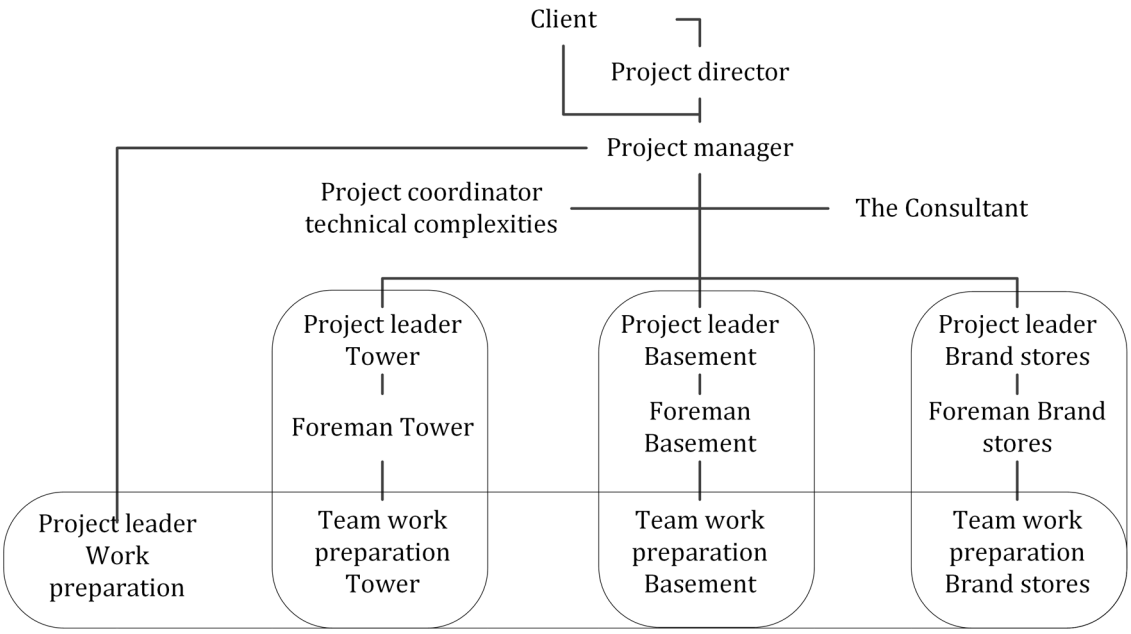


Figure 12 Project organization case 2

The scheduling process consists of five meetings that influence the schedule, depicted in Figure 13. This is the scheduling process that was formally established by the project organization. The meetings are discussed below from 1-5 in Figure 13. Note that meetings 1,2 and 5 were not dedicated to scheduling only, but also to matters such as quality of the delivered works, risks and finance. These subjects were however not relevant for the investigated scheduling process.

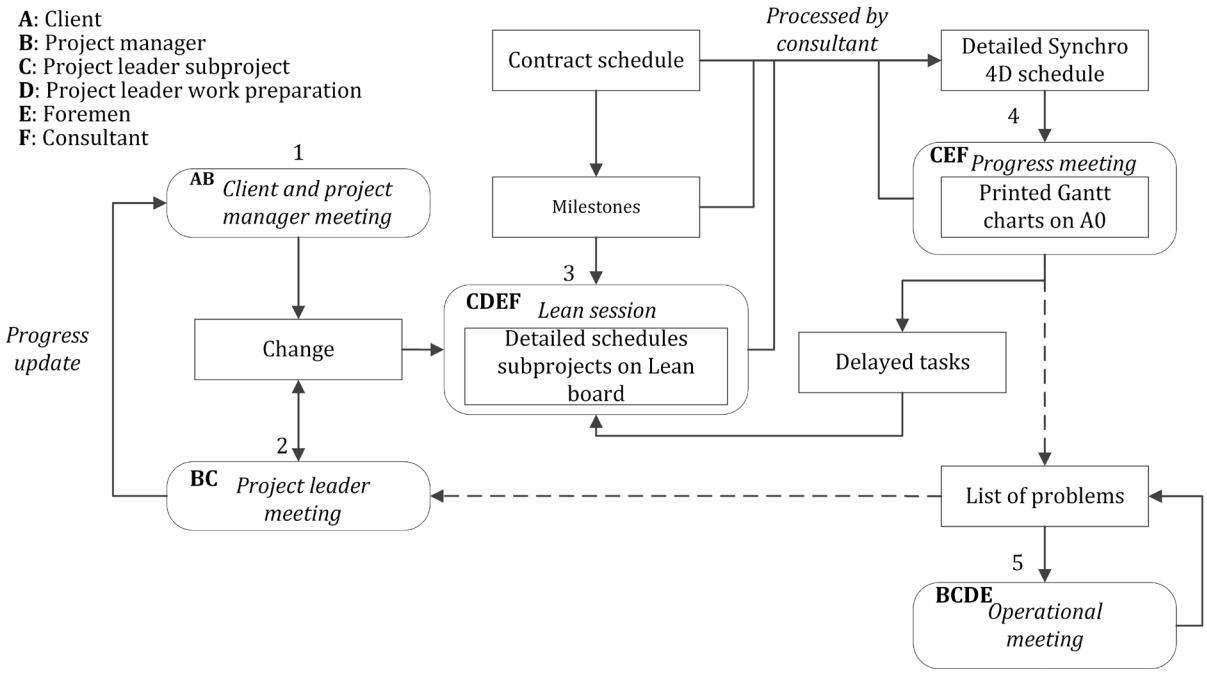


Figure 13 Scheduling process case 2

During the *client and project manager meeting* (1) the project manager presented the project's progress to the client, using Gantt charts that were provided by the Consultant. The client presented changes to the project manager. The changes coming from the client must be investigated by the main contractor, according to the contract. The project manager would therefore also present its solutions to proposed changes to the client during this meeting. If the client had decided on a change proposal, this was discussed during this meeting and could afterwards be realized by the project's organization.

The changes, progress and client's decisions were discussed between the project leaders and the project manager during the *project leader meetings* (2). Problems that required the client's attention were presented to the project manager. The project leaders and the project manager also discussed the necessity to change the schedule based on the changes or the progress.

The change of the schedule was done during *Lean Sessions* (3). The input for this Lean session was the already established contract schedule including the milestones that were agreed upon with the client. This contract schedule is a traditionally predicted schedule on task level. The Lean Sessions had a lookahead window 6 weeks and concerns one or two work packages at once.

The *progress meetings* (4) were weekly meetings where a Gantt chart concerning the coming milestone was discussed for a specific subproject. The period to the milestone and the number of tasks that were discussed per meeting varied. The meetings were always on a task level of detail. During the meeting each task was discussed with the foreman, the project leader and the Consultant, who led the meeting. The progress meeting is a meeting where a short-cyclic tool could have been applied.

The *operational meeting* (5) was the closest thing to a short-cyclic meeting. The foremen met regularly to align the specifics of the works. However, in practice these meetings were used to solve immediate problems. No access was provided to these meetings.

4.2 Findings case 2 Urban building project

This Section presents the findings from case 2. A finding is presented as C2F# and consists of interview and observation results. Every theoretical condition is concluded with a discussion on the case's appropriateness based on the findings.

Critical project factors are formulated after each theoretical condition. These CPFs are generalizations of the findings which are used to describe essential factors that influence a project's appropriateness for short-cyclic scheduling. An elaborate description of the CPFs is found in the next Chapter where the insights from this case and the previous case studies are combined.

The findings are presented in the following order:

4.2.1 Effective collaboration

C2F1: Changing management members

C2F8: Little face-to-face alignment and information sharing using e-mail

4.2.2 Appropriate use of tools and procedures

C2F3: Ad-hoc prioritization of tasks

C2F4: Unclear responsibilities.

4.2.3 Effective communication between organization levels

C2F10: No common goal, no overall commitment

C2F2: No uniform schedule

4.2.4 Appropriate qualifications and competences

C2F6: Unreliable estimation of tasks

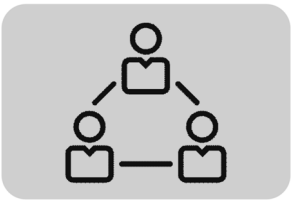
C2F7: Unprofessional behavior

4.2.5 Appropriate culture and attitude

C2F5: Problems caused by project manager and project leader

C2F9: Negative attitude towards scheduling sessions and unreliable attendance

4.2.1 Effective collaboration



C2F8 Little face-to-face alignment and information sharing using e-mail

The offices were closed and most communication was done using e-mail. The practical circumstances in the Monument caused a forced separation of offices. However, the subdivision of those offices was done based on function or originating company. Another configuration such as per subproject was not applied, which forced the project members to communicate beyond the doors of their offices.

The work planner of the basement indicated that he forces himself to talk with his colleagues over a cup of coffee. Otherwise he does not have enough information for his work. However, when asked if he did the same with his supervisor, the coordinator of work preparation he denied that. He did not see the added value in notifying his supervisor about problems face-to-face. "when I have sent my e-mail, my job is done". He trusts his supervisor to read his e-mails and act appropriately.

The complexity coordinator and the foreman of the basement both discussed the problem with follow-ups on e-mails. The complexity coordinator indicated that schedules that are spread

through e-mails are not read and safeguarded. His explanation is that face-to-face alignment is necessary to create a sense of responsibility for these schedules. This required face-to-face alignment is however absent.

The face-to-face meetings that the foreman experienced with the project leaders and the project manager were not effective from his point of view. Often his points of interest were not discussed. Therefore, he started sending the points of interest for the coming meeting to all participants. He brought a print of those point to the meeting and still they were not discussed.

C2F5 Problems caused by project manager and project leader

The project manager's competences are questionable based on the assessment of the observations and interviews. The project manager bypassed his project leaders, he created stress by ignoring the procedures of change and establishing schedules and he informed participants incorrectly to enforce scheduling decisions.

A scheduling meeting was organized by the project manager to see whether delay related to the truck elevator in the basement could be solved. The participants were the Consultant who led the meeting, the foreman and project leader of the basement. The project manager was absent but left explicit orders for the project leader to maintain a certain milestone for the delivery of the truck elevator. According to the foreman this milestone was incorrect, because the permit to lift the truck elevator into the basement was given by the municipality for another moment, four weeks later. However, even after consulting the project manager somewhere else in the building, the project manager maintained claiming this false milestone. Eventually, the true information came to light, which was indeed four weeks later than the project manager had claimed.

Critical project factors and appropriateness for short-cyclic scheduling

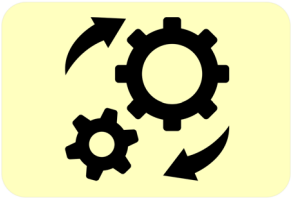
Little face-to-face alignment (C2F8) is caused by inappropriate use of e-mail and lacking procedures to enforce alignment on the project members. Inappropriate use of procedures has led to isolation of teams, which is inappropriate for short-cyclic scheduling. The resulting critical project factor is CPF3: *Appropriate use of procedures.*

The claims that were made by the project manager and the manner project leaders were bypassed inhibited effective collaboration (C2F5). No freedom was given to project leaders to collaborate and project members were authoritatively steered by the project member. C2F5 illustrates the opposite of giving support to project members and enabling them to schedule their own tasks. The related critical project factor is CPF2: *Support by internal management.*

The management support towards short-cyclic scheduling was difficult to assess by the absence of its use. The changing management (C2F1) is however an indication that this project is not appropriate for short-cyclic scheduling related to management support. Different people have different points of view on the use of tools. Besides, new people need to be prepared for short-cyclic scheduling, which has not been done according to the project leader that immediately eliminated the use of sprints.

The critical project factors that relate to finding C2F1 is: CPF2: *Internal management support* and CPF4: *Prepared organization for short-cyclic scheduling.* With the changing management the internal support is a risk for short-cyclic implementation. With new persons coming to the project, preparation is required to make sure the tools remain applied appropriately.

4.2.2 Appropriate use of tools and procedures



C2F3 Ad-hoc prioritization of tasks

Not only the absence of a uniform schedule impeded the project's members to know what tasks to perform. The work planner, foreman of the tower, project leader of the tower and the complexity coordinator all ascribed ad-hoc behavior as one of the project's biggest issues. They all indicated that the project manager changed the priority of the tasks based on the input delivered by the client. This meant, that the project manager directly gave orders to work planners or foremen to perform different activities than previously planned.

The foreman: "we work from bottleneck to bottleneck". This was explained by all participants as the cause for new bottlenecks. By focusing on the bottlenecks, the normal tasks were neglected, which caused new bottlenecks. This was described by the previously mentioned interviewees as a negative spiral causing nothing but delays.

The observations supported this described behavior. During meetings, participants left the meeting when called upon. This happened often, which made the meetings ineffective. The project leader of the basement even said that having meetings is a waste of time, because there are other tasks to perform. This indicates that scheduling normal tasks was less of a priority than the ad-hoc bottlenecks

C2F4 Unclear responsibilities

The responsibilities related to the functions that are depicted in Figure 12 do not correspond with the actual responsibilities the people on those functions have. The foreman indicated that the change of management positions has caused overlap and uncertainty in responsibilities. The interviewed project leaders, the foreman and the complexity coordinator all describe the loss of knowledge and uncertain responsibilities caused by the changing project organization.

Another aspect of the changing responsibilities was caused by the project manager. The project manager bypassed the project leaders, the foreman and the complexity coordinator multiple times. Influenced by the input of the client the project manager directly went to work planners and subcontractors, without informing his project leaders and delegating tasks to them. The effect that was observed, was that the project leaders had a position where they did not have the power to direct their own teams, because they all listened to the project manager.

Critical project factors and appropriateness for short-cyclic scheduling

Considering the theoretical condition, this project does not appropriately use their tools and procedures. The organization is not able to safeguard procedures, agreements and responsibilities. The effects of these problems are visible looking the number of bottlenecks and ineffective meetings. Before the project can move towards the implementation of short-cyclic tools. The organization should first be able to maintain a steady state and procedures.

The overlapping problem for C2F3 and C2F4 is that the agreements for procedures and responsibilities were not respected. This has led to an organization where prioritization and responsibilities are unclear, leading to bottlenecks and a profusion of documents and assignments. This problem can be described as a critical project factor CPF3: *Appropriate use of procedures.*

4.2.3 Effective communication between organization levels

C2F2 No uniform schedule

The first observation that could be done in the office of the work preparation and the Consultant were the many schedules hanging on the wall. Various versions of the same schedule were displayed. According to project leaders and the coordinator for technical complexities (complexity coordinator) these schedules were not read, once they were pinned to the wall or sent by e-mail.

A reason for this according to the complexity coordinator was the time pressure on the project. People did not have the time to properly schedule their works using drawings and knowledge from subcontractors. Instead they focused on finishing the nearest tasks without focusing on their "normal tasks".

According to the foreman of the basement, which was considered the main foreman there was no lookahead schedule for every subproject on a work package level. The tasks were imposed on the foremen on a high level of detail which could hardly be comprehended by the subcontractors that received these schedules.

C2F10 No common goal, no overall commitment

The overall commitment to the project was absent in this project. None of the interviewees appeared motivated to commit to this project and indicated problems with the mutual goal and focusing on a common objective.

According to the foreman of the basement and the complexity coordinator people use e-mails to cover their position. They use it to transfer responsibility and to show their works later. The ad-hoc behavior explained with finding C2F3 supports the lack of a common objective, because no uniform schedule was followed and bottlenecks kept arising, with no clear pattern.

C2F1 Changing management members

One of the three interviewed project leader participated in this project for a relatively short time. This project leaders entered the project when the work planners used sprints (derived from the Scrum methodology). These sprints were not used for establishing the main schedule of the project, but they were the short-cyclic tool that was used in this project.

One of the project leaders considered sprints a waste of time and cancelled them as soon as he entered the project. The work planner that was interviewed indicated that since cancelling their sprints, overview of their tasks has decreased, and meetings have become less effective. Changing management members is a risk for the support, because they are not aware of the choices that were made by their predecessors and have their own way of handling projects.

Critical Project factors and appropriateness for short-cyclic scheduling

No uniform schedule that translated the project goals top-down was observed (C2F2). This resulted in a lack of overview and a profusion of handmade schedules that did not correlate with the actual project's goals. Time pressure inhibited project members to schedule or read schedule properly. In other words, the procedures were not followed as a result of time pressure, which is generalized by critical project factor CPF3: *Appropriate use of procedures.*

C2F10 shows the tendency to use e-mails to transfer responsibility. The information in the e-mails is not used for the project's goals. Besides, the ad-hoc behavior that supports this lack of a common goal inhibits the organization to communicate about the critical tasks and to follow information

procedures, because they are fully occupied to solve bottlenecks. The critical project factor based on this finding is CPF7: *aligned interests to reach common project's goal.*

Managers are introduced to the project without an explanation of the current procedures and the reasons for these procedures (C2F1). Frequent change of management therefore leads to frequent change of procedures. This finding shows that lack of support from management leads to changing procedures, which is inappropriate for short-cyclic scheduling and that managers are not prepared appropriately on project entry. Resulting in two critical project factors; CPF2: *Support by internal management* and CPF4: *Appropriate preparation for short-cyclic scheduling.*

4.2.4 Appropriate qualifications and competences

C2F6 Unreliable estimation of tasks

Most of the attended scheduling sessions had the goal of exploring the possibilities for making up for delay. The participants were the Consultant, the work planner, foreman and project leader for the basement. At the beginning of this session post-its were used on sheets with a grid to visualize the tasks and the milestone for the relevant period. This visualization showed that the milestone with the previously estimated task durations was impossible to meet.

When the sessions started the tasks' durations and the order were changed. Leaving a schedule that met the milestone but was not realistic. The tasks that were changed were not realized by the participants in the room and considered activities of subcontractors. Their input was however not used.

C2F7 Unprofessional behavior

The observer worked in the Monument to process the interviews and observations. He was situated in the office with the work planners and the Consultant. When he walked through the office, he observed a broken filing cabinet and broken doors. Sometimes during meetings loud screaming and hard bangs were audible. He asked one of the Consultants what those noises were to which he replied that this was the way to vent aggression on objects. Apparently, some project members used those objects to get rid of their aggression.

The project members also swore to each other on the hallways and rude remarks were made. Besides, the participants of scheduling meetings behaved unprofessionally. Participants used WhatsApp during meetings and laughed out loud. Even when the Consultant repeatedly asked the participant to pay attention, this behavior did not change and he said, he did not really care.

Critical project factors and appropriateness for short-cyclic scheduling

All findings related to the qualifications and competences of the project members are negative. The project manager and leaders are not capable of safeguarding the procedures and project's goals. The participants of the meetings do unrealistic estimations under pressure. Unprofessional behavior such as aggression is noticeable in the office and people barely talk with each other. Based on these findings the project seems inappropriate for any tool that requires a professional project situation, including short-cyclic scheduling.

The unprofessional behavior (C2F7) shows that under pressure, the organization's behavior starts to become less professional. People get aggressive, indifferent to chosen procedures and management tries to yield better results by applying more pressure.

In this project, management was involved in activities on the lowest level of detail without monitoring the processes within their organization. Project management failed to give the right

example, which result in the rest of the organization to follow that example. The generalized critical project factor is CPF8: *Exemplary behavior by project's management*.

The level of aggression that has been displayed is considered beyond the responsibility of management. It could be argued that project manager should send away people that behave that way, but it is also largely the responsibility of individuals to behave professionally. The project management does however have the possibility to choose their workforce. Therefore, a basic level of professionality can be demanded, which leads to CPF9: *A safeguarded standard for professionality.*

4.2.5 Appropriate culture and attitude

C2F9 Negative attitude towards scheduling sessions and unreliable attendance

Short-cyclic scheduling was not applied in this project, but commitment to other processes and tools was assessed, nonetheless. This does not prove commitment to short-cyclic in this project but gives an indication of the feasibility of implementing new tools.

As already discussed with finding C2F7 the general attitude during scheduling sessions was unprofessional. This is supported by the interviewees' opinion on the sessions' feasibility. The complexity coordinator argued that these scheduling sessions were considered information sessions to enlighten the project leaders and the project manager instead of scheduling tasks.

The foreman of the basement expressed the uselessness of scheduling sessions during the sessions. In his interview he indicated that the project should stop all activities for one week to calibrate the schedule and the progress and move forward. All scheduling efforts for repairing were ineffective in his eyes, because no clear starting point could be defined.

Critical project factors and appropriateness for short-cyclic scheduling

This project does not show commitment to chosen procedures. Therefore, commitment to a tool such as short-cyclic scheduling can be questioned, which makes this project inappropriate. Not only the commitment to the tools is an important finding, also the commitment to the project itself is lacking. This overall commitment is necessary to make people believe that the chosen procedures are the way forward.

The critical project factor that relates to committing to procedures and the project starts with having a shared interest. This interest does not necessarily have to be the same, but the chosen method and the project's goal must serve an interest of all involved parties, including subcontractors and project members. CPF11 *A shared interest for involved parties.*

4.3 Summary of findings and appropriateness for short-cyclic scheduling

The project experienced delay during the three months of observation. The lack of grip on the project was clearly visible. The causes of the project problems are not part of this research scope, but the failing scheduling processes did not improve the project's performance. The pressure on the project led to ignoring agreements, responsibilities and procedures, which shows that the theoretical condition describing the appropriate use of tools and procedures was not met.

The other theoretical conditions were not met either. Table 8 shows that no findings had a positive effect on the appropriateness of short-cyclic scheduling. This result could be skewed for two reasons. First, because this case is a traditional project. The procedures are different in a

traditional project, which could lead to other findings when the project is under pressure. C2F1 and C2F8 are findings that can be influenced by the project being traditional.

The management change (C2F1) can be more necessary in a hierarchical project, due to loss of trust in leadership. When project members do not accept the leadership of management a hierarchical project must change. The lack of face-to-face alignment (C2F8) can be inherent to the traditional approach which uses imposed schedules, without the necessity to collaboratively establish schedules.

The second reason for skewed results is the already negative attitude of the interviewees. C2F10 shows that there is no common goal. Other findings also illustrate the pressure on the organization. There could have been a more positive image on the same project if the observations were done in an earlier stage.

Table 8 The case 2 findings linked to the critical project factors

C2F#	Case 2 findings	CPF#	Critical project factors
Effective collaboration			
C2F8	Little face-to-face behavior and information sharing using e-mail	CPF3	Appropriate use of procedures
C2F5	Problems caused by project manager and project leader	CPF2	Support by internal management
Appropriate use of tools and procedures			
C2F3	Ad-hoc prioritization of tasks	CPF3	Appropriate use of procedures
C2F4	Unclear responsibilities		
Effective communication between organization layers			
C2F2	No uniform schedule	CPF3	Appropriate use of procedures
C2F10	No common goals, no overall commitment	CPF7	Aligned interests to reach common project's goal
C2F1	Changing management members	CPF2	Support by internal management
		CPF4	Appropriate preparation for short-cyclic scheduling
Appropriate qualifications and competences			
C2F6	Unreliable estimation of tasks	CPF2	Support by internal management
C2F7	Unprofessional behavior	CPF8	Exemplary behavior by project's management
		CPF9	A safeguarded standard for professionality
Appropriate culture and attitude			
C2F9	Negative attitude towards scheduling sessions and unreliable attendance	CPF7	Aligned interests to reach common project's goal

Table 8 shows that this project has yielded four additional critical project factors, CPF8, 9, 10 and 11. These CPFs are added to the list that was established in Chapter 3, see Table 7. The complete list of 11 CPFs is used in the next chapter for expert validation, Section 5.2 and a comparison with the literature in Section 5.3. The definitive list of critical project factors is presented in Section 5.4.

5 Synthesis

This Chapter describes the critical project factors categorized per theoretical condition as presented in Table 9. First descriptions of the critical project factors based on the findings are given in Section 5.1. These descriptions are validated as explained in Section 5.2. These validated critical project factors are compared to the literature on appropriateness for short-cyclic scheduling to assess relation between literature and the results of this research in Section 5.3. Section 5.4 presents the model, which is the final list of critical project factors completed with the validated expert insights and literature insights.

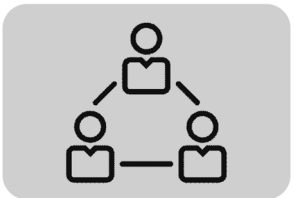
5.1 Critical project factors

The critical project factors that are found in case 1 and case 2 are explained below. The originating findings can be found in Table 9. Based on these findings a general description of each CPF is given, using the same subdivision of theoretical conditions as in the previous chapters.

Table 9 Critical project factors per theoretical condition

Critical project factors		**Case 1 Findings**	**Case 2 Findings**
Effective collaboration			
CPF1	Support by external management	C1F1	
CPF2	Support by internal management	C1F2, C1F3	C2F1, C2F5, C2F6
Appropriate use of tools and procedures			
CPF3	Appropriate use of procedures	C1F4	C2F2, C2F3, C2F4, C2F8
CPF5	A tailored version of the short-cyclic tool	C1F6	
CPF6	A competent and informed coordinator	C1F7, C1F9	
Effective communication between organization layers			
CPF7	Aligned interests to reach common project's goal	C1F10, C1F11, C1F12	C2F9, C2F10
Appropriate qualifications and competences			
CPF4	Appropriate preparation for short-cyclic scheduling	C1F1, C1F5, C1F8	C2F1
Appropriate culture and attitude			
CPF8	Exemplary behavior by project's management		C2F7
CPF9	A safeguarded standard for professionality		C2F7

5.1.1 Effective collaboration

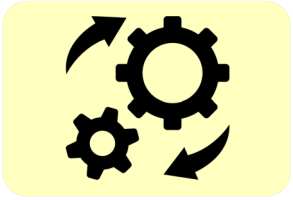


Construction projects' organizations are a combination of multiple companies. They consist of a main contractor, subcontractors and consultants. The persons that are allocated by these different companies into one project organization serve the interest of their own company. They bring the culture of their own company and their ways of working. If the companies' management do not support short-cyclic scheduling this creates tension between the project members and their managements. This tension can lead to strategic behavior

and reversion to old habits which is undesirable. Therefore, support by external management is required for an appropriate project for short-cyclic scheduling (CPF1)

The project organizations itself also have management teams. Each construction project is different, but generally the management team decides what tools and procedures are used by the rest of the organization. In order implement short-cyclic scheduling the management should fully support this tool. Otherwise a part of the organization reverts to old habits and different tools start to coexist. This is called support by internal management (CPF2).

5.1.2 Appropriate use of tools and procedures



CPF3 and CPF5 relate to the technical implementation of the tool. This means that the appropriate use of procedures (CPF3) entails ensuring that a list of requirements and activities has been realized. Examples are establishing an organization structure with responsibilities that are respected and procedures for communication flows. The tailored implementation (CPF5) means that the contents of the list of requirements and activities have been modified to comply with the project's characteristics.

A competent and informed coordinator (CPF6) is considered part of the implementation of short-cyclic scheduling. Foremen and work planners on construction sites are relatively new to short-cyclic scheduling and two-way interaction with management. A coordinator is essential to form the link between management and the construction site and to help operational teams to get used to short-cyclic scheduling. The coordinator does not have a technical responsibility for performing activities on the construction site but has the responsibility to deliver a realistic schedule and ensure progress.

5.1.3 Effective communication between organizational layers

The critical factor that leads to effective communication between organizational levels is: aligned interests to reach common project's goals (CPF7). If the goal is not clear, the information sharing is ineffective. Project members share information that is irrelevant for reaching the project's goal or hold on to information to serve their own interests rather than the project's interests.

Aligned interests also lead to more effective meetings. The topics in the meetings serve the project's goal and the attendance is more reliable. Last, the prioritization of information is more effective if the common goal is known. A good prioritization of information can prevent ad-hoc behavior.

5.1.4 Appropriate qualifications and competences

Short-cyclic implementation cannot be done without preparation (CPF4). The preparation entails assessing the list of requirements and activities to ensure a tailored and complete implementation and preparing the project members. The project members must be prepared by training and coaching, but also management teams must understand and support implications of using short-cyclic scheduling compared to their normal way of working.

Another aspect of preparation is getting new project members up to speed on entry. A risk for failing short-cyclic implementation is reversion to old habits, because new project members do not understand the choice for short-cyclic scheduling.

5.1.5 Appropriate culture and attitude

The project's culture must be appropriate for short-cyclic scheduling. Short-cyclic scheduling requires a degree of professionalism that enables the operational teams to collaborate, estimate their own tasks and respect procedures. Operational teams have more freedom, because management does not impose detailed schedules. However, inappropriate behavior that inhibits the ability to self-organize on the construction site must be prevented by a safeguarded standard for professional behavior (CPF9).

Another determining factor for the culture within the project and the attitude of project members is management's behavior. If management does not respect procedures, behaves professionally or supports short-cyclic scheduling, the rest of the organization is not expected to follow. Therefore, exemplary behavior of management (CPF8) is essential for successful short-cyclic implementation.

5.1.6 Discussion on the critical project factors

Looking at Table 9 there are CPFs that are supported in both cases and CPFs that are supported in one case. The distinction between CPFs with one supported case is the difference between good practice and bad practice. The CPFs supported by case one originate mostly from findings that show good practices that influenced the effectivity of the short-cyclic tool positively. The other CPFs, derived from case 2 originate from findings that show a negative influence on the project. The bad and good practices give multiple perspectives on the appropriateness for short-cyclic scheduling which could be more complete than solely investigating good or bad practices.

5.2 Expert validation on critical project factors

The expert validation has been conducted with two experts on project management within the construction sector. The validation protocol can be found in Appendix D.

5.2.1 Tender manager

The tender manager's first remark on the CPFs was that some of the CPFs assume certain behavior of the project members to meet comply with these CPFs. The examples that were used by the tender manager are safeguarded procedures and agreements (CPF3) and a safeguarded standard for professionality (CPF9).

The tender manager agrees with both these CPFs being critical for successful implementation of short-cyclic scheduling but finds it difficult to imagine how these CPFs can be met by management teams. He indicates that management can choose from instruments such as implementing procedures, rules and tools, but that setting a culture is difficult. The project members' behavior does influence the extent to which the CPF3 and CPF9 are safeguarded.

He acknowledges that support by external and internal management (CPF2 and CPF1) is critical for short-cyclic scheduling. He recognizes the difference between project members. This means that teams consisting of these different project members are not automatically self-organizing. The tender manager stresses that this is to be supported and facilitated by the project's management. He did not make a distinction between internal and external management.

The coordinator's competences and qualities (CPF6) are not enough to describe the role of the coordinator. During the discussion about the coordinator the tender manager indicated that both the competences and the position or role in the organization are important. In his experience teams function less self-organizing when a manager is attending the meetings. Even if a

coordinator is leading this meeting, the participants tend to listen to the manager. Therefore, CPF6 must contain both the coordinator's role and the required competences.

All critical project factors categorized underneath the theoretical condition appropriate use of tools and procedures (Table 9) are recognized as important. However, the tender manager indicated that assessing a project concerning these factors requires more information. "What organizational changes must be realized? What are the organizational guidelines to determine the appropriate use of tools and procedures?" Are questions that have been asked by the tender manager. He said that a list of steps or guidelines could help managers to assess their project's appropriateness.

An aligned interest to reach common project's goal (CPF7) is difficult to achieve. The tender manager indicates that he cannot think of ways to comply with this CPF. The main goal here is to align the interests of different parties in order to achieve the project's objectives, according to the tender manager. He indicates that somehow a certain dependency between parties helps working towards common project objectives.

5.2.2 Design manager at a large contractor

The design manager has seven years' experience on large infrastructure projects. He is used to organizing teams that work under time pressure in complex projects. During the time of the validation meeting the design manager was leading a team preparing for a large infrastructure project.

The design manager acknowledged the importance of a competent and informed coordinator (CPF6). He indicated that it is possible to simply hire such a coordinator. He explained that the coordinator must have enough knowledge about the project to recognize flaws in the schedule and strategic behavior of participants. However, replacing a coordinator in running projects is not common practice. There must be a clear reason, such as introducing a consultant to the project to change the role of a current coordinator in a construction project.

The design manager indicates that the coordinator's role is not clear from the description of CPF6 only. More information about the "abstraction level" related to the project organization must be given. The design manager suggested to draw the traditional project organization and show which CPF is applicable for each organization layer or member. In his eyes this gives more feeling to managers what is within and beyond their influence.

Exemplary behavior by project's management (CPF8) and CPF9 A safeguarded standard for professionality are not formulated clearly according to the design manager. The goal is to describe effective communication between project members and a code of conduct that is enforced by management.

The design manager explained the essence of exemplary behavior by the project's management. He states that before a project behaves appropriately the principle, which is the project's management must set an example. Exemplary behavior entails behavioral rules, such as; face-to-face alignment, refrain from e-mailing and conflict resolution.

This also related to CPF1 and CPF2, support by external and internal management. The design manager wondered what type of support and behavior was expected from management related to supporting short-cyclic scheduling. He acknowledged that management support is essential for changing tools and procedures.

CPF8 and CPF9 should be *effective communication between project members*. This covers the problems that information sharing is not effective caused that strategic behavior or unprofessional behavior. The design manager also considered CPF8 and CPF10 solutions to a problem, instead of describing a project factor.

CPF8 and 9 do indeed enhance effective communication. However, in this research the theoretical condition that describes effective communication between organizational layers relates to the ability to translate project goals towards comprehensible tasks on the construction site. CPF8 and 9 have a better fit with appropriate culture and attitude that describe the ability to behave professionally and learn short-cyclic scheduling, as described by (Owen et al., 2006).

Whilst discussing the theoretical condition commitment to short-cyclic scheduling the design manager stressed that this is not a starting condition for projects. This commitment must grow. If the short-cyclic method and the team progresses through the project and results are visible this commitment might grow. Aligned interests (CPF7) do not automatically lead to commitment to short-cyclic scheduling. The design manager suggested that teambuilding and coaching were ways to create this commitment as well. This should be part of the appropriate preparation for short-cyclic scheduling (CPF4).

The CPFs related to the appropriate use of tools and procedures were not explicitly discussed with the design manager. He adopted the idea of improving projects with short-cyclic scheduling after introducing it. The CPFs were introduced as well, but no further comments were given by the design manager.

The design manager's overall impression of the CPFs was that it can be useful for project managers as a checklist for appropriateness. If this checklist is connected to a list of actions to change the project, managers can change their projects effectively. The design manager indicated that a prioritization of CPFs was missing. The design manager wondered what CPFs must be present before others can be realized.

5.2.3 Summary of expert validation

The experts considered the CPFs as useful for assessing the appropriateness of construction projects for short-cyclic scheduling. The experts understood the categorization based on the theoretical conditions. The experts did not recognize CPFs that are not applicable for construction projects.

However, some improvements were suggested. First, the prioritization of the CPFs. The experts did not have a clear image on what CPF to solve before the other. A suggested order of ensuring the CPFs is proposed in Section 6.2.

Another comment was made on the abstraction level of the CPFs. Some CPFs relate to a management and organizational abstraction level and some CPFs relate to a detailed and personal level. The experts did not suggest how this abstraction level could be clarified. A suggestion to add the abstraction level to the CPFs is linking the theoretical conditions to the layers of a project organization as depicted in Figure 14.

The theoretical conditions on the left, *effective collaboration* and *appropriate culture and attitude* apply to the entire organization. The entire organization must collaborate appropriately to function properly. Effective collaboration relates to the horizontal collaboration between project members. Enabling effective collaboration is mainly a management responsibility but applies to the entire organization. The appropriate culture is necessary to work with the same

procedures through the entire company. This requires professionalism and the right attitude towards the chosen procedures.

Effective communication between organizational layers applies to the link between management and the construction site. Project goals (milestones) must be translated to the short-cyclic schedules on the construction site. Effective communication between these layers means that the information that is shared vertically contributes to meeting the project's goal.

The two bottom theoretical conditions *appropriate qualifications and competences* and *appropriate use of tools and procedures* apply to the construction site. Especially the workers on the construction site are not used to changing procedures, self-organization and scheduling their own tasks. The professionality level on construction sites is lower than the professionality level of management. The appropriate implementation of tools and procedures are mostly related to the construction site, because this project focuses on short-cyclic scheduling on the construction site.

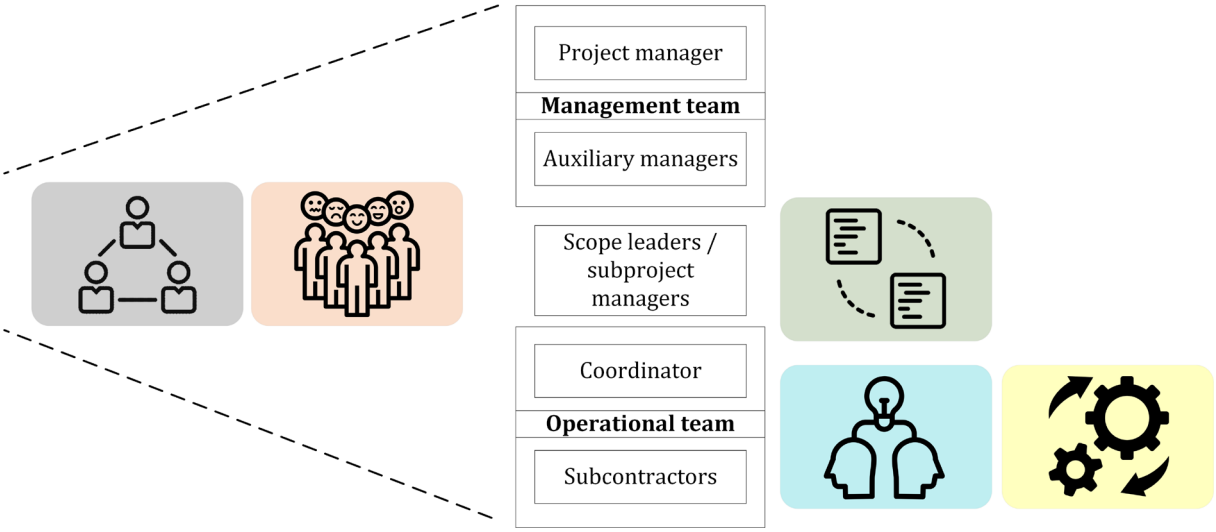


Figure 14 Abstraction level of theoretical conditions

5.3 Comparing CPFs to theoretical conditions (literature)

The framework of the five theoretical conditions for appropriate implementation of short-cyclic scheduling is described in Sections 2.4 and 2.5. This Section compares the findings that are presented in Table 9 to the framework. Paragraph 5.3.1 compares the theoretical condition effective collaboration to the related critical project factors are compared. In Paragraph 5.3.2 the appropriate use of tools and procedures is compared to the related CPFs. Effective communication between organizational layers is compared to practice in Paragraph 5.3.3. The comparison of practice and literature for the appropriate qualifications and competences can be found in Paragraph 5.3.4. The last comparison relates to the theoretical condition; appropriate culture and attitude, as described in Paragraph 5.3.5. The insights from 5.1 and 5.2 and 5.3 are combined to the final model in Section 5.4.

5.3.1 Effective collaboration

Table 10 presents the critical project factors (on the left side) and the highlights from literature, Section 2.4 (on the right side). Below the table the CPF are compared to the highlights. This comparison is done to evaluate the categorization of the CPFs and to discuss the differences between literature insights and practical insights.

Table 10 Comparison between CPFs and theory for theoretical condition Effective collaboration

Critical project factors (practice)	Theoretical insights (literature)
• CPF1 Support by internal management • CPF2 Support by external management	• Create commitment towards the project as management responsibility (Nicholas & Steyn, 2017) • Role of management and team chemistry big challenge for LPS implementation (Habchi et al., 2016) • Leadership, management support and team autonomy as success factors for collaboration (Dikert et al., 2016) • Management support should be constantly visible (Dikert et al., 2016) • Operational teams should have the freedom of self-organization (Dikert et al., 2016)

Support by internal management (CPF2) is comparable to the insights from literature. The roles and responsibilities of management result from the case studies as well as from literature (Dikert et al., 2016; Habchi et al., 2016; Nicholas & Steyn, 2017).

Support by external management (CPF1) however has not been clearly described in literature. The role of subcontractors related to projects' appropriateness for short-cyclic scheduling was underrepresented. This can be explained by the absence of many short-cyclic implementations during the realization phase of projects. Also the study on the success of LPS in construction projects did not explicitly mention external management as a challenge for LPS implementation (Habchi et al., 2016). The study did however mention the importance of preparing the involved parties for LPS, to prevent resistance and reversion to old habits.

The insight that is gained by CPF1 can therefore be described as addition to the preparation of involved parties. The results from the case studies showed that preparing the persons that join the project organization is not enough. The preparation should go beyond the limits of the project organization.

5.3.2 Appropriate use of tools and procedures

Table 11 presents the insights from the case studies, the critical project factors on the left side and the literature insights on the right side.

Table 11 Comparison between CPFs and literature for theoretical condition Appropriate use of tools and procedures

Critical project factors (practice)	Theoretical insights (literature)
• CPF3 Appropriate use of procedures • CPF5 A tailored version of the short-cyclic tool • CPF6 A competent and informed coordinator	• Too much information gathering leads to ineffective scheduling sessions (Ann et al., 2011; Dave et al., 2015) • Visualization tools enhances commitment to the works and between participants (Ann et al., 2011) • Project organizations have the tendency to change their procedures, which has a negative influence on performance (Nicholas & Steyn, 2017) • Partly implementing LPS is ineffective (Ann et al., 2011; Dave et al., 2015)

	• Lack of guidance for implementing Agile in other (Dikert et al., 2016) • For agile transformations the organization needs to be trained and coached and supported by people with prior agile experience (Dikert et al., 2016)

CPF3 and CPF5 describe the appropriate and tailored implementation of short-cyclic tools. This means that if a project organization cannot implement the short-cyclic tool completely and customized for its needs; more preparation is required. The literature shows that partial implementation of LPS is ineffective (Ann et al., 2011; Dave et al., 2015), referring to CPF5. For large agile transformations a careful customization of the tools is necessary to achieve an appropriate implementation (Dikert et al., 2016), referring to CPF3.

Changing the procedures and therefore not sticking to a complete or tailored implemented tool has a negative effect on project performance (Nicholas & Steyn, 2017). However, a lack of guidance exist for implementing Agile in other sectors than the IT sector (Dikert et al., 2016). This limits the applicability of CPF3 and CPF5, because it can be difficult to determine what a complete and tailored implementation of an Agile tool entails.

CPF6 describes the competences and knowledge of the coordinator, which had an important role in the projects that have been investigated. The role of the coordinator is not represented in literature. Dicer et al. (2016) mention the support of people that have prior agile experience in Agile transformations, which could be linked to the role of a competent coordinator. However, the coordinator has not been mentioned as a person that can cope with the deficit in competences of the other project members. The insight as a compensating coordinator that forms the link between management and the operational layer is new compared to the existing theoretical knowledge.

5.3.3 Effective communication between organization layers

Table 12 presents the insights from the case studies, the critical project factors on the left side and the literature insights on the right side.

Table 12 Comparison between CPFs and literature for theoretical condition Effective communication between organization layers

Critical project factors (practice)	**Theoretical insights (literature)**
• CPF7 aligned interests to reach common project's goal	• The construction sector is a conservative sector (Blom et al., 2016) • Resistance to change is a challenge for the implementation of LPS and for agile transformations (Dikert et al., 2016; Habchi et al., 2016) • Top management commitment is critical for LPS implementation (Ann et al., 2011) • Preventing reversion to old habits is critical for Agile and LPS implementation (Dikert et al., 2016; Habchi et al., 2016)

5.3.4 Appropriate qualifications and competences

Table 13 presents the insights from the case studies related to appropriate qualifications and competences on the left side. These insights are compared to the theoretical insights, presented on the right side.

Table 13 Comparison between CPFs and literature for theoretical condition Appropriate qualifications and competences

Critical project factors (practice)	Theoretical insights (literature)
• CPF4 Prepared organization for short-cyclic scheduling	• Appropriate training is a critical success factor for implementing LPS (Ann et al., 2011; Cerveró-Romero et al., 2013) • The average competences of construction workers are not compatible with agile scheduling (Owen & Koskela, 2006a) • For agile transformations the organization needs to be trained and coached and supported by people with prior agile experience (Dikert et al., 2016)

Prepared organization for short-cyclic scheduling covers the theoretical insights. Literature indicates that training, coaching and preparation are success factors for LPS and Agile transformations (Ann et al., 2011; Dikert et al., 2016).

5.3.5 Appropriate culture and attitude

Table 14 presents the insights from the case studies on the left side and the theoretical insights on the right side. These insights are compared below the table in order to evaluate the categorization and to discuss the differences between the findings.

Table 14 Comparison between CPFs and literature for theoretical condition Commitment to short-cyclic scheduling

Critical project factors (practice)	Theoretical insights (literature)
• CPF8 Exemplary behavior by project's management • CPF 9 A safeguarded standard for professionality	• Users had a negative attitude towards LPS (Habchi et al., 2016) • Top management commitment to LPS is a critical success factor for implementation (Ann et al., 2011) • Especially preventing managers to revert to old habits is important for Agile implementation (Dikert et al., 2016) • Behavior such as micromanaging, remaining bureaucratic, keeping the traditional waterfall mode and remaining islands within the organization inhibit the successful introduction of agile (Dikert et al., 2016; Habchi et al., 2016)

CPF8 describes the exemplary behavior of management. This is especially supported by the study of Dicer et al. (2016). They describe the important role for management to lead large agile transformations in different sectors. Additionally, Nicholas and Steyn (2016) describe the importance of management sticking to their roles and procedures. The organization follows

management which requires setting an example. This is especially important in the construction sector that is still hierarchical (Blom et al., 2016).

The average level of competence in the construction sector is described by Owen & Koskela (2006). In case 2 this was recognized as a problem. Unprofessional behavior and little face-to-face alignment are indications of lacking competences to work in a professional environment. These theoretical and practical insights relate to CPF9 A safeguarded standard for professionality.

5.4 Overview model

Table 15 depicts the final list of critical project factors. The critical project factors correspond with the factors from Table 15 which represents the final categorization of the critical project factors. Project managers can use the model to assess the appropriateness of their projects for short-cyclic scheduling. If a construction project in the realization phase contains the depicted critical project factors, it is considered appropriate for short-cyclic scheduling.

Table 15 Final critical project factors per theoretical condition

Critical project factors	
Effective collaboration	
CPF1	Support by external management
CPF2	Support by internal management
Appropriate use of tools and procedures	
CPF3	Appropriate use of procedures
CPF5	A tailored version of the short-cyclic tool
CPF6	A competent and informed coordinator
Effective communication between organizational layers	
CPF7	Aligned interests to reach common project's goal
Appropriate qualifications and competences	
CPF4	Appropriate preparation for short-cyclic scheduling
Appropriate culture and attitude	
CPF8	Exemplary behavior by project's management
CPF9	A safeguarded standard for professionality

6 Conclusion and discussion

This chapter presents the conclusion and discussion of this research. First the main research question is answered in Section 6.1. The managerial implications of the research's results are discussed in Section 6.2. The research's limitations are presented in Section 6.3. Recommendations for future research are given in Section 6.4.

6.1 Answering the main research question

The main research question is: *What determines the appropriateness for short-cyclic scheduling of construction projects in the realization phase?* Literature on success and challenges for short-cyclic scheduling provided a set of theoretical conditions. Critical project factors that are necessary for a construction project to meet the theoretical conditions have been established in this research. The theoretical conditions can apply to the entire organization, management or the construction site. The theoretical conditions and the accompanying critical project factors are presented below.

Theoretical conditions *effective collaboration* and *appropriate culture and attitude* apply to the entire project organization. To meet these conditions a construction project should contain the following critical factors:

- Support by external management
- Support by internal management
- Exemplary behavior by management
- A safeguarded standard for professionality

Project organizations for large construction projects consist of (sub)contractors and consultants. People working in the organization are used to habits of their own companies and answering to their own managers. However, this is not always in the best interest of the project. External management support is needed to give the freedom to their employees to answer to the project's management only.

Internal management support prevents the coexistence of different tools and procedures. Managers have the power to choose their own tools. When managers do not support the chosen tools and procedures, they tend to choose their own habits. Besides, if the project's management does not support the chosen tools, the rest of the organization is not likely to use them.

Effective collaboration is not met when the management gives the wrong example. Project organizations are not likely to behave appropriately when their management is giving the wrong example.

The professionally level of an organization relates to project members' behavior. This relates to the way an organization collaborates and communicates. Examples of behavior that causes ineffective communication are team isolation and aggressive behavior.

Theoretical condition *effective communication between organization layers* relates to the vertical interaction between project members. This entails the communication between management and the construction site. Effective communication between organization layers describes the ability to share project goals with the operational layers (top-down) and progress with management (bottom-up). The critical project factor is:

- Aligned interests to reach common project's goal

This critical facture ensures that the information which is shared contributes to meeting the project's goal. With the interests aligned project members are more likely to work on the same milestone. This is effective when ad-hoc behavior and team isolation is prevented.

Appropriate qualifications and competences and *appropriate use of tools and procedures* relate to the implementation of short-cyclic scheduling on the construction site. The critical project factors that determine the appropriateness related to these two theoretical factors are:

- Appropriate preparation for short-cyclic scheduling
- Appropriate use of procedures
- A tailored version of the short-cyclic tool
- A competent and informed coordinator

Before short-cyclic tools can be implemented, the entire project should be prepared. There must be a mutual consent on the chosen tools, procedures and core values.

The complete and tailored implementation of a short-cyclic tool influences its effectivity. An appropriate use of procedures is required to prevent blind spots in information flows. Especially information flows need to be implemented completely to prevent the loss of information, which inhibits accurate and quick decision making.

The coordinator is essential to integrate management and operations. He or she safeguards information flows, management decisions and agreements between schedulers. The coordinator chairs scheduling meetings and is not responsible for any construction activities.

Concluding, this list of factors is critical for the appropriateness of a construction project for short-cyclic scheduling during the realization phase. The list can be used as a list for assessing current projects and as a checklist for preparing projects. This list adds practical insights to literature that was mostly focused on the success of short-cyclic implementations instead of asking the question if these projects were already appropriate for short-cyclic scheduling.

6.2 Managerial implications

The critical factors that are presented in the previous section can be used to assess and prepare project organizations for short-cyclic scheduling, see Paragraph 6.2.1. However, the wish for short-cyclic scheduling is often rooted in disappointing experiences of managers with traditional scheduling. Changing or preparing a project alone as a management team has proven to be ineffective (Ann et al., 2011). Therefore, management should hire specialized advisors to facilitate the implementation.

The project's preparation can be done using the critical factors as a checklist. Managers can use a consultant to facilitate training and to check the preparation processes. This means giving advice on which responsibilities should have and whether subcontractors are appropriate.

A consultant or change manager can be used to assess a current project by doing interviews and observations on current practice. This leads to insight in the critical project factors that require improvement before short-cyclic implementation.

In ongoing projects resistance can be expected, especially when it seems that problems are caused by managers or hired subcontractors. Ideally problematic project members are replaced. However, one can question if this is realistic in current project situations. The success of using the critical factors to assess projects and their subsequent actions is dependent on the management commitment and the constitution of the project. If contracts limit the room for maneuver of the consultant or the change manager, the transformation is likely to fail.

6.2.1 Achieving critical project factors

Table 16 shows the CPFs that relate to project members' behavior and to management decisions. Below the table it is explained how managers can achieve these critical factors.

Table 16 Behavioral and procedural critical factors for managerial implications

Behavioral critical project factors	Managerial critical project factors
• Support by internal management • Support by external management • A safeguarded standard for professionality • Aligned interests to reach common project's goal • Exemplary behavior by project's management	• Appropriate use of procedures • Prepared organization for short-cyclic scheduling • A competent and informed coordinator • A tailored version of the short-cyclic tool

First, achieving the behavioral CPFs and afterwards the managerial CPFs is the preferred order. A project organization that has aligned interests and behaves appropriately is more likely to accept managerial changes than a divided project organization.

The project manager should facilitate workshops and education for his or her managers. All managers should be aware of the procedures and tools and aligned on how to use them. External management support can be reached by showing metrics that prove the benefits of short-cyclic scheduling to subcontractor's organizations.

Preparation of management is very important in transformations to new tools. An example is the introduction of Enterprise Resource Planning systems (ERPs). Managers had little time to learn to use with ERPs which resulted in a limited implementation of these tools with a limited exploitation of the many possibilities these systems have (Dery, Hall, & Wailes, 2006).

Besides, the project manager should manage the expectations towards external managers. Expectations that mainly relate to scheduling with other parties instead of imposing schedules traditionally. The internal and external support of managers is referred to "organizational leadership" (Sambamurthy & Zmud, 2000).

The basic competence level has been an impediment for large software implementations in projects (Kim, Lee, & Gosain, 2005). A basic competence level for professional organizations can be influenced during a project's preparation phase. This entails selecting the right subcontractors, managers and other project members. Assessments on their professionality can be done on entry. Changing the competence level of ongoing project can mean firing people that were loyal, but not appropriate. This decision can be difficult; therefore, it is recommended to select a project organization carefully.

Aligned interests to reach the common project goal is achieved by creating incentives for parties to choose for project goals instead of deviating interests. Contractual incentives that force parties to work together can be used. Possible incentives are shared risk or reward systems for when milestones are met.

Commitment to the chosen scheduling tool can be achieved by facilitating trainings and workshops that show the benefits. Project members can also be involved in the decision-making process when tools are chosen. This gives them a sense of importance and influence, which can create commitment later in the project.

The managerial critical project factors relate to factors that managers can take to safeguard the appropriateness of their projects. The first two critical factors relate to a situation that does not require using a short-cyclic tool yet. The last three discuss the actual implementation of a short-cyclic tool.

Effective communication between project members is reached by setting rules for the organization regarding communication. This entails introducing procedures, tools and core values for collaboration. Managers should safeguard the procedures, tools and core values by introducing consequences for not following communication rules. Such consequences could be plenary sessions that stress the importance of effective communication or performance interviews.

Safeguarding a prepared organization for short-cyclic scheduling can be achieved by introducing entry requirements for new project members. Managers can facilitate trainings and information sessions to get new members up to speed.

Implementing short-cyclic scheduling starts with hiring the appropriate coordinator. The coordinator must be informed about the project specifics. He or she must be able to communicate with construction workers and managers to form the bridge between construction and management. The coordinator must be specialized in short-cyclic scheduling.

Project managers must hire specialized advisors to completely implement a tailored version of a short-cyclic scheduling tool. This requires being prepared for a transition period. Suggestions for implementation are pilot implementations on separate parts of the scope. Project organization with a large project portfolio can consider implementation in a smaller project.

An important note for project managers is that short-cyclic scheduling does not solve problems that already exist relating coexisting procedures, collaboration, ineffective communication and conflicts. First solve these problems, before implementing short-cyclic scheduling. This recommendation is comparable with the recommendations found in a study on the implementation of ERPs in projects stating that ERP implementation is " a process of accepting

new rules and process knowledge in the organization" instead of purely implementing the technique (Lee & Lee, 2000).

6.3 Limitations

The first limitation relates to the interview results. The interviewer had access to interviewees with help of a consultancy company. The interviewer was independent, but this was sometimes not clear for the interviewees. They addressed the interviewer as one of the consultants, which could lead to a discussion about choices that were made by the consultant. This gave the impression that sometimes the interviewees were overly positive or negative towards the interviewer. This can be explained for two reasons. The interviewers either wanted to make a point hoping that it would reach the consultant or were holding back, because they worked closely together with the consultant and did not want to harm the relationship.

Another limitation to the interview result relates to the second case. That project organization was under time pressure. This was clearly visible and could be sensed in the project office. The stress was also noticeable during the interviews. All interviewees of the second case were unhappy with the project management and the progress of the project which has influenced the interview results towards a more negative image.

Another limitation relates to the number of observations that has been done for the second case. The accessibility to scheduling sessions was limited. This forced the researcher to base the results on the interviews. A more complete image and perhaps a more positive image could have been established if more meetings would have been attended.

The list of critical factors has not been tested yet. The completeness of the list and the applicability for other cases can still be challenged. One of the applicability challenges relates to the flexibility of project organizations. Some of the critical project factors refer to project managers' behavior. There is no insight in the extent to what this behavior can be influenced.

6.4 Future research avenues

The main future research objective should be finding a way to assess projects on the critical factors. This can be done by investigating projects that have implemented short-cyclic scheduling and compare their appropriateness with the performance of the implemented tools. The relation between the appropriateness and the tools performance can give an indication of the critical factors' validity.

The next step for research is testing the critical factors on projects that want to transform to short-cyclic scheduling. The projects can be assessed and subsequently be improved. Afterwards the short-cyclic tool can be implemented and evaluated to investigate the contribution of ensuring the critical factors. The contribution can be tested by comparing similar projects that used short-cyclic scheduling from the beginning and projects that transformed.

Another research opportunity is investigating other types of project organization in the construction sector related to the critical project factors. Traditionally construction projects are hierarchical with management determining what procedures and tools are used. The effect of more horizontal and professional organizations can be explored. This could lead to insights in the type of project organization related to the appropriateness for short-cyclic scheduling in the construction sector.

The impediments that are found for introducing LPS (Ann et al., 2011) and for introducing ERP systems (Kim et al., 2005) and the critical factors of this study can be compared to find a more complete image of the organizational requirements for implementing new tools. The lessons learned from ERP to overcome the found impediments can be used to improve short-cyclic implementation in construction projects. The critical project factors can be used to assess whether these improvements had an effect on the appropriateness of the improved construction project.

7 Reflection

The research' process has been a learning experience. From diving in activities headfirst towards thinking about the desired results and the required steps to reach these results. This headfirst approach resulted in the first draft, being a consultancy report with many words and solutions, but no clear theoretical conclusion or contribution. After receiving the feedback for this initial draft, it became clear that the data had much potential, but that writing, thinking and analyzing simultaneously is a recipe for a nonscientific unreadable report. These are the lessons I have learned:

- Thinking about the product/report that should be delivered
- Asking help earlier on in the process
- Start building the product earlier to receive feedback earlier
- More self-reflection during the process

At some point in the writing process, focus on scientific writing was lost. Perhaps influenced by the consultancy environment or personal preferences the report started to become a consultancy report. Guidelines for conciseness, language and layout were neglected more often. The idea existed at that time that producing quantity had a higher priority than creating qualitative content.

In retrospect the feedback from the graduation committee; "write a scientific report" makes sense. This could have been achieved by focusing on the report structure and the goal of writing a report.

Asking help fortunately helped me getting more perspective on what to write and where. Help was asked late and could have saved a lot of work when this was asked earlier. Next time I will ask help to challenge the choices I make. Especially related to structure, which is not my strong suit I need more guidance in the future.

My initial working method was starting at the beginning and work to the end. This is almost embarrassing when the report is on short-cyclic methods. My working method should have been iterative. Thinking about all the blocks that are required in a report beforehand could have helped me separating secondary information from the main message.

This does however require believing in working this way and understanding what should be in a report. Something that left me puzzled for quite some time.

Criticize findings instead of finding reasons for them being correct relates to the purpose of writing a graduation thesis. First, I believed that I had to write world changing results. Proving that what I investigated is awesome and that my solutions are the best. If I would have done some self-reflection and asked myself if I was walking the right path, things would be different.

What I have also learned is that the story in my head is not the story in someone else's head after two minutes of quick introduction. I should have taken more time to explain the context of the thesis or theories before asking questions. This leads to better answers and discussions and less frustration from my part.

A lesson that I have learned is that I don't have to do everything alone and that people like to help. A reason for not asking help was that I felt that I did not want to waste other's time for trivial questions. I forgot that everybody has the freedom to say no.

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Appendices

Appendix A Initial theoretical conditions

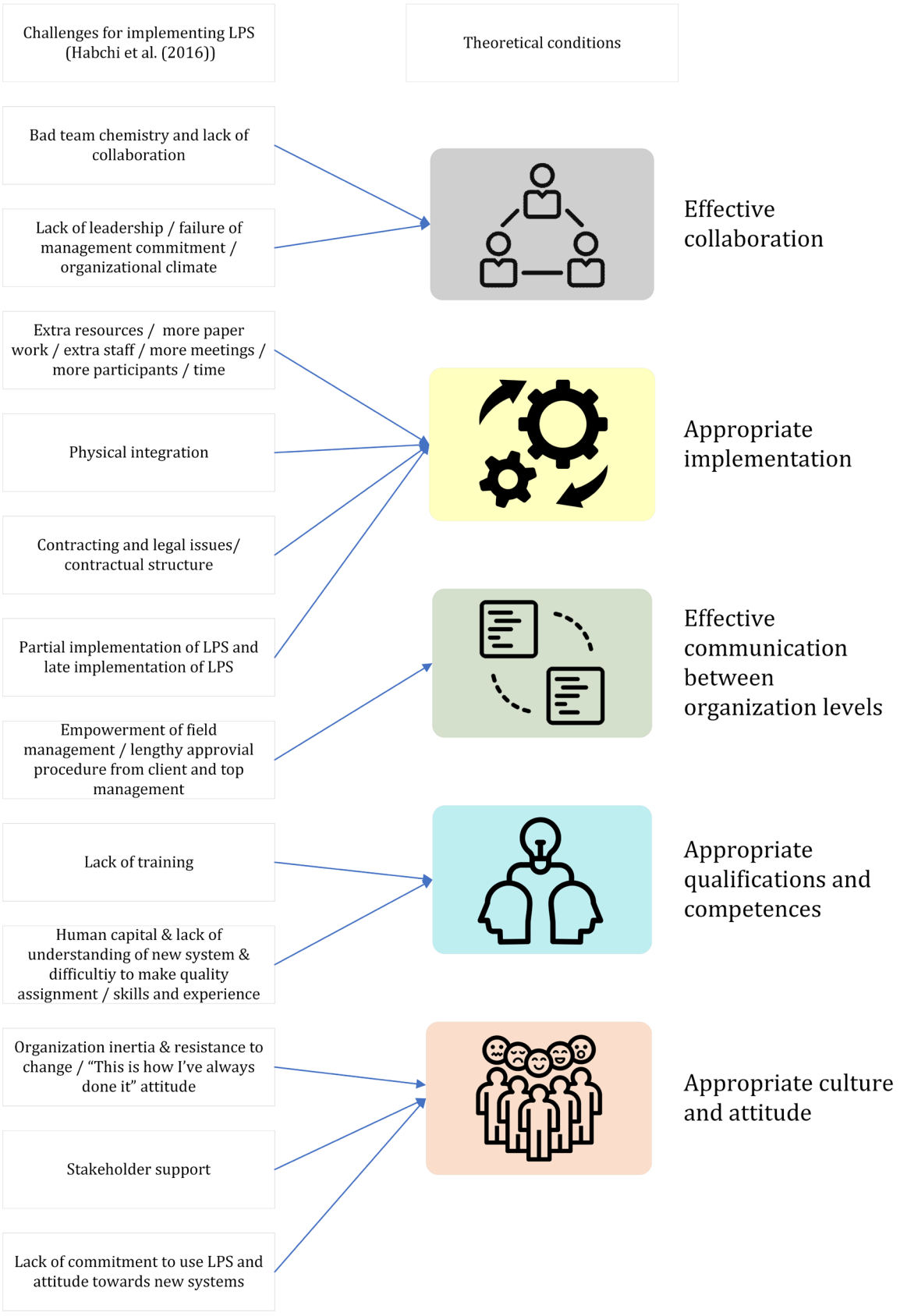

Figure 15 Clustering theoretical characteristics based on 12 challenges for implementing LPS (Habchi et al., 2016)

Appendix B Interview protocol case respondents

The interviews that have been conducted are the same for both cases. The interviewer brought small snacks to the interviews because it was during Christmas time and Sinterklaas and it is habit to have a sweet snack accompanied with coffee in The Netherlands.

The interviews take one hour and ten minutes and were divided as follows:

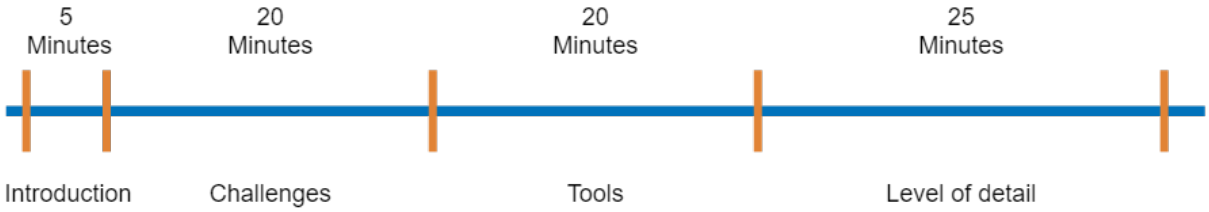

Figure 16 Interview timeline

The interviews are conducted at the location chosen by the interviewee.

The interviewer made sure there was a peaceful ambiance where the interviewee could talk freely. The interviewee remained critical and focused on the subjects of the interviews. The interviewer has all the questions in front of him on a paper. After the interview a summary of the conversation is send to the interviewee within a week.

Introduction

- Bedankt voor uw tijd en moeite om dit interview te doen
- Ik zal u zo min mogelijk vertellen over de inhoud van mijn onderzoek voor het interview om zo objectieve resultaten te krijgen
- Heeft u er bezwaar tegen als dit gesprek wordt opgenomen?
- De resultaten zullen geanonimiseerd worden en de opname zal gebruikt worden voor het uitschrijven van het interview.
- Vindt u het goed om een samenvatting van dit gesprek te lezen en goed te keuren?
- Wat is uw rol binnen dit project?
- Wat is uw werkervaring binnen de constructiesector?
- Heeft u ervaring met traditioneel plannen en het bijhouden van de voortgang

Questions about the process

- Wat zijn volgens u de belangrijkste uitdagingen van dit project?
- Introduceren uitdagingen van plannen:
- Coördinatie
- Raakvlakken
- Tijd inschatten
- Wat is het effect van deze uitdagingen op het project?
- Op welke manier wordt op dit moment met deze uitdagingen omgegaan?

Questions about scheduling tools

- Heeft u ooit geparticipeerd in een Lean of Sprint sessie?
- Welke verschillen ziet u tussen traditioneel plannen en kort-cyclische tools zoals Lean en Sprint
- Heeft u een voorkeur tussen traditioneel plannen of kort-cyclisch plannen?

Questions about level of detail

- Is er een verschil tussen de gekozen planningstechnieken per detailniveau?
- Hoe wordt er tussen management lagen gecommuniceerd over de planning?
- Wat is volgens u de beste manier om de planning bij te houden?
- Wat moet er in dit project veranderen om dat te bereiken?

Finalizing

Bedankt voor uw medewerking. U krijgt een samenvatting van dit gesprek toegestuurd binnen een week. Zou u deze willen lezen en aanpassen waar nodig? Daarna als u hem gemaild heeft dan beschouw ik hem als goedgekeurd.

All the documents contain quotes which are numbered in Atlas.TI. On request the documents including the quotes can be supplied in order to trace the origin of the findings. It should be noted that the quotes could need the context of a part of the summary or audio document. The quote number gives an indication of the location in the document and the audio file where the information was found.

Appendix C Observation protocol for observing scheduling activities

The observations are done on the construction site of the two selected cases. The activities that are followed are scheduling activities. These are the activities where tasks are scheduled in a certain sequence, durations are estimated, and agreements are made on how to cope with difficulties performing these tasks.

Access to the scheduling activities was given by the project organizations which are cooperating with The Consultant on the two construction projects. The period of observations is from the 1st September to the 21st of December of 2018.

8.1.1 Observation setup

- Notes are made on a laptop
- No recording
- Observer behaves as inconspicuous as possible

8.1.2 Role of observer

The role of the observer is to be independent and not interfering during the scheduling sessions. The coordinators of The Consultant explicitly introduce the observer as an independent observer graduating at the company.

If one of the participants of the meetings asks for input the observer politely answers that it is not his place to answer that question during this meeting. There would however be room to discuss with the observer after the meetings.

8.1.3 Behavior of the observer

After the introduction the observer takes place in the same room as the meeting. The observer would sit in a corner as still as possible. No attention should be drawn to the observer.

8.1.4 Behavior of the participants

The participants can be expected to behave differently as proven in the Hawthorne experiment. This would skew the results of the observations. The results are discussed with the coordinator of the meetings which has experience with the participants and had meetings without observations before. If the behavior is significantly different, the causes are discussed, and the results are nuanced.

Observations are done as much as possible in the same types of meetings. The participants can get used to being observed and go back to their default behavior. Repeated observations also contribute at monitoring different types of behavior and not be bound to a momentary observation.

Appendix D Validation protocol

Expert opinion is used to validate the found critical project factors. The aim of the validation is assessing the applicability of the critical project factors to assess the appropriateness of projects for short-cyclic scheduling. Also, the applicability of the CPFs considering managerial implication is discussed, to assess whether the CPFs have an actual practical use for construction managers in future projects.

The experts that are used for the validation are:

- Independent tender manager
- Project leader at a contractor

All three experts have experience working for both consultancy companies such as The Consultant and contractors. The experts are chosen on experience with scheduling during the execution phase of construction projects.

The validation sessions are held using a semi-structured interview of one hour.

Begin gesprek

Bedankt voor uw tijd. Het gesprek zal ongeveer een uur duren.
Heeft u er bezwaar tegen als dit gesprek wordt opgenomen? Ik stuur u een Engelse uitwerking van het gesprek, als u onjuistheden vindt, zou u dan via de mail willen reageren? Dan pas ik het aan.

Uitleg doel van het gesprek

Met dit gesprek wil ik inzicht krijgen in de toepasbaarheid van de basiscondities voor het implementeren van kort cyclisch plannen. Met kort cyclisch plannen bedoel ik het frequent houden van standups of planning sessies waar de planning wordt bijgehouden door de personen die verantwoordelijk zijn voor de uitvoering van het werk. In de meeste gevallen dus de uitvoerders.
Ik wil onderzoeken in welke mate u de KPFs erkent als vereisten voor kort cyclisch plannen. Na een gesprek over de basiscondities van ongeveer twintig minuten bespreken we de aanbevelingen voor constructieprojecten.

Dit zal in drie stappen gaan, namelijk de voorbereiding van KPFs, het aanpassen van het projectcondities en het onderhouden van de KFPs. Hier zal het gaan om de activiteiten die uitgevoerd moeten worden om de basiscondities voor kort cyclisch plannen te bewerkstelligen.
Introductie van de gegroepeerde kritieke project factoren

Per groep wordt besproken of de KPFs compleet zijn en toepasbaar zijn
Per groep wordt besproken of de basiscondities echt basiscondities zijn of niet noodzakelijk