Towards Proactive Project Management of large construction projects

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CoSEM master thesis

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TU Delft

PACER
Houdt vaart in uw proces

Colophon

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Preface

My interest in large construction projects and the course 'Strategic Management of Large Engineering Projects' in my master program are the main reasons to choose project management as topic for my thesis. For this course we had to study projects that were dealing with tremendous budget, cost and time overruns and analyze the causes of these overruns. I wondered how it was possible that all these big companies were not able to meet their goals since the causes of these problems were so obvious, so I decided to solve that problem.

Or so I thought. I have been studying project management of large construction projects and factors associated with their success and failure for the last few months and I must admit, I understand why managing complex projects can be so hard. But by studying lessons learned and success and failure factors in projects and identifying leading indicators for project management success, I think I have contributed something useful to the field of project management.

This contribution could not have been made without the guidance of my graduation committee. I would like to thank my second supervisor Martijn Leijten with his useful remarks regarding project management practices and chairman Hans de Bruijn for his insightful comments on how to maintain applicability of my deliverable. Then I would like to thank Vincent van der Meijden for his useful insights and granting me the opportunity to conduct my research at PACER. In addition to that, I want to thank the people at PACER who always made time for me when I needed a different perspective on my thesis, a professional opinion and participation in interviews and the workshop. Furthermore, I am grateful for having Martijn Warnier as my first supervisor, who was always there for advice, feedback and support whenever I needed it.

Last but not least, I want to thank my friends, my parents and especially my brother for supporting me during the whole graduation process. They provided me with a listening ear when I needed one and with advice when I did not know what to do. Special thanks to Yentle, who has been a great support and helped me to take the design of my thesis to a higher level.

Ronald Bierlaagh

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Executive Summary

Introduction

Large Construction Projects are complex undertakings: they are one-of-a-kind projects that take a long time to complete, involve a broad variety of stakeholders with conflicting goals and are subject to a variety factors. From time to time, high profile projects make the news by exceeding their budget and schedule and end up taking longer to complete and costing more than twice than their initial estimates at the start. This is caused partially by factors that exceed the level of the project and result from difficult economic, environmental and political decisions and influences, but also by factors that could have been dealt with by the project management. This thesis focusses on the factors which project management can respond to in order to improve project management success.

Problem statement

'Project management success' has three criteria: meeting schedule, budget and scope, maintaining process quality and meeting process needs for stakeholders. Projects have monitoring and controlling practices in place in order to achieve project management success, but these monitoring practices mainly focus on indicators for the first criterion (meeting schedule, budget and scope). The results are lagging indicators that do not monitor the process or its quality.

The metrics that are measured are outcomes of the project until thus far and are only predictive for project management success in the sense that past performance is extrapolated and used as forecast. Currently, there is a lack of indicators that are leading for project management performance and that reflect project management processes instead of project outcomes.

Objective and research questions

The objective of this research is to develop Proactive Project Management in which leading indicators for project management success are monitored and can responded to by the project management. This requires the identification of Control Indicators, which are defined as: 'leading indicators for the performance of project management success which can be acted upon by the project management'.

In addition to identifying Control Indicators, a monitoring system has to be designed. This monitoring system should come with a process description to ensure that it can be used by project managers and other project management professionals to respond to the Control Indicators. This leads to the following main research question and sub questions:

> ***Can traditional project management be redesigned to incorporate the monitoring of leading indicators during the project?***

- Which Control Indicators can be identified and formulated?
- What would the design of the Monitoring/feedback-system look like?
- How can the Monitoring/feedback-system be used to respond to processes reflected by Control Indicators?

Research methodology

Proactive Project Management is realized by identifying Control Indicators. These indicators are formulated based on existing literature on (critical) success/failure factors, Key Performance Indicators and lessons learned in Large Construction Projects. In addition to this literature, project management professionals are interviewed regarding their experiences with monitoring in projects and why projects succeed or fail. Based on this information Control Indicators are identified and formulated. They are validated by an Expert Panel consisting of six project management experts.

Control Indicators have to be selected, monitored and displayed in order to allow project management professionals to responding to the indicators. To fulfil this function, the Monitoring/feedback-system is designed in which the Control Indicators are embedded. The functional requirements for the Monitoring/ feedback-system are collected through a literature study into monitoring and controlling practices, a brainstorm with project management professionals, requirements stemming from the ability to incorporate the Control Indicators and considering practical applicability of the system. In order to ensure practical relevance and applicability, the Monitoring/feedback-system is evaluated by an expert.

Results and conclusions

Proactive Project Management is designed by answering the three sub research questions. The result of the research is a list consisting of 93 validated Control Indicators in four different categories. For each of the categories a Quality Function Deployment is provided; this is a tool for selecting a set of Control Indicators that could be monitored. By allowing the user to enter preferences regarding certain properties of Control Indicators (measurability, communicability, reliability and sensitivity), a set of ranked Control Indicators is suggested for monitoring.

This tool is accompanied by a flowchart that describes the process that a project manager should follow in order to effectively use the Monitoring/feedback-system and its Control Indicators. The flowchart describes three phases in project monitoring:

1. Designing a monitoring plan
2. Creating support for the plan, develop a dashboard for monitoring and defining follow-up actions
3. Monitoring the selected Control Indicators and respond using the suggested process

The combination of the Control Indicators, their selection tool and the flowchart allows project managers to select leading indicators suitable to their management preferences and supports them in developing a monitoring plan to respond to Control Indicators.

Reflecting on the main research question, it can be concluded that traditional monitoring can be redesigned to incorporate leading indicators. However, Proactive Project Management alone will not be able to fully control Large Construction Projects, but it could provide insight in the performance of project management processes and contribute to achieving project management success.

Recommendations

Proactive Project Management should be combined with traditional monitoring and controlling to cover a broader spectrum of indicators than under the current practices. This way leading and lagging indicators are measured for both 'project' and 'process' aspects of project management success.

The Control Indicator selection tool can be used by companies to select Control Indicators based on their clients' preferences and shift their focus to processes that the client considers important. In addition to the use by companies, project management professionals all have their own specialization in projects, such as contract- and environment management and project controlling. These professionals could use the Control Indicators as 'process' addition to their 'project' services and this way distinguish themselves from competitors.

The recommendations for further research regarding Proactive Project Management would focus on its validation, identification of additional Control Indicators and exploring standardized project controlling. Although the Control Indicators are validated and the Monitoring/feedback-system is evaluated, it is not validated in practice. Therefore, a study into the validation of the Monitoring/feedback-system is recommended. The list of Control Indicators is non-exhaustive; not all factors identified in this thesis are translated into Control Indicators due to time constraints. The Control Indicators are based on success and failure factors in projects. Project management processes and theory on process management could be a useful source for the identification of additional Control Indicators. During the research it was found that there are no standardized project controlling management methods and that more research into project controlling could be conducted.

Samenvatting

Introductie

Grote bouw- en infraprojecten zijn complexe ondernemingen: ze zijn uniek, nemen veel tijd in beslag en er zijn veel verschillende partijen bij betrokken met soms tegenstrijdige belangen. Daarbij zijn ze onderhevig aan een groot scala van interne en externe factoren. Van tijd tot tijd komt er een groot project zoals de Noord/Zuidlijn of de Betuweroute in het nieuws doordat het project langer gaat duren en de kosten hoger uitvallen dan verwacht. Dit komt deels door factoren die boven het project uitstijgen en te wijten zijn aan economische en politieke besluiten. Maar het kan ook liggen aan factoren waarop het management van het project had moeten reageren. De focus van dit afstudeeronderzoek ligt op de factoren waar het projectmanagement op kan reageren ter verbetering van het projectmanagement succes.

Probleemformulering

'Projectmanagement succes' heeft drie criteria: de mate waarin planning, budget en het doel worden behaald, de kwaliteit van het proces en de mate waarin het proces voorziet in de behoeftes van betrokken partijen. Projecten worden gemonitord en beheerst om ervoor te zorgen dat projectmanagement succes wordt behaald, maar het monitoren richt zich voornamelijk op indicatoren voor slechts een van de drie criteria voor projectmanagement succes: het halen van de planning, budget en doel. Het nadeel hiervan is dat dit lagging indicators[1] zijn en er gebrek is aan indicatoren voor het proces of de proceskwaliteit.

De indicatoren die worden gemeten zijn het resultaat van het project tot aan dat moment en zijn alleen voorspellend voor projectmanagement succes door de huidige trend door te trekken. Momenteel is er een gebrek aan leading indicators[1] die voorspellend zijn voor de prestaties van het projectmanagement en die het projectmanagement proces reflecteren in plaats van alleen het resultaat.

Doel en onderzoeksvragen

Het doel van het onderzoek is om Proactive Project Management te ontwikkelen waarmee leading indicators voor projectmanagement succes kunnen worden gemonitord en projectmanagement professionals in staat worden gesteld hierop te handelen. Dit vereist de identificatie van 'Control Indicators', die gedefinieerd zijn als: 'leading indicators voor de prestaties van het projectmanagement succes waarop gehandeld kan worden door het projectmanagement'.

[1] In het monitoren van projecten wordt onderscheid gemaakt tussen twee verschillende soorten indicatoren: leading indicators (lastig te meten, maar hebben voorspellend waarde) en lagging indicator (makkelijk te meten, maar hebben beperkte voorspellende waarde).

Naast de identificatie van Control Indicators wordt een monitoringsysteem ontworpen: het Monitoring/feedback-system. Dit monitoringsysteem moet worden voorzien van een procesbeschrijving die projectmanagement professionals in staat stelt te reageren op de Control Indicators. Deze vereisten leiden tot de volgende hoofdonderzoeksvraag en deelvragen:

Kan traditioneel projectmanagent worden herontworpen zodat leading indicators tijdens het project kunnen worden gemonitord?

- Welke Control Indicators kunnen worden geïdentificeerd en geformuleerd?
- Hoe ziet het ontwerp van het Monitoring/feedback-system eruit?
- Hoe kan het Monitoring/feedback-system worden gebruikt om te handelen op Control Indicators en de onderliggende processen?

Onderzoeksmethode

Proactive Project Management kan worden gerealiseerd met behulp van Control Indicators. Deze indicatoren zijn geformuleerd op basis van de bestaande projectmanagementliteratuur over (kritieke) succes-, en faalfactoren, Kritieke Prestatie Indicatoren en opgedane kennis uit de bouw- en infrasector. Daarnaast worden projectmanagement professionals geïnterviewd over hun ervaring met het monitoren in projecten en waarom projecten slagen of falen. Al deze informatie vormt de basis voor het formuleren van de Control Indicators die vervolgens zijn gevalideerd door een panel bestaande uit zes projectmanagement experts

Control Indicators moeten worden geselecteerd, gemonitord en getoond om projectmanagement professionals in staat te stellen hierop te reageren. Deze functie wordt vervuld door het Monitoring/feedback-system. De functionele eisen voor het Monitoring/feedback-system worden verzameld door middel van een literatuurstudie naar het monitoren en beheersen van projecten en een brainstormsessie met projectmanagement professionals. Daarnaast moet ook de praktische toepasbaarheid worden meegenomen en wordt het systeem beoordeeld door een expert.

Resultaat en conclusies

Proactive Project Management is ontworpen met behulp van de antwoorden op de drie deelonderzoeksvragen. Het resultaat is een lijst van 93 gevalideerde Control Indicators, opgedeeld in vier categorieën. Voor iedere categorie is er een tool (de Quality Function Deployment) gemaakt waarmee Control Indicators kunnen worden gerangschikt op basis van de voorkeur van de gebruiker aangaande verschillende aspecten van de indicatoren (meetbaarheid, communiceerbaarheid, betrouwbaarheid en gevoeligheid).

Naast deze tool is er een flowchart gemaakt die beschrijft welk proces een projectmanager moet doorlopen om het Monitoring/feedback-system effectief te gebruiken. De flowchart beschrijft drie fasen in het monitoren van een project:

1. Het ontwerpen van een monitoring plan
2. Draagvlak creëren voor het plan, het ontwikkelen van een dashboard voor het monitoren van de Control Indicators en het definiëren van vervolgstappen
3. Het monitoren van de geselecteerde Control Indicators en wanneer nodig het voorgestelde proces doorlopen

De combinatie van Control Indicators, de Quality Function Deployment en de flowchart stelt projectmanagers in staat leading indicators te selecteren die aansluiten bij hun managementstijl en ondersteund hen bij het ontwikkelen van een monitoring plan.

Reflecterend op de hoofdonderzoeksvraag kan worden geconcludeerd dat traditioneel projectmanagement zo kan worden ontworpen dat het leading indicators monitort. Dit betekent echter niet dat Proactive Project Management op zichzelf voldoende is om grote bouw- en infraprojecten te beheersen. Het geeft wel inzicht in de prestaties van projectmanagement processen en draagt daarmee bij aan het behalen van projectmanagement succes.

Aanbevelingen

Proactive Project Management zou gecombineerd kunnen worden met traditionele monitor- en beheersmaatregelen zodat een groter spectrum van indicatoren kan worden gemonitord dan in de huidige situatie. Op deze manier worden zowel leading als lagging indicatoren gemonitord voor zowel de proces- als de project aspecten van projectmanagement succes.

De Control Indicator selectietool kan worden gebruikt door bedrijven om Control Indicators te selecteren op basis van de voorkeur van hun klanten en zich op deze manier te richten op de wensen van de klant. Daarnaast kan het ook gebruikt worden door projectmanagement professionals. Zij hebben hun eigen specialisatie, zoals contract- en omgevingsmanagement of projectbeheersing, maar kunnen zichzelf onderscheiden van de concurrentie door naast projectservice ook processervice te bieden gebaseerd op Control Indicators.

De aanbevelingen voor verder onderzoek aangaande Proactive Project Management zou zich richten op de validatie in de praktijk, de identificatie van meer Control Indicators en gestandaardiseerde projectbeheersingsmethoden.

Ondanks dat Control Indicators zijn gevalideerd en het Monitoring/feedback-system is geëvalueerd, is het niet gevalideerd in de praktijk. Daarom zou er een studie moeten worden gedaan naar de validatie van het Monitoring/feedback-system. De lijst van Control Indicators is nog niet volledig omdat niet alle gevonden factoren zijn vertaald naar Control Indicators wegens tijdgebrek. Control Indicators zijn gebaseerd op succes- en faalfactoren in projecten. Projectmanagement processen en procesmanagement zijn mogelijk goede bronnen voor het vinden van nieuwe Control Indicators. Tijdens dit onderzoek is naar voren gekomen dat er binnen de bestaande literatuur over projectmanagement weinig informatie beschikbaar is over gestandaardiseerde beheersmethoden; een studie hiernaar doen en een methode ontwikkelen zou nuttig kunnen zijn.

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CI	Control Indicator
CM	Contract Manager
CSF	Critical Success factor
EP	Expert Panel
EVA	Earned Value Analysis
EVM	Earned Value Management
HoQ	House of Quality
IPM	Integral Project Management (Integraal Project Management)
KPI	Key Performance Indicator
KRI	Key Result Indicator
LCP	Large Construction Project
LL	Lessons Learned
MFS	Monitoring/feedback-system
OM	Environment Manager (Omgevingsmanager)
PB	Manager Project Control (Project Beheerser)
PI	Performance Indicator
PM	Project Manager
PMBoK	Project Management Body of Knowledge
PMS	Project Management Success
PPM	Proactive Project Management
PRINCE2	Projects In Controlled Environments
QFD	Quality Function Deployment
RI	Result Indicator
RWS	Rijkswaterstaat
SADT	Structured Analysis and Design Technique
SSF	Success/failure factor
TM	Technical Manager (Technisch Manager)

1 Introduction

1. Introduction

This research proposes a more proactive approach to project management of Large Construction Projects. Section 1.1 explains why there is a need for Proactive Project Management and how this type of management differs from traditional project management. This section ends with an initial problem statement. Section 1.2 elaborates on the scientific contribution of this research and practical relevance of Proactive Project Management. PACER, the company that facilitates this research, is briefly discussed in section 1.3. The introduction is concluded with a reading guide for the rest of the thesis in section 1.4.

1.1 Proactive management

Large Construction Projects fulfil important functions in society (Eriksson, Larsson, & Pesämaa, 2017), cost large sums of money and therefore, need to be of sufficient quality to fulfil their roles (Atkinson, 1999). From time to time LCPs make the news because of their overruns in schedule (Noord/Zuidlijn[2]), budget and/or failing to deliver (Betuwelijn[3]); reasons for this can be caused by a broad variety of technical, social, political, environmental, economic and legal factors . The combination of these factors makes the management of projects a complex practice (Veeneman, 2004). Some factors are a part of trends that exceed the scope of the project, such as decisions made by the government; other factors are within the scope of the project, such as the design of certain processes. Project success is achieved through two different types of success: project management success and product success (Figure 1). This research focusses on project management success (PMS).

Figure 1: Project success, based on (Collins & Baccarini, 2004) and (Al-Tmeemy, Abdul-Rahman, & Harun, 2011)

Project management performance is the measure to which extent project management success is achieved (Collins & Baccarini, 2004), which is illustrated in Figure 1. After the project is finished, its performance is assessed by comparing their initial budget, schedule and quality with the realization, resulting in scores on Key Performance Indicators (KPIs) such as 'profit', 'budget overrun' and 'schedule overrun'. These KPIs are lagging, meaning they only reflect past performance (Poel, 2011); measuring them does not necessarily help in reducing overruns or achieving the desired quality. These KPIs often only reflect the criteria of point 1 of PMS (Figure 1). The quality of the process to reach a goal (such as 'project success') can be an indication of whether the goal will be reached at all; through this line of reasoning, process performance can be an indicator for PMS and thus for project performance. Monitoring and measuring indictors that predict performance (leading indicators) opposed to indicators

[2]This project is not yet finished (March 2018) while its delivery was originally planned in 2011 (Cobouw, 2017)
[3]The Betuwelijn cost 4,7 billion euro; more than four times as much as scheduled while not living up to expectations (Volkskrant, 2017)

that merely reflect performance could provide valuable insights during the project and allow an intervention before budget/schedule overruns have taken place (which results in bad performance on KPIs). Monitoring leading indicators in order intervene on time instead of measuring lagging indicators as outcomes, is a proactive approach; it allows projects to be controlled sooner (as illustrated in Figure 2) and require interventions to be less invasive.

LCPs are complex projects in which many different processes and procedures have to be followed to ensure that LCPs are completed according to their plans. The focus in projects often lies with the outcome of these processes and not with the process itself, while the performance of these processes can be leading for whether the desired outcome is achieved.

This research aims to provide project management professionals involved in LCPs with leading indicators that can be monitored and indicate performance of processes influencing PMS. The combination of providing project management professionals with leading indicators and using these indicators to respond timely in projects, results in the following initial research question:

> ***Can leading indicators be identified and contribute to project management by making it more proactive?***

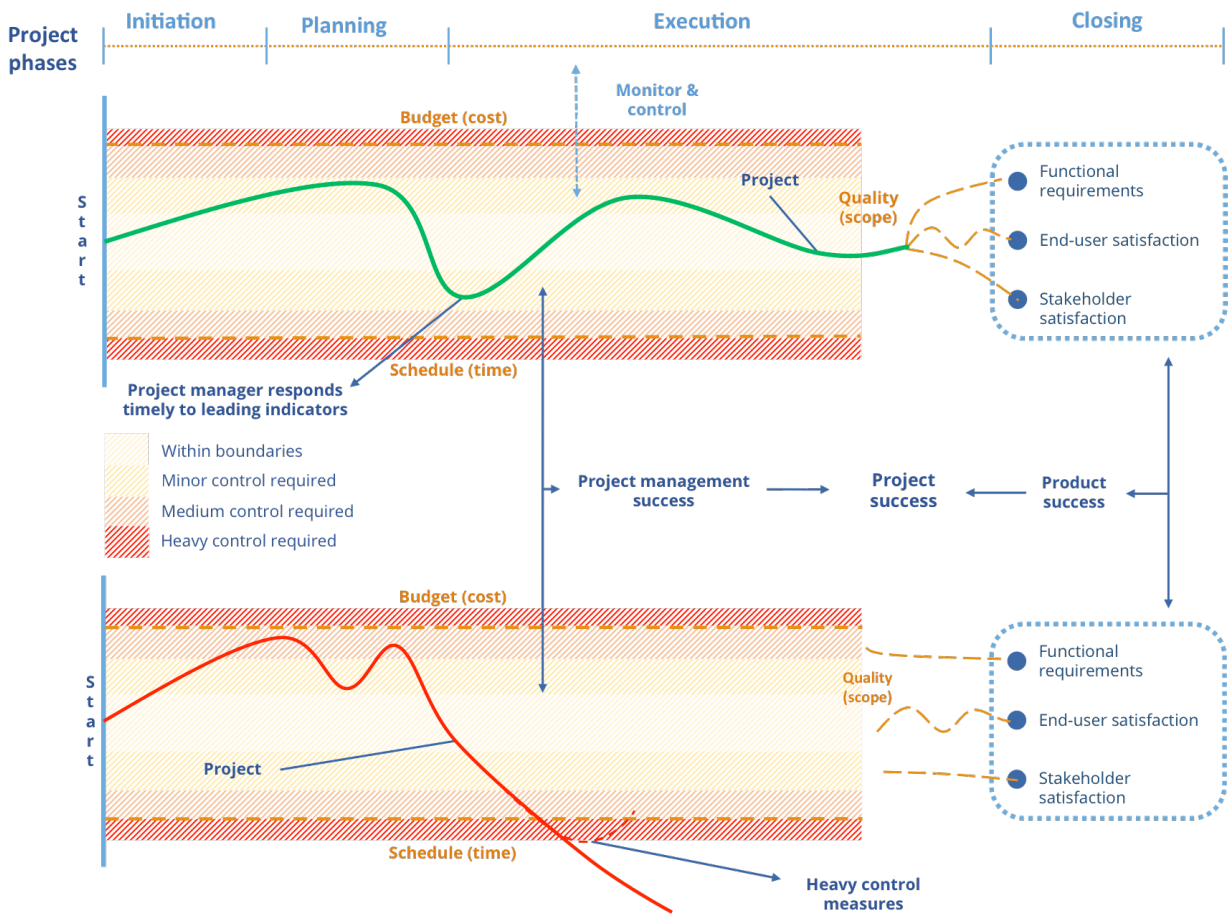


Figure 2: Project controlled in time (upper); Project not controlled sufficiently (bottom)

Through contributing to the development of a more proactive form of project management, this thesis aims to make the control of projects easier on the level of processes relevant to project management success (Figure 2). Therefore, this research will focus on monitoring indicators for project management performance that are different from indicators monitored in traditional project management, which will be explained in more detail in section 2.4.

1.2 Contribution of this thesis

This thesis aims to contribute to the scientific knowledge of project management, with the focus on identification of leading indicators for project management performance based on (critical) success and failure factors, Key Performance Indicators and Lessons Learned in LCPs. Since every LCP is unique, a tool and process are developed that supports the selection and monitoring of the leading indicators.

The societal relevance of this thesis is achieved through making the knowledge of project management professionals regarding success and failure of projects explicit using different methods (interviews, workshops). These activities forces project management professionals to think differently in terms of performance and monitoring and might provide them with a different perspective.

Proactive Project Management aims to provide insight in processes by monitoring indicators that otherwise would not have been monitored. Through monitoring leading indicators for project management processes and by suggesting a follow-up procedure, this thesis aims to contribute to the improvement monitoring and controlling in projects. Project management professionals could use the indicator selection tool to find leading indicators for project management success suitable to their project, management team and organization.

1.3 PACER

The practical knowledge and project management professionals that are consulted for this research are provided by PACER B.V. PACER is a project management consultancy firm based in Utrecht and Rotterdam. The name is an abbreviation of its fields of expertise: Project management Advice, Contract management and Risk management.

PACER has been involved with different municipalities and large project developers; its consultants have been involved in a variety of project types, such as sluices, highways and off-shore windfarms: ranging from small projects to large infrastructural ventures. In addition to providing project management consultants, PACER also organizes courses such as Contract Management and System Engineering.

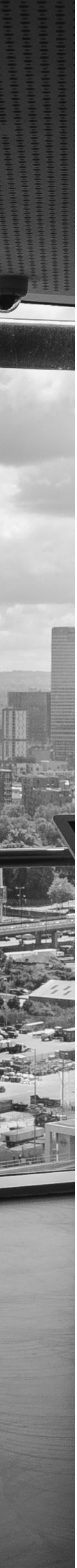
1.4 Reading guide

'Identification of leading indicators for Proactive Project Management', is a broadly formulated statement which needs further examination in order to demarcate the boundaries of this research. Therefore, the thesis starts with a literature review which covers topics such as Large Construction Projects, project success, project performance and monitoring and controlling in projects (Chapter 2). The results from the literature study are used to develop a research design, which is described in chapter 3.

In order to realize the monitoring of processes in projects, Control Indicators are suggested as an alternative to KPIs, which are explained chapter 4. These Control Indicators are embedded in a Monitoring/feedback-system, which helps project managers selecting Control Indicators suitable to the project. This Monitoring/feedback-system is discussed in chapter 5.

In chapter 6 the most important findings of this research are presented. This thesis is concluded in chapter 7 where the research questions are answered and recommendations are made regarding proactive management in practice and possibilities for further research. Chapter 8 contains a personal reflection.

2 Literature review



2. Literature review

In the introduction is argued that a more proactive approach to project management could help to control projects. This chapter contains the literature review, sets the context of the thesis and explains important concepts such as project success, performance and monitoring are explained. The chapter ends with the conclusions of literature review, a description of proactive project management and the identified knowledge gaps.

2.1 Context: Project Management Body of Knowledge

Every endeavor undertaken in order to achieve a goal is in essence a project. As long as people roamed the earth, large construction projects have been executed: from the pyramids in Egypt (2630 BC) to the 829m-tall Burj Khalifa in the United Arab Emirates (2010). The construction process of the Egyptian pyramids remains shrouded in mystery, but how the (currently) tallest building in the world is build has been well documented. Although every project is a unique one, project management methods have simplified the way projects are managed, or at least structured its management.

Project Management as field of research as we know it started in the aerospace, defense and construction industry and originates from around 1960 (Healy, 1997). The most used methods are PMBoK, PRINCE2 and Agile. Since PMBoK is the most used method (PWC, 2012), this project management methodology is used as a reference for this research and its history is briefly explained.

PMBoK is the abbreviation of 'Project Management Body of Knowledge'. It is a method compiled by the Project Management Institute (PMI), which was founded in 1969 as a non-profit organization (Project Management Institute, 2017). In 1975 its mission was to "foster recognition of the need for professionalism in project management; provide a forum for the free exchange of project management problems, solutions and applications" (Chumas & Hartman, 1975, p. 141). These efforts eventually led to the first PMBOK in 1996 and has been used widely all over the world, in particular in North America, South America and Asia. It also forms the basis for the 'Project Management Professional'-certification.

Since its first version from the 1996 the PMBOK as well as general project management practices has evolved significantly, the fifth version appeared in 2013. PMBoK is known for its waterfall-like structure and consists of the following project management phases: initiation, planning, execution, monitoring & control and closing (Project Management Institute, 2013).

2.2 Large Construction Projects

This section will provide a brief definition of the concept 'Large Construction Project', elaborate on what makes projects and LCP in general difficult to manage and explain the need standardized project management methods.

Characteristics of Large Construction Projects

When is a project considered a 'Large Construction Project'? It is difficult to label a project 'Large' solely by its physical size. Large in this context means a multimillion Euro project with a timespan (planning/execution/closing) covering more than two years. The construction part of LCP relates to projects in the construction sector (both private and public) such as buildings, bridges, canals and roads. LCPs are characterized by:

- Covering a large time span
- One-of-a-kind projects
- Physical construction

Due to these features LCPs differentiate themselves from for example IT projects (require low investment in materials, physical construction and permits) and the manufacturing industry (iterative, continuous processes).

Complexity and uncertainty in Large Construction Projects

Project management is in essence all practices used to realize a project from initiation to planning to execution to closing; during this realization the project is being monitored and corrected (controlled) were necessary. The reason project management is a challenge is because of complexity and uncertainty; these are the causes to all kinds of unexpected turns and events that could occur. Both are briefly explained along their implications for project management.

Complexity

In project management there are two types of complexity: structural complexity and dynamic complexity (Padalkar & Gopinath, 2016). Structural complexity in projects emerges through interfaces and elements: interfaces between both internal and external sociological and technological elements (Veeneman, 2004). Examples within LCPs are contact between different the owner and the project managers, the transfer of a construction from one contractor to its successor or the integration of different information and electrical systems.

Dynamic complexity within projects emerges from the fact that relations between elements and between elements and their environment can change. Dealing with change in scope, strategic behavior or with the shifting priorities of stakeholders can be very difficult and costly, especially when investments already have been made (Aaltonen & Kujala, 2016). In addition to these two types of complexity, uncertainty also contributes to complexity (Jarkas, 2017). Although both of these concepts have interdependency of sub systems as a confounding factor, uncertainty is closely related to the absence information, whereas complexity emerges from size, diversity, organization arrangements (Padalkar & Gopinath, 2016).

Uncertainty

There are different types of uncertainty: known unknowns and unknown unknowns. The first category includes identified risks: there is an (estimated) chance that an event will strike, and when it strikes this will have impact on the project. Different risk management tools have been developed and integrated in project management methods over the last decades. Risk management is proved effective in reducing negative impact from risks (Raz & Michael, 2001) and is considered essential for good project management (A. Pinto & Alali, 2009). An example of a risk is the fluctuation of fuel prices or unusual harsh weather conditions. The second category uncertainty, unknown unknowns, are events that could occur but are beyond the realm of expectations (and sometimes even imagination).

Due to the complexity of LCPs project management is often not satisfactory (Bertelsen, 2003). Uncertainty and organizational complexity rank 1 and 2 as sources of complexity in a survey conducted under project management professionals (Jarkas, 2017) and require flexibility of the process. Complexity generates unexpected behavior (Floricel, Bonneau, Aubry, & Sergi, 2014), which makes it hard for project management methods to deal with it (Böhle, Heidling, & Schoper, 2016). And since LCPs are temporary endeavors with a waterfall-structure (Project Management Institute, 2013), have a strong emphasis on planning-and-control structures and limited sensitivity to environmental influence (Daniel & Daniel, 2017), it is very hard to respond to issues that occur in projects.

Concluding: The characteristics of LCPs (singularity, physical construction and covering a large time span) together with the sources of complexity and uncertainty (such as stakeholder interactions) are a difficult combination to manage.

2.3 Performance and success

The statement from section 2.1 states that project management performance has not improved over the last decade. This raises the questions: what exactly is 'performance'? When is a project a 'success'? In this section the meaning of project performance and success are defined. Section 2.3.1 elaborates on what makes a project a success. Project performance and the link to project success is explained in 2.3.2. The link between success and performance is discussed in section 2.3.3.

2.3.1 Defining success

Among project management professionals there are different ideas on how to evaluate and determine success; it is one of the most studied topics in the field (Littau, Jujagiri, & Adlbrecht, 2010). Since this concept is essential to this thesis and the broader understanding of project management it will be discussed in this section.

LCPs are arena's in which many stakeholders with divergent interest are bound together through their participation in the project (Maylor, Vidgen, & Carver, 2008). They are not necessarily bound by a common goal: whereas the client wants the most durable materials for the lowest price, the supplier of the materials wants to maximize his profit by providing the materials that marginally satisfy the client; this reciprocity can result in a suboptimal situation (Davis, 2014). This is not something that always occurs, but examples of conflicting interests are plentiful in projects and happen on all layers. Since projects involves high-level organizational management, low-level construction site workers and everything in between, principle/agent issues arise (Turner, 2009), resulting in contradictory interests and goals (Schneeweiss, 2003).

From a project management perspective there are three different aspects to project success: project management success, product success and project success. Although the success of each aspect depends on the goals of the stakeholders involved, these concepts and how they are linked will be explained in in order to understand project success. On account of completeness, market success will be explained to paint the broader context.

Project management success

Project management success (PMS) is the success of the management of a project. This implies that the success is determined in how effective the management of project is in reaching its goal; which is ensuring that projects are finished as efficiently as possible within budget, schedule and of required quality, as well as securing sufficient quality of the project management process (Collins & Baccarini, 2004).

Product success

In the initiation phase a product (construction) is proposed in order to suffice in someone needs or a product is looking a window of opportunity to be realized. Either way, the next phase is entered and the product is designed, the project is planned and executed. The goal that has to be reached in order to speak of product success are customer satisfaction, functional requirements and technical specifications (Al-Tmeemy et al., 2011).

Project success

When product success is achieved along with project management success it could be stated that project as a whole was a success since the right product was completed within the constraints in terms of process quality and schedule, budget and quality.

Market success

Regardless what the product is, there is always a 'beyond the project'; stakeholders will have to deal with what is constructed, how they experienced the process and whether they made a loss or profit. If everything went well, stakeholders build a positive reputation, produced profit, gained knowledge and maybe even market share (Al-Tmeemy et al., 2011). Through this mechanism project management success influences market – or corporate – success (Cooke-Davies, 2002). In this case market success and PMS go hand in hand.

It is not unthinkable that market success, product success and PMS are at odds with each other: in the pursue to maintain a company, it has to have a steady revenue and at least make sure they do not have a negative turnover. When a company faces financial difficulties and cannot afford to lose a tender, it is possible the company want to ensure winning a tender by competing with an offer that barely covers the cost – or worse, does not cover the cost at all, which makes achieving project management success impossible.

Success across different scales

In figure 3 the relation between PMS, product success and market success is displayed. Finishing a project and adhering to budget, schedule and quality (depending where the client priorities lay) is necessary to ensure that project success is achieved. Repeatedly bringing products and projects to a successful end contributes to the market success of an organization. A stable and (financially) healthy organization that is able to compete and win in tenders and is more likely to finish projects according to plan. Through this mechanism short term success can ensure success on larger time scale.

The opposite is also possible: if an organization consistently fails to achieve PMS and/or product success and does not perform well in the market, it is more likely to take risks and tender for price and with a schedule that are not realistic. It is not hard to imagine this competitive tendering puts pressure on the availability of resources in project; which reduces the chances on project management success and subsequently jeopardizes the product success. With product success being essential for market success the loop is closed (Figure 3).

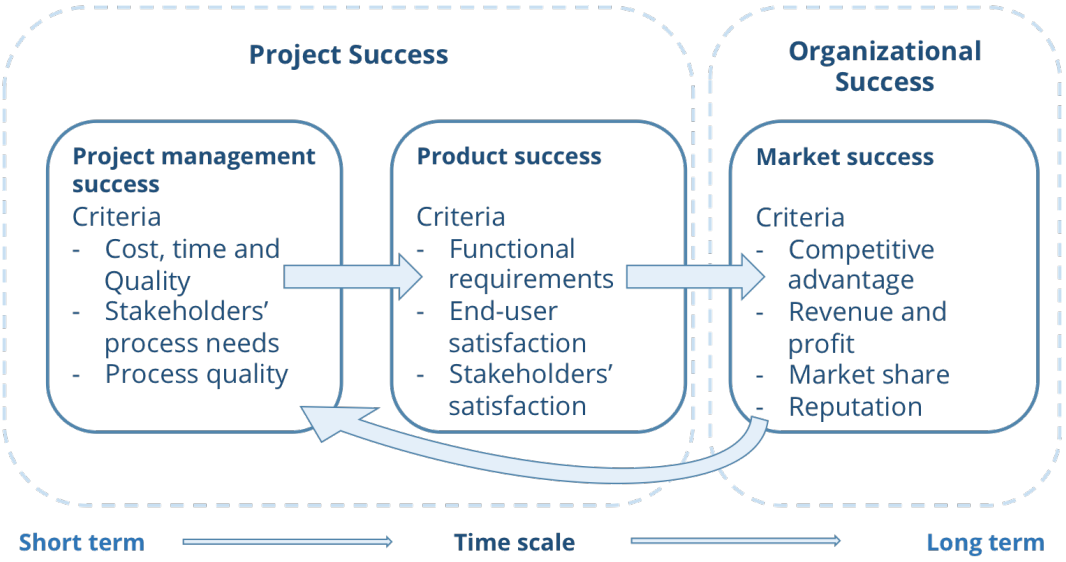
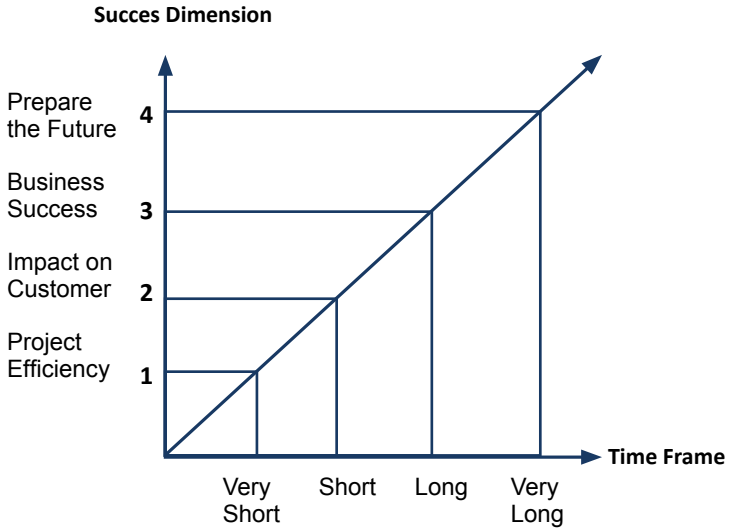


Figure 3: Project success in context – edited and reframed from (Al-Tmeemy et al., 2011) and (Collins & Baccarini, 2004)

The success dimension spans over different facets of an organization and thus different stakeholders, which creates ambiguity within the definition of success. The time frame complicates its definition even further since people in organizations and projects are replaced over time. The way different levels are defined by Shenhar et al. correspond in large with definitions of success from this section: project management success (1 – Project efficiency); product success (2 – Impact on customer); market success (3 – Business success).



Succes dimension	Measures
1. Project efficiency	Meeting schedule goal
	Meeting budget goal
2. Impact on the customer	Meeting functional performance
	Meeting technical specifications
	Fulfilling customer needs
	Solving a customer's problem
	The customer is using a product
	Customer satisfaction
3. Business success	Commercial success
	Creating a large market share
4. Preparing for the future	Creating a new market
	Creating a new product line
	Developing a new technology

Figure 4: Success versus Time (left); Success dimensions and their measures (right)(Dvir, Lipovetsky, Shenhar, & Tishler, 1998, p. 712 & 716)

Project management success has three criteria: meeting the iron triangle, satisfying process needs of stakeholders and ensure sufficient process quality (Collins & Baccarini, 2004). The iron triangle criteria also reoccurs in the literature by Shenhar et al., only they spread it across different dimensions (Figure 4). The lowest level described by Shenhar et al. included budget and schedule, but excludes quality/scope. They include it along with 'meeting functional requirements' and 'stakeholder satisfaction' in the second dimension 'impact on customer', whereas Collins & Baccarini see it as a part of 'product success'. The most important distinction between Collin & Baccarini and Shenhar et al. is that the former make the approach success in terms of the project (process and product), whereas the latter see success in the light of the organization.

According to Shenhar et al. the second dimension is about 'product success' which has to be achieved, preferably as efficient (fast and cheap) as possible. This creates tension within the iron triangle between quality goals and budgetary/schedule constraints, since their definition of success is not fully aligned.

Depending on the perspective, the definition success can differ; trying to satisfy one definition of success could put pressure on other definitions. The complications of the different perspectives of success are clear, but in order to measure to what extend success is achieved, it is necessary to determine the performance on the measures mentioned in Figure 4. The next section will elaborate on how success can be determined.

Concluding: different definitions of success include different goals. These goals can differ from stakeholder to stakeholder, even within the same project organization. Focusing on a certain goal could have implications for other dimensions of success across different time spans and organizational levels. The degree of success can be established by determining its performance on certain measures: performance.

2.3.2 Measuring performance

The research objective contains the sentence: 'improve overall performance of Large Construction Projects'. It is necessary do define performance of LCP in order to understand this sentence. 'Performance' is defined as: "the manner in which or the efficiency with which something reacts or fulfills its intended purpose" (Dictionary, 2017). In case of LCPs 'its intended purpose' is the purpose of the project: achieving the project goals. The extent to which organizational goals are achieved is often measured using Key Performance Indicators (KPIs) (Turner, 2009). But what exactly are KPIs?

Parmenter (2007) answers this question as following: "KPIs represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization" (Parmenter, 2007, p. 3). KPIs are one of the four types of performance measures (Badawy, El-Aziz, Idress, Hefny, & Hossam, 2016):

1. Key result indicator (KRI)
2. Result indicators (RI)
3. Performance indicator (PI)
4. Key performance indicator (KPI)

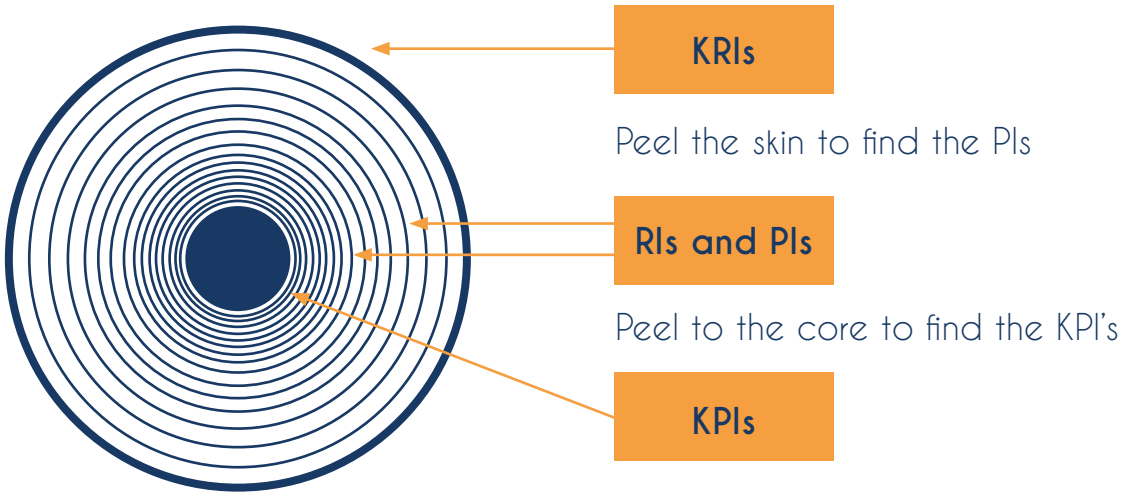


Figure 5: Four types of performance measure (Badawy et al., 2016, p. 48)

Monitoring these performance measures could result in the following conclusions: KRIs give an indication to what extend critical goals are achieved; RIs indicate what is achieved in general; PIs are an indicator for what should be done; KPIs are indicators for what should be done in order to increase performance considerably. Their relation is illustrated in Figure 5.

Leading versus lagging indicators

Apart from the difference between (K)PIs and (K)RIs, there is another important distinction in indicators to be made: leading and lagging. In Table 1 their main differences are listed.

Leading indicator	Lagging indicator
Input	Output
Hard to measure	Easy to measure
Easy to influence	Hard to influence

Table 1: Characteristics of leading and lagging indicators (Poel, 2011)

Leading indicators are measured in the beginning of a causal chain and carry a predictive value where lagging indicators (outcomes) are the results of business activities. Lagging indicators are not necessarily KRIs, but they are the result of decisions made.

2.3.3 Linking success and performance

Parmenter argues that the labels lead and lag are not useful for defining indicators and he supports this claim with the following argument: "At seminars, when the audience is asked "Are the late planes in the air KPI, a lead indicator, or a lag indicator?" The vote count is always evenly split. Surely, this is enough proof that lead and lag labels are not a useful way of defining performance measures" (Parmenter, 2007, p. 7)

Without any context Parmenter might have a point. But in light of the varying dimension of success (from the previous section) that is to be achieved, it can be useful to refer to the concepts of leading and lagging indicators. 'Planes flying on time' could be a lagging indicator (KRI of RI) for the boarding crew, but also be a leading indicator (KPI or PI) for the 'profitability' or 'customer satisfaction' of the airline company.

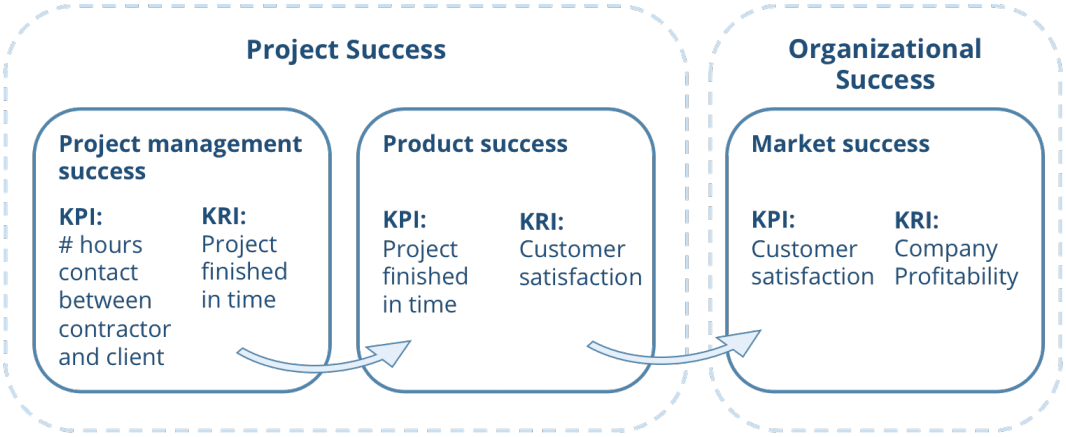


Figure 6: Key Performance Indicators and Key Result Indicators in different success-perspectives

Figure 6 visualizes that on a certain 'success'-level a Key Result Indicator (KRI) is a KPI for a different level. The yellow arrow could be interpreted as a 'contributes to' relation. In reality there are more KPIs per level and success can have multiple KRIs, depending on the stakeholder's definition of success.

Figure 3 and Figure 6 both include project management success, product success and market success and linking them through defining KPIs and KRIs for each step; the KRI for on success definition is the KPI for the other. This emphasizes that it in order to improve PMS, the correct KPIs have to formulated to achieve the KRIs, which comes down to complete the project within time and budget.

Analysis: ambiguity of KPIs

Although Key Performance Indicators are explained and its definition is clearly formulated, there is much ambiguity surrounding KPIs. It happens more than often that companies formulate the wrong KPIs: 'client satisfaction' is an example of a KRIs rather than a KPI. This may seem trivial, but it is of great importance to formulate KPIs that have a predictive value over what the performance will be on the final criteria, instead of reformulating project goals into KPIs.

Other KPIs are actually PIs because they are not essential in achieving the goal of the activity (this could be success in projects or profit in sales). KPIs are defined in different arenas throughout the professional world (Parmenter, 2007), ranging from KPIs for achieving long-term organizational goals to short-term project goals. This difference in scope muddies the waters around KPIs: 'Overall Project Profitability' is not a KPI for the construction of a new highway; it could be a KPI in reaching the goal of 'Market Success'. Analyzing KPIs among different sectors and projects is further frustrated by the difference scope of the KPIs.

In order to realize the proactive approach, the KPIs should be of a leading nature instead of a lagging nature. Keeping track of metrics during the project in order prevent the project to spiral 'out of control' requires them to be leading, not lagging. For as far KPIs are being monitored in LCPs (which is not often) they are mostly lagging (Ahmad, Svalestuen, Andersen, & Torp, 2016), thus providing little possibilities to respond to in a running project.

2.4 Project monitoring

In section 2.3 success and performance are discussed. In order to achieve success and perform sufficiently on the predefined measures project are monitored. Monitoring projects according to the PMBoK is: monitoring "... the work of producing the products, services or results that the project was undertaken to produce" (Project Management Institute, 2008, p. 9)

Monitoring is practice performed during almost the entire project, with emphasis on the planning and execution phase (Figure 7). The goal of monitoring is to notice irregularities or problems; the goal of controlling is to have an appropriate response to mitigate or contain negative effects. Therefore, monitoring is the first step in controlling a project and an adequate diagnosis is essential to deal with a problem.

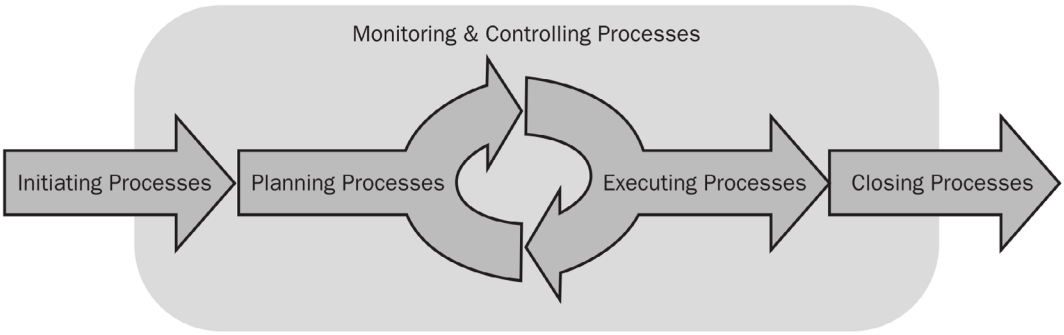


Figure 7: Project phases according to PMBOK (Project Management Institute, 2008, p. 19)

As mentioned earlier, LCPs are characterized by their nature as projects that are non-iterative; this creates the urge to do it right the first time. Diagnosing problems in an early stage saves time and money later in the process. The fact that in the introduction is argued for an proactive approach in order to intervene timely in projects might suggest that up until now nothing is monitored. That is not the case.

Different monitoring methods are used in practice and can be divided into two groups: quantitative and qualitative monitoring (Figure 8). Which monitoring practices are used is decided by the project management team, but in practice, if they are used both, they are used separate. In section 2.4.1 quantitative monitoring is discussed, in section 2.4.2 is elaborated on qualitative monitoring.

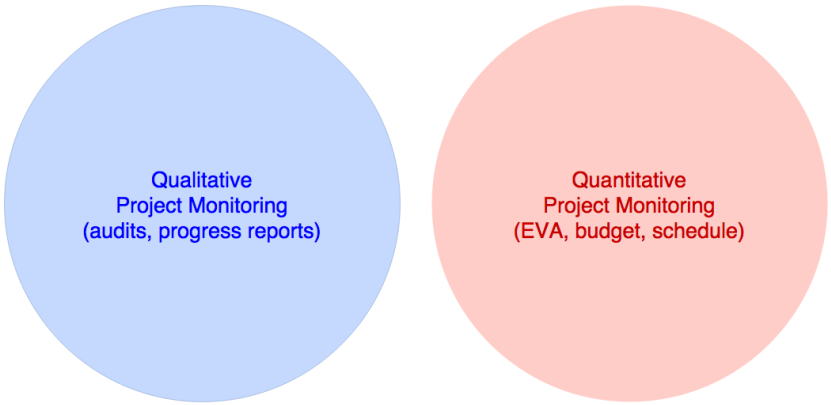


Figure 8: Qualitative and quantitative monitoring practices have no overlap

2.4.1 Quantitative Monitoring in project management

Project management in its current form already has certain metrics that are monitored during projects. 'Earned Value Management' (EVM) has been developed originally to support cost management and later to provide an indication regarding the project performance by integrating schedule, cost and technical performance (Vandevoorde & Vanhoucke, 2006). One of the advantages of EVM is that as long as a project has a clear schedule and budget,

it is possible to make a performance prediction (Chen, Chen, & Lin, 2016); this allows every project to be assessed in a standardized manner. EVM included a variety of analyses using (actual and expected) schedule and costs and had as goal to highlight corrective action (Vandevoorde & Vanhoucke, 2006). It compares the baseline schedule and budget to what has already been built and completed. Unless there are clear causes for a strong discrepancy between budget spent and work performed (e.g. high upfront investment), an EVA (Earned Value Analysis) could point out that value is not being created according to plans somewhere within the project.

One major drawback is that EVM has a heavy focus on cost and time (only two out of three iron triangle criteria, leaving quality/scope out) and the field of monitoring and controlling quality in the execution phase of projects has been understudied (Willems & Vanhoucke, 2015). Since project management success is often measured only through schedule and budget, the larger context (product success and projects success) can get lost in pursuit of success on the lowest level (Shenhar et al., 2001). EVM's focus on schedule and budget could result in decision-making on project management level that is counterproductive to goals on a higher organizational level.

The quantitative nature and "objectivity of numbers" of EVM make a strong case when decisions have to substantiated and communicated (e.g. towards higher management). EVM can be used to compare the project progress with the original plans, and this way provides (some degree of) performance measurement. The diagnostic value is dependent on the level of the EVM (whole project or specific work packages); more specific work packages are a better delineation of the problem area, but the analysis is also more time/cost consuming. Although the EVM is neutral in theory, it is possible contractors stretch the truth about work they performed. Pressure to satisfy the analysis could also lead to inaccurate results. The summary of advantages and disadvantages are listed in Table 2.

Quantitative monitoring in project management	
Advantages	Disadvantages
Predictive of project management performance	Schedule and budget as main drivers, leaving quality out
'Hard' numbers on schedule and budget are often available	Pressure to pass the monitoring audit instead of satisfying project
Objectively/neutral in theory	Numbers are not always neutral in practice
Baseline is available for budget and schedule	Limited diagnostic value: overruns are symptoms, but the causes or not clear

Table 2: Advantages and disadvantages of quantitative monitoring

2.4.2 Qualitative Monitoring in project management

Qualitative monitoring is broad collection of different monitoring methods: varying form mandatory progress reports from contractors to certified audits to diagnostic frameworks.

An analogy between project performance and human health was proposed by Mian et al.: "...project health is synonymous with project performance, if a project or any particular aspect of a project is not performing as expected by the stakeholders it would be perceived as unhealthy or failing on the other hand if it is fulfilling the expectation of the stakeholders it would be perceived as healthy or successful" (Mian et al., 2004, p. 3). The more 'sick' or 'out-of-control' a project is, the more radical its healing or recovery-efforts will be (Figure 9).

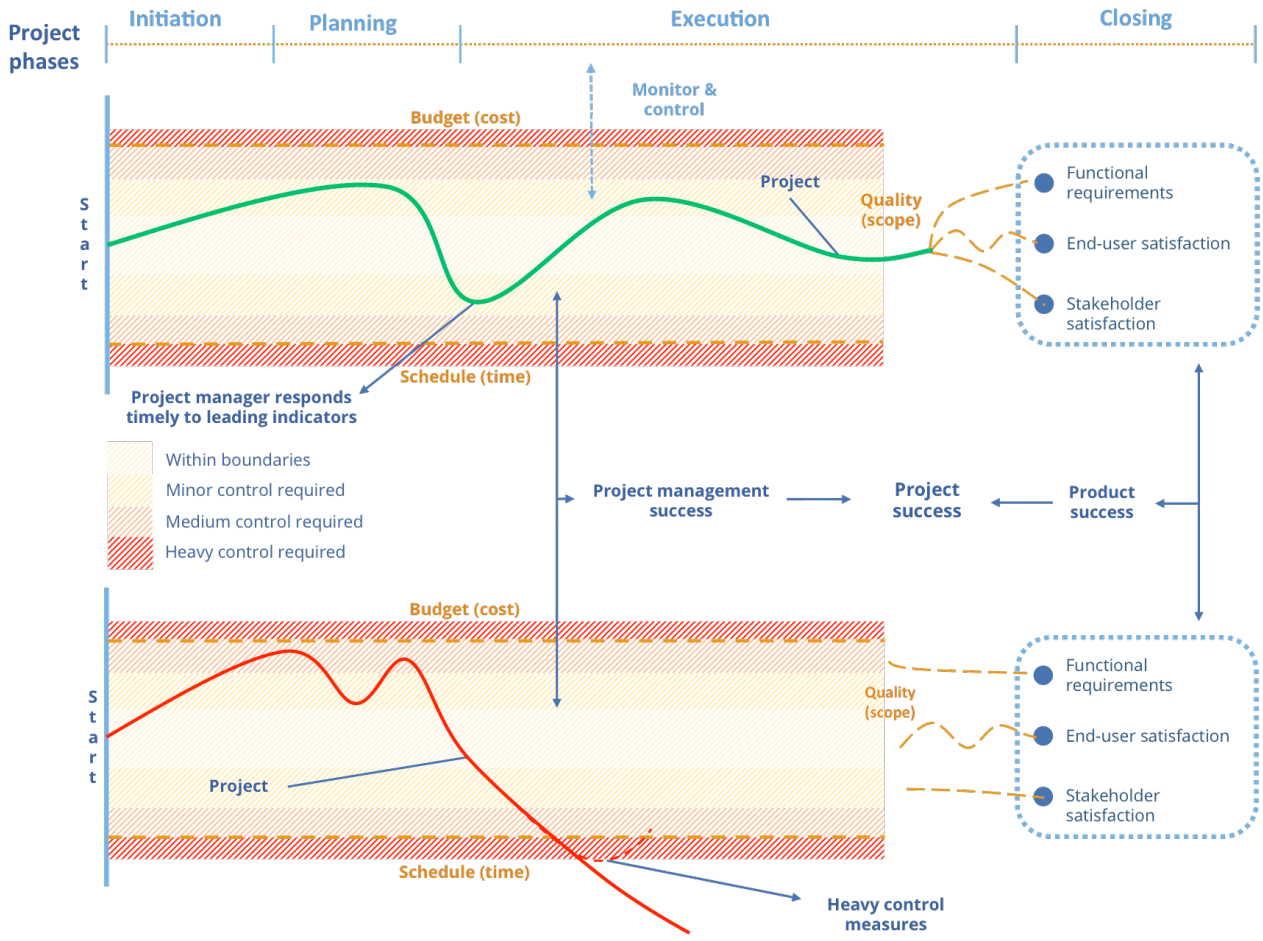


Figure 9: Upper diagram: in-control (healthy); Bottom diagram: out-of-control (sick)

When an out-of-control project is 'diagnosed' with a 'disease', project management can try to 'cure' it by reallocating resources. That is what makes the comparison so striking: if someone does not show up to work it is obvious that there is something wrong; but if you can feel the lymphs or notice that one's face is swollen, the symptoms (unusual values of KPIs) are identified and linked to a cause so treatment can commence. This is where qualitative monitoring could have an edge over current EVM practice.

In 2014 a tool is designed for a qualitative framework to perform a health check (Philbin & Kennedy, 2014). Projects are assessed on 'resources', 'technology', 'process', 'knowledge', 'culture' and 'impact'. This effort is worth mentioning since it tries to uncover what the cause is if of the project's underperformance, but it remains purely qualitative and provides little guidance in follow-up actions.

Monitoring & controlling audits and progress reports are qualitative monitoring methods often used in practice. Their main advantage is that provide detailed information (Ruskin & Estes, 1985). Audits can happen announced or be performed at random within the sample of contractors. Since performing audits is costly and time consuming not every contractor is audited. In this sense audits are not necessarily used as monitoring method, but more as a tool to ensure that contractors are delivering. Demanding progress reports from project participants serves the same purposes as the audit: gain information on the progress and stimulate progress. The drive to report progress stimulates participant to be productive in the project; the downside to this drive is that contractors might exaggerate the work performed.

Whether the results from progress reports and audits are either positive or negative, there is room for nuance and feedback to contractors or other participants. The main drawback of the qualitative monitoring is that although the 'soft' data could draw a more complete picture, it lacks the hard quantitative base and could cast doubt about the interpretation of auditors and the honesty of contractors. The advantages and disadvantages are summarized in table 3.

Qualitative monitoring in project management	
Advantages	Disadvantages
Includes a variety of aspects, including 'unmeasurable' data	Data is soft, causing it to be interpreted different ways
Target specific practices	Assessment could be experienced as 'biased'
Diagnostic due to the various aspects	Progress reports often have to come from bottom up (contractors)
	Only a small sample of work is audited
	Collecting data is laborious

Table 3: Advantages and disadvantages of qualitative monitoring

2.5 Integral Project Management – model

The IPM-model (explained in 3.3.1) is a model used widely in the Dutch construction and infrastructure sector (Rijkswaterstaat, n.d.) and is displayed in Figure 10. It provides structure and standardization in project management practices. The model is briefly explained related to project control.

The OM, TM and CM are the managers responsible for respectively the project environment, technical aspects and contracts. Project control is managed by the Manager Project Control and the client and management team are managed by the Project Manager. This model shows that the system of the monitoring and control of a project is primarily focused on managing the scope, schedule and cost.

Scope, schedule and cost management are performed by analyzing different indicators that are basically intermediate outcomes, such as cash flows, cost of realization, performed work versus scheduled work and to what extend the scope has changed.

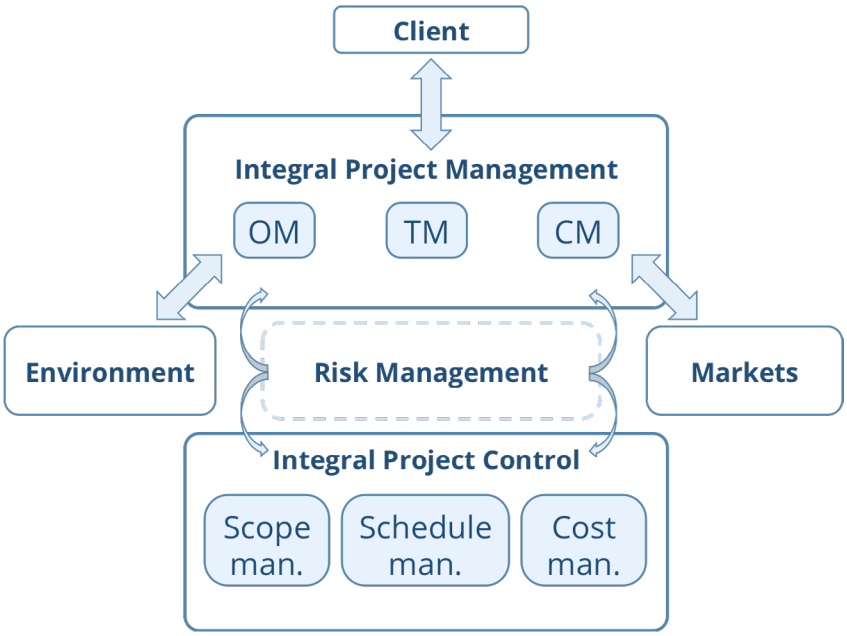


Figure 10: IPM-model as used by RIjkswaterstaat (Expertgroep Projectmanagement, 2008, p. 3)

This research does not question the effectiveness of this model, but it illustrates the fact that current project management methods are primarily focused on lagging indicators within the iron triangle.

2.6 Concluding the literature review

The literature review has covered three major themes in project management: Large Constructions Projects, success/performance and monitoring (and control) practices. In Table 4 an overview of the conclusions is presented.

Subject	Results
Large Construction Projects	The characteristics of LCPs (singularity, physical construction and covering a large time span) together with the sources of complexity and uncertainty (such as stakeholder interactions) are a difficult combination to manage.
Success and performance	Success is defined as achieving set goals. Dimensions of success like project management success, product success and market success are measured differently. How well a project scores on these measures is called performance (is the degree to which success is achieved). KPIs are the most important (key) metrics used to determine performance. KPIs are often lagging, meaning that they are the result of past performance. The disadvantage of these KPIs is that it is difficult to respond to since it is an outcome.
Monitoring	The quantitative monitoring practices are focused primarily on the iron triangle and are limited diagnostic on a high level. Qualitative monitoring is often laborious and subjective. The IPM-model prescribes project control through monitoring of lagging indicators within the iron triangle. Controlling measures are less invasive and intense if problems are tackled earlier on in the project before negative effects could cascade through the project.

Table 4: Conclusions from the literature review

2.7 Proactive Project Management

Based on the results of the literature review, a different type of project management is proposed: Proactive Project Management (PPM). This form project management aims to increase the proactivity in project management by:

1. Defining leading indicators that can be responded to outside of traditional indicators (2.7.1); and
2. Providing project managers with a tool to monitor these indicators and respond to them (2.7.2)

Both of these features are discussed in this section and will concluded with an explanation of the knowledge gaps.

2.7.1 Necessity for Control Indicators

In the literature review is argued that Key Performance Indicators are not sufficiently leading. The indicators will have to allow the project managers to respond to them and use them to control the project. These indicators are aimed to be outside of the well-established metrics of used in EVM such as schedule and budget.

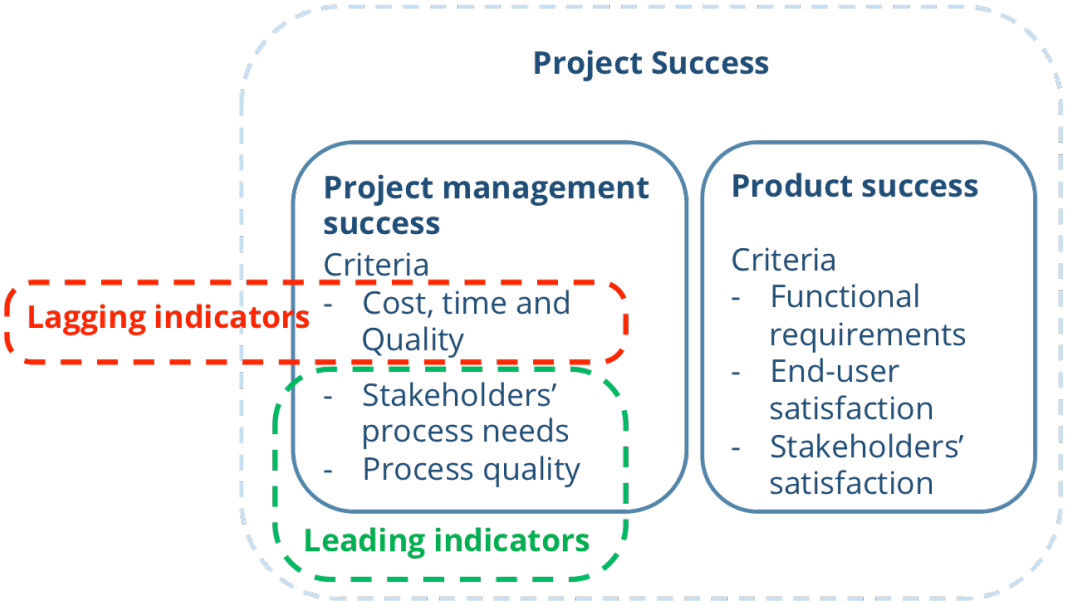


Figure 11: Criteria for project management success in perspective

The metrics measured in EVM are often lagging indicators, which are only predictive in the sense that past performance is representative for performance in the future (through extrapolation).

This research pleads for measuring leading indicators that reflect processes influencing project management performance. Since these leading indicators are not (K)PIs nor (K)RI and will be used to control the project, they will be referred to as Control Indicators (CIs). Control Indicators are defined as following:

> **Control Indicators: leading indicators for the performance of 'project management success' which can be acted upon by the project management**

Since there is not yet something like a 'Control Indicator' (or at least not defined as one), CIs are not yet defined and have to be formulated. A study into lessons learned in LCPs and factors that influence project management performance is necessary in order to identify Control Indicators.

2.7.2 Monitoring and responding to Control Indicators

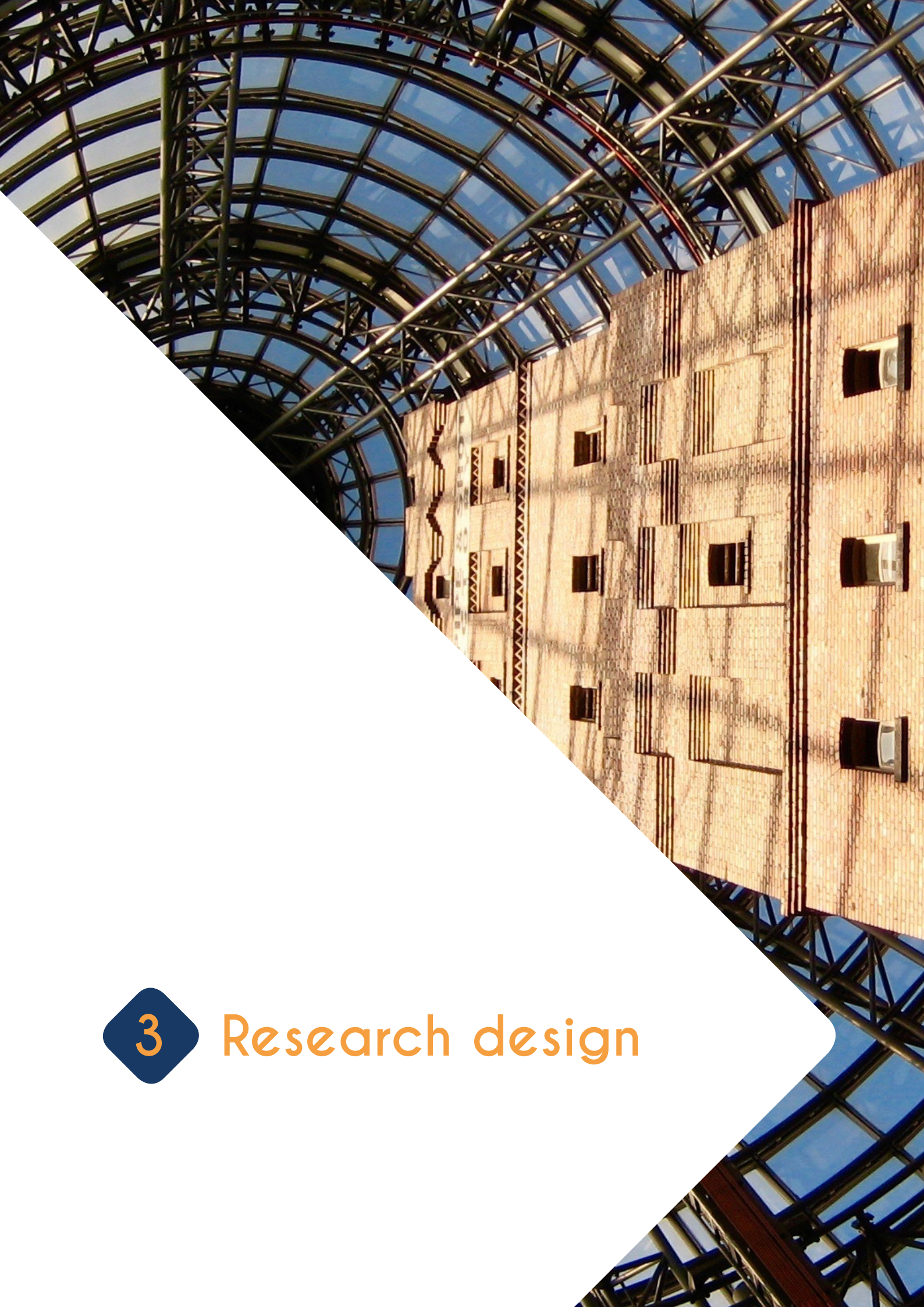
Aside from the lack of Control Indicators, there is little literature on standardized project control response to leading indicators as formulated in this thesis. The singularity of projects is created through a mix of project aspects, external factors, different stakeholders and their interactions, therefore not every CI will be relevant to each project or fit the management style of the project manager. In addition to the identification of CIs, a system is required that keeps track of the values of CIs and displays them to the project managers, who in turn can respond to these values. Due to the feedback from measured values (such as CIs) to interventions in the project, the system in which the CIs are embedded is called the Monitoring/feedback- system.

2.7.3 Knowledge gaps

Realizing a more proactive form of project management requires efforts to fill certain gaps of knowledge in the current field of project management:

1. There is lack of explicit leading indicators for project management processes (that form two of the criteria for project management success); which are Control Indicators
2. A tool for project management professionals for selecting, monitoring and responding to Control Indicators

In the next section the process and methodology is described that will lead to fulfillment of these knowledge gaps and the concrete deliverables this will result in.



3 Research design

3. Research design

This chapter elaborates on the research design for this master thesis. In the first sub section the research objective is stated. Section 3.2 contains the main research question and the sub questions formulated to make the research more manageable. The scope of this research is discussed in section 3.3 and the research strategy is explained in section 3.4.

3.1 Research objective

Large Construction Projects are endeavors where technology meets people, creating a complex environment subject to uncertainty (Baccarini, 1996). The combination a non-iterative project that covers a long time span with complexity that emerges from both technical and human factors makes LCPs different from other types of projects and could benefit from a more proactive approach when it comes to monitoring and controlling.

Currently, most project controlling efforts take place through monitoring performance on the iron triangle (time/cost/scope), which results in monitoring lagging indicators only related to the budget, schedule and scope. Meeting the iron triangle is just one criteria in achieving project management success and only one way to measure project management performance. Other criteria are 'process quality' and 'meeting process needs for stakeholders'. A more proactive form of project management can be realized through the identification of leading indicators for the other two criteria and developing a system that allows project management professionals to respond to these indicators; this results in the following research objective:

> **Provide project management professionals with a monitoring system that includes leading indicators for project management success**

In section 2.7 is explained that the leading indicators for project management performance are different from Key Performance Indicators and Key Result Indicators and that they are called 'Control Indicators'. The system that is used to monitor Control Indicators (CIs) supports project management professionals responding to these indicators, therefore the system is called the Monitoring/ feedback-system (MFS).

LCPs are complex endeavors and merely improving monitoring and controlling will not prevent problems from occurring. But by providing project management professionals with the MFS and CIs it should be easier to gain insight in how certain processes perform in LCPs and be able to respond to problems that emerge in those processes. Although these problems might not always emerge from factors within the project (but external factors such regulations or economic issues), the project management team should be able to react to them by altering processes or by anticipating or mitigating negative effects.

3.2 Research questions

Given the literature review and the identified knowledge gaps, the initial research question from the introduction can be specified; leading to the following main research question:

> ***Can traditional project management be redesigned to incorporate the monitoring of leading indicators during the project?***

To answer the main question three sub questions have been formulated:

- Which Control Indicators can be identified and formulated?
- What would the design of the Monitoring/feedback-system look like?
- How can the Monitoring/feedback-system be used to respond to processes reflected by Control Indicators?

Figure 12 illustrates how the sub questions relate to each other and how they together contribute to the greater purpose of improving project management.

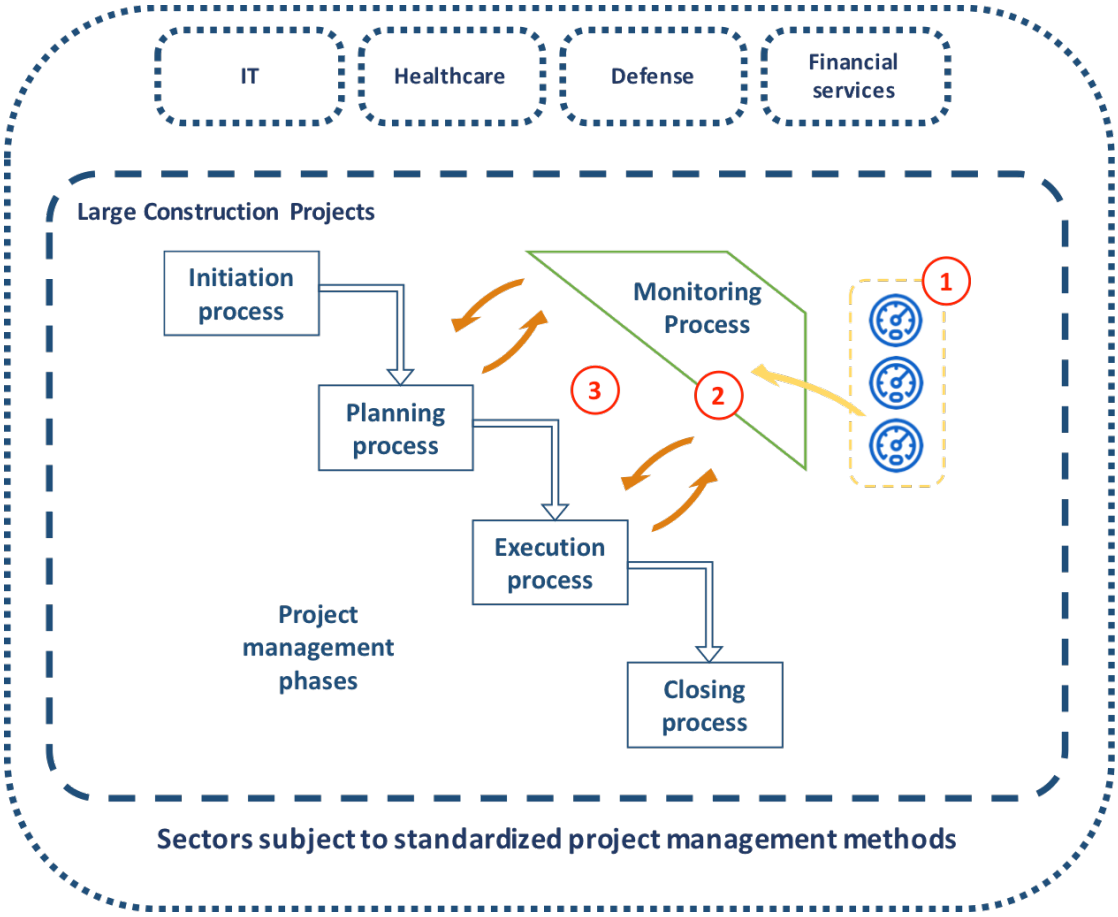


Figure 12: Sub questions visualized

3.3 Research scope

In order be able to conduct the research within the time available for a master thesis, the scope is clearly defined. The boundaries of this thesis are discussed (3.3.1) and the project deliverable (3.3.2). They will be discussed separately in this section.

3.3.1 Context of the thesis

The initial problem statement proposed in the introduction is the enhancement of project management by making in more proactive. In the literature review is explained how different definitions of success are related; this lead to narrowing

the scope of this research down to identification of leading indicators related to the process aspects of project management success. Figure 13 visualizes the different layers that demarcate the scope of this thesis. Each layer is discussed in this section.

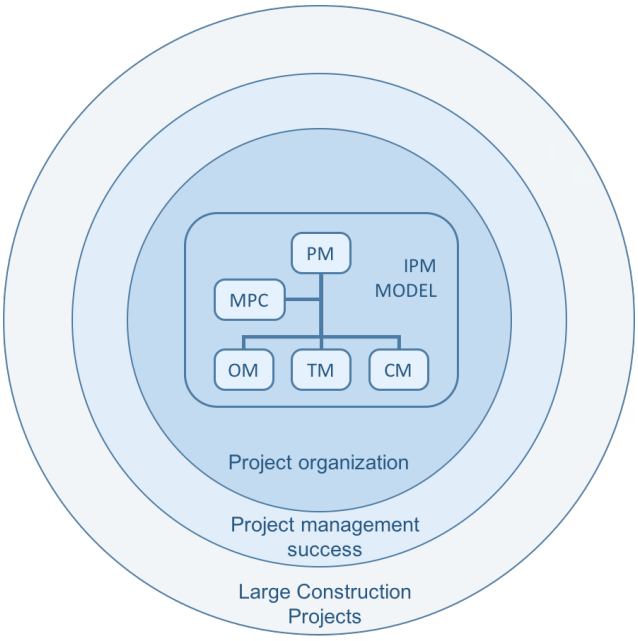


Figure 13: Research scope

Large Construction Projects

In the introduction is argued that project management practices and methods are applied across different sectors but that LCPs could benefit from monitoring leading indicators due to its characteristics such as singularity, long time span and little possibility to iterate; therefore, this thesis focusses on LCPs.

Project Management Success

Improving project performance of projects is difficult since LCPs are subject to a broad variety of factors which are nearly impossible to influences all. Project success is achieved through product success and project management success. In the introduction is argued that LCPs should be managed differently, which comes down to altering the project management process. Therefore, this thesis focusses on improving project management performance on the criteria of process quality instead of the iron triangle (Figure 3).

Project Organization and IPM-role model

Project management success is assessed on three criteria (Collins & Baccarini, 2004):

1. Meeting time, cost and quality objectives
2. Quality of the project management process
3. Satisfying project stakeholders' needs related to the project management process

As stated in the previous sub sections, projects are affected a many different factors. In this thesis is focused on the factors that can be influenced by the project organization and the management team. A widely used management team structure is the IPM-model from Figure 14. This model is used to select factors from the literature study and formulate the leading indicators for project management success (Control Indicators). OM, TM and CM represent respectively Environment Management, Technical Management and Contract Management.

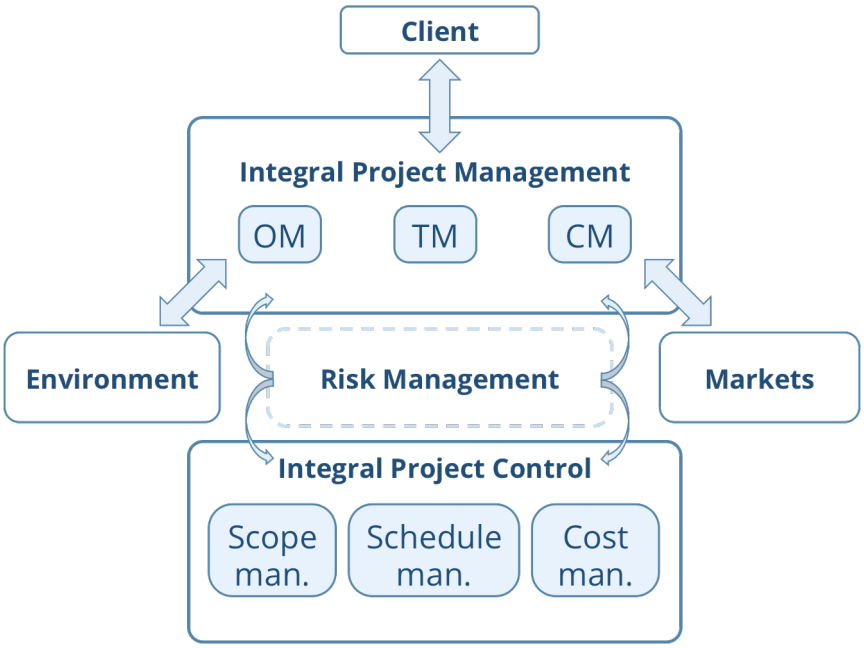


Figure 14: IPM-role model, based on (Expertgroep Projectmanagement, 2008, p. 3)

This model is used by Rijkswaterstaat (RWS), the entity responsible for the execution of projects for the Ministry of Infrastructure and Waterworks (Rijkswaterstaat, 2017). The reason RWS uses this model is to increase uniformity and standardization necessary for efficient exchange of personnel within the organization and to adopt a single, professional approach towards (market) parties and stakeholders (Expertgroep Projectmanagement, 2008). This model is widely used in the Dutch construction sector and using the IPM-model as basis for the identification and classification of leading indicators should increase the applicability of the indicators for project management professionals.

3.3.2. Project deliverable

Aside from the context described in 3.3.1, this research is delineated by the deliverable and what role it should fulfill in projects. Figure 15 reflects the current form and phases of management as described by PMBoK: the initiation, planning, execution and closing, while the monitoring and controlling practices as described in 2.4 take place.

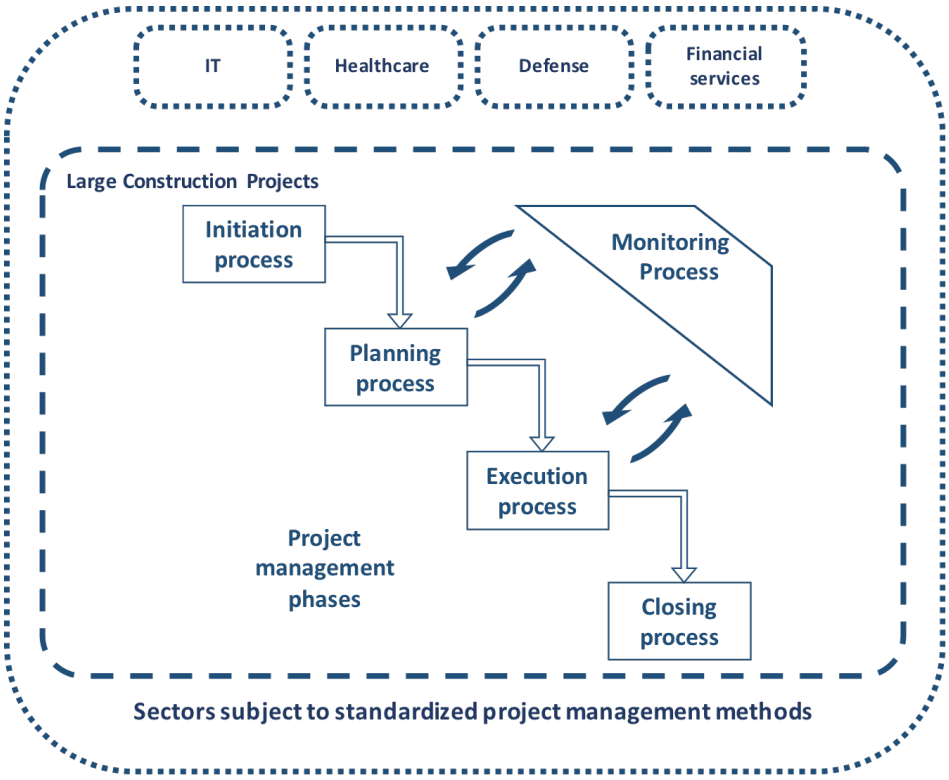


Figure 15: Traditional project management based on (Project Management Institute, 2008)

In relation to the IPM-role model from Figure 13, Figure 16 should be viewed from the perspective from project manager: how can the project be controlled by responding to monitored Control Indicators?

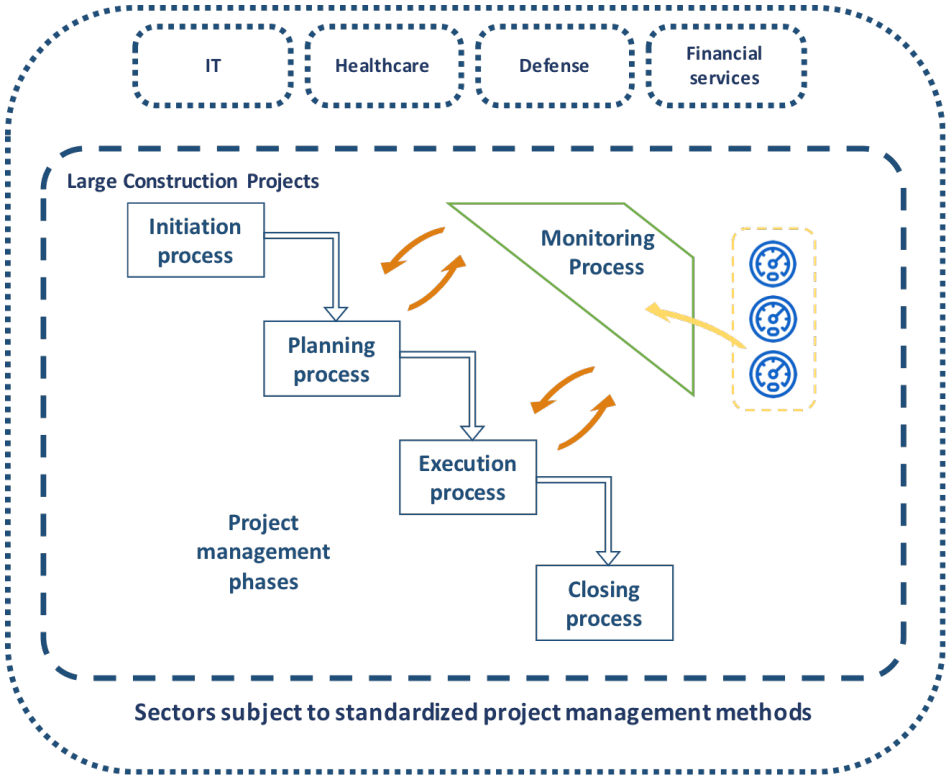


Figure 16: Proactive project management consisting of Control Indicators embedded in the Monitoring/feedback-system

Control Indicators

As stated in the introduction, most metrics that are being monitored in projects are related to the iron triangle (schedule and budget in particular). Indicators that are leading for project management performance, Control Indicators, are identified based on factors associated with project success and failure. These factors in turn, are derived from literature, reports, interviews or other observations.

The identifying of these Control Indicators is the main scientific contribution of this research. This part of the deliverable is represented in yellow/blue in Figure 16.

Monitoring/feedback-system

An important feature of the proposed deliverable is the fact that it allows project management professionals to select Control Indicators suitable to their preferences such as IPM-role, measurability or other attributes.

In addition to this selection tool a process description is provided in order to allow project management professionals to respond to the monitored Control Indicators. This part of the deliverable is visualized through the green 'monitoring process' and the orange arrows representing the control measures.

3.4 Research Strategy

In this section the research strategy that will be used to reach the research objective is explained. The research trajectory will follow the research design as described in Figure 17. In this section each of the steps are described.

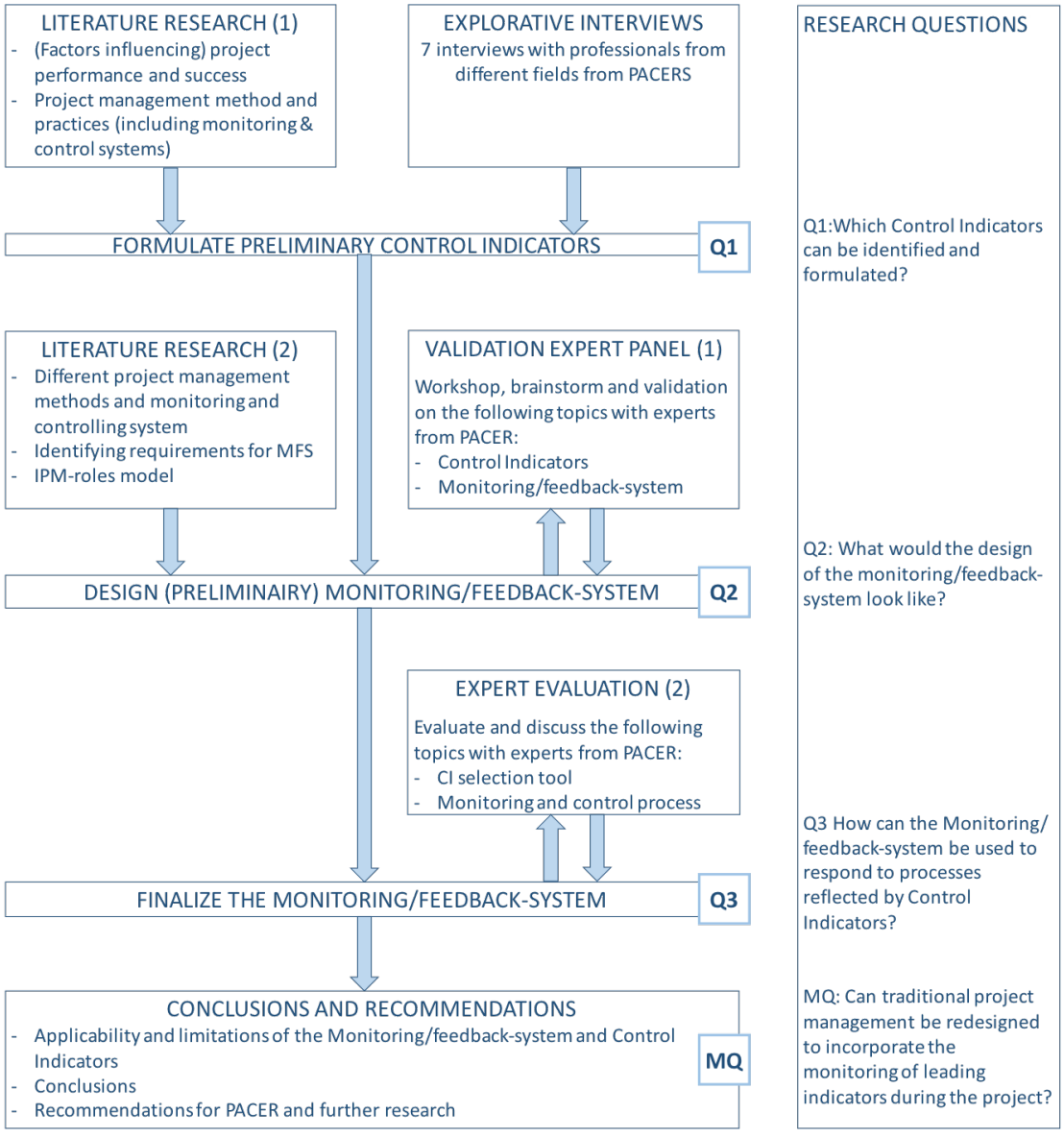


Figure 17: Research design

3.4.1 Literature research

In order to be able to provide answers to the research questions, the sub questions are answered first. Answering these questions requires two literature studies:

- The first literature study is performed to gain better understanding of project management practices, its context and application. During this literature study factors associated with project management success or failure are collected in a data base, which serves as basis for the formulation of the Control Indicators.

- The second literature study is more delineated by the results of the first literature study and the explorative interviews; it is focused on collecting information necessary to shape the proposed proactive approach (the Monitoring/feedback-system) by analyzing the current practices of monitoring and control.

3.4.2 Exploratory interviews

As an addition to the first literature study explorative interviews with project management professionals are conducted. Because of the exploratory nature, the interviews will be semi-structured in order to maximize input from the experts. The goal of the interviews is to gain insight in their experience with performance measuring and project success/failure in their professional careers and make this tacit knowledge explicit. The exploratory interviews are conducted by first explaining the outlines and context of this master thesis, which will be followed by questions regarding their specialization and performance measurement in different aspects of projects. They will also be asked how they would quantify their own performance and whether external influences/actors influence their performance. The result of the exploratory research gives an indication of problems encountered in Dutch projects and a course in which to continue the research.

3.4.3 Expert validation and evaluation

The final Monitoring/feedback-system (MFS) including the CIs will be difficult to validate due to reasons extensively discussed in 6.2.3 and falls outside of the scope of this research.
The Control Indicators however, are validated through expert validation. Since the final deliverable has two main components, two steps are required:

- The Control Indicators that have been formulated based on the exploratory interviews and literature study are validated by experts of PACER. This session is also conducted to receive extra input on the MFS. In appendix D is elaborated on this workshop.
- The Monitoring/feedback-system which incorporates the CIs and is used to control to project is evaluated by a project management expert from PACER. The feedback is used to tweak the design of the MFS and improve its practical applicability.

The first validation session will be from a panel of experts, from the different disciplines within PACER: technical-, contract-, environment managers and project controllers. This creates feedback from different facets of the IPM-role model.

The expert evaluation is performed by an expert who has experience in project monitoring and tracking project data through dashboards. The feedback from the evaluation serves as main purpose the improvement of the applicability of the MFS and to ensure that the MFS is relevant to project management professionals.

4 Control Indicators

4. Control Indicators

In order to realize a more proactive form of project management, it is necessary to find leading indicators for project management performance which can be responded to. It has been argued these indicators should be broader than the KPIs based solely on the iron triangle (schedule, budget and scope). That KPIs are not the adequate indicator in proactive project management and a different type of indicator is needed (Control Indicator) is explained at the end of the literature review (2.7).

This chapter described how the Control Indicators (CIs) are identified and formulated. In section 4.1 is explained how the data is collected that forms the basis for CIs. Section 4.2 describes the process is which data is structured and categorized; the result is a database with factors, lessons learned and KPIs. Control Indicators are formulated based on this factor database. This formulation is described in section 4.3. The results of the Expert Panel workshop that functions as validation is briefly discussed in section 4.4. A more detailed description of the workshop can be found in appendix D. In section 4.5, the chapter on Control Indicators is concluded with the most important differences between Control Indicators and 'conventional' indicators which are explained and illustrated with examples. The limitations of CIs are explained in the discussion (6.2.1).

4.1 Collecting the data

The first step in formulating Control Indicators is identifying factors associated with project management success. Control Indicators are only effective if they are:

1. Associated with performance and success (or failure) of projects
2. Leading indicators, allowing project management to respond to them (in contrast to lagging indicators, which are 'outcomes')

For this step only the first requirement is satisfied since there is ambiguity regarding the leading or lagging properties of indicators in the literature (section 2.3.3). The first literature study does not distinguish leading or lagging properties; this is done when the CIs are formulated.

The study into factors associated with project performance is conducted in two parts: a literature and exploratory interviews conducted among project management professionals employed at PACER. The literature study is described in section 4.1.1 and the exploratory interviews in section 4.1.2. The CIs are formulated based on the information derived from the literature study and exploratory interviews. All this data is labelled in the database in order to be able to trace a CI back to its source (in literature and interviews). This traceability is explained in section 4.1.3.

4.1.1 Literature study

The literature on project management success reviewed in this study is divided in three categories: Factors influencing project performance, Key Performance Indicators (KPIs) and Lessons Learned (LL). These categories will be discussed respectively in this section.

Factors influencing project performance

The literature on factors is extensive (Daniel & Daniel, 2017; Gomes & Romão, 2016; Jha & Iyer, 2007). The jargon used to categorize them as well, factors are referred to as success factors, problem areas, failure factors, critical success criteria, variables, success criteria and critical success factors. The concepts of KPIs and CIs are already defined, but this is not the case for Success and Failure Factors (SFFs) and Critical Success Factors (CSFs); the literature is more ambiguous on these concepts. Just like the definitions of KPIs and KRIs are used erroneously (and sometimes wrongfully as substitutes), 'criterion' and 'factor' are rarely defined in scientific articles and thus interpreted differently by academics. For this thesis the following definitions of CSFs, factors and criteria are used:

> **Critical Success Factors (CSF): "characteristics, conditions, or variables that can have a significant impact on the success of the project when properly sustained, maintained, or managed" (Milosevic & Patanakul, 2005, p. 183).**

Factors & criteria: "Criteria are used to measure success whilst factors facilitate the achievement of success" (Collins & Baccarini, 2004, p. 3)

Although there are similarities between CSFs and 'regular' factors, an important difference is determining impact (CSF) versus facilitating success or causing failure (factor). A factor being extremely critical to success essentially turns it into a requirement if it is urgent enough: if there is an absolute due date, 'time' is no longer a criterion but a constraint or requirement. The combination of CSF having a "significant impact on success" and the thin line between success criteria and CSFs in the literature, causes CSFs to approach the definition of success criteria and Key Result Indicators (KRIs) from section 2.3.2.

Although this ambiguity does not have a large impact on the formulation of Control Indicators, in the database the distinction between CSFs and SFFs is made for the sake of completeness and usability in further research. In practice this distinction will not have a strong impact, since the concepts of CSFs and factors in the literature are mixed up and used as substitutes by some and as a sliding scale by others. But not taking this difference into account would be an oversimplification of the literature. Table 5 contains an overview of the literature on factors.

Author(s)	Year	Title
J. K. Pinto & Slevin	1987	Critical Factors in Successful Project Implementation
Dvir, Lipovetsky, Shenhar, & Tishler	1998	In search of project classification: a non-universal approach to project success factors
Atkinson	1999	Project management: cost, time and quality, two best guesses and a phenomenon , it's time to accept other success criteria
Cooke-Davies	2002	The "real" success factors on projects
Westerveld	2003	The Project Excellence Model: Linking success criteria and critical success factors
Chan, Scott, & Chan	2004	Factors affecting the success of a construction project
Jha & Iyer	2007	Commitment, coordination, competence and the iron triangle
Khang & Moe	2008	Success criteria and factors for international development projects: A life-cycle-based framework

Remington, Zolin, & Turner	2009	Monitoring the Performance of Complex Projects from Multiple Perspectives over Multiple Time Frames
Al-Tmeemy, Abdul-Rahman & Harun	2011	Future criteria for success of building projects in Malaysia
Kog & Loh	2012	Scenario Based Proactive Robust Optimization for Critical Chain Project Scheduling
Alzahrani & Emsley	2013	The impact of contractors' attributes on construction project success: A post construction evaluation
Ofori	2013	Project Management Practices and Critical Success Factors – A Developing Country Perspective
Alias, Zawai, Yusof & Abra	2014	Determining Critical Success Factors of Project Management Practice : A conceptual framework
Clarizen	2015	Project Management Survey
Gomes & Romão	2016	Improving project success : A case study using benefits and project management
Livesey	2016	Insights of project managers into the problems in project management

Table 5: Literature on factors influencing project management

Lessons Learned

Large Construction Projects often take a long time to complete (from the end of initiation to its closing). In combination with little possibilities to iterate, learning from mistakes within projects is difficult. Organizations document problems that are encountered and try to avoid these in the future; or at least come up with a suitable response. Because clients in LCPs value projects delivered 'right the first time' (The KPI Working Group, 2000), lessons learned in previous projects could form a useful resource to mitigate or to anticipate on events that could reoccur. Cooke-Davies (2002) states that one of the key success factors in organizations is the ability to learn from past projects.

Most (mature) organizations that work on a project basis have programs for evaluation of (completed) project (CMMI Product Team, 2010). Evaluating projects forces project participants to look back on the project, reflect on their practices and what went good and what went bad. Detailed documentation of how problems were tackled are bundled in 'lessons learned' documents. These documents are available throughout an organization and are a resourceful database for projects to come. In light of this research these documents provide

valuable insights in what problems were encountered and how these situations could have been avoided or handled better. Table 6 contains an overview of the documents found in the literature regarding lessons learned in LCPs.

Author(s)	Year	Title
Staal-Ong et al.	2016	Lessons Learnt and Challenges Ahead 10 Years of Managing Large Infrastructure Projects in Europe
Amalraj & Doucet	2007	Project Management : Challenges & Lessons Learned
Chan & Kumaraswamy	2002	Compressing construction durations : lessons learned from Hong Kong building projects

Table 6: Literature on lessons learned influencing project management

Key Performance Indicators

As discussed in section 2.3.2 of the literature review, Key Performance Indicators (KPIs) are the most important ('key') metrics indicating the performance of an organization or project. KPIs are often incorrectly formulated as Key Result Indicators (KRIs): the KPIs should be indicating to what extend the desired results (goals) are going to be achieved; which is also the case for some of the KPIs in the literature. Regardless of this ambiguity, KPIs are still a valuable source of information for the formulation of CIs since they still reflect areas of importance. An overview of the literature on KPIs used in this research is presented in Table 7.

Author(s)	Year	Title
A. P. C. Chan & A. P. L. Chan	2016	Key performance indicators for measuring construction success
Ahmad, Svalestuen, Torp & Andersen	2016	A Review of Performance Measurement for Successful Concurrent Construction
Ali, Al-Sulaihi, & Al-Gahtani	2013	Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia
The KPI Working Group	2000	KPI Report for The Minister for Construction

Table 7: Literature on Key Performance Indicators in project management

4.1.2 Exploratory interviews

As an addition to the existing literature, the cooperation with PACER enabled the possibility to interview project management experts on their views and experiences regarding success/failure factors, project management methods and practices.

The interviews where semi-structured in order to use of the openness and creativity of the interviewees. This research is two-layered: 1) the identification of factors and 2) developing a monitoring system. In these interviews there was sufficient room to discuss both and gain useful insights in how project management is viewed in practice from different perspectives. PACER experts have been selected based on the function they fulfill within the IPM-role model (the model as discussed in chapter 3). The factors that derived from the exploratory interviews can be found in Table 29 in appendix A. Summaries of the interviews and their results are discussed in appendix A.

It should be noted that not all roles of the IPM-model are interviewed. Furthermore, the sample of interviews in limited to PACER employees, which could cause a bias or blind spot in the information obtained; these limitations are discussed in section 6.2.5.

4.1.3. From factor to Control Indicator

All the pieces of information that are collected in the literature study and the exploratory reviews (lessons/factors/KPIs) are referred to as factors is the next section. All the information is collected in a scientific manner, whether it is through interviews or literature study.

To maintain the scientific basis of the factors and convey this to the Control Indicators, the sources of the factors are coded. This code consists of one letter and a number (e.g. L12). Since the sources provide multiple factors, each factor itself is coded as well (e.g. F1605). In Table 8 an overview of the codes is provided.

Source code		Factor codes	
#	Number	#	Number
L	Literature	C	Critical success factor
I	Interview	F	'Regular' factor
K	KPI	K	Key Performance Indicator
E	Lesson learned	I	Factor from interview
		E	Lesson learned

Table 8: Source and factor codes

By using this code system, each Control Indicator formulated in 4.3 can be traced back to its scientific source. This traceability guarantees that CIs are not made up on the go but are embedded in knowledge collected in this research. The process the factors go through is illustrated Figure 18. The factor codes are different from the CI codes described in 4.2.

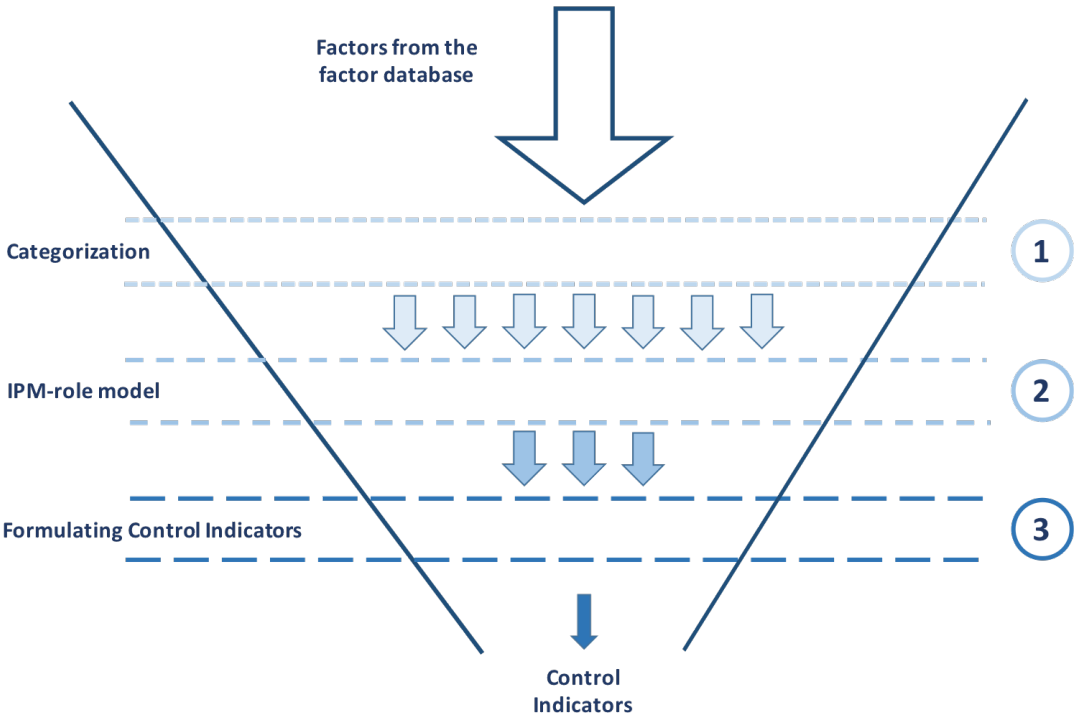


Figure 18: From factor to Control Indicator

The first step in Figure 18, is the categorization described in the next section (4.2). Due to time constraints not all categories are used to base Control Indicators on and therefore, the categories that are most closely to the IPM-role model are chosen. The demarcation based on the IPM-roles is further substantiated in 4.2. The Formulation of CIs based on the remaining categories is described in 4.3.

4.2 Structuring the information: the factor database

In order to formulate coherent Control Indicators, the factors derived from the literature study and interviews are structured. The term 'factor' in this sense refers to (critical) success/failure factors, KPIs, lessons learned and results from the interviews; as long as it is included in the database it is referred to as a factor. The complete factor database can be found in appendix B. The process of categorizing the factors is described in appendix C.

Categorization

The categorization (Figure 18) is used to concentrate factors that are related to each other and form Control Indicators. It also highlights which aspects of project management is most written about. The factors are assigned to at least one category with a maximum of two; the categories are displayed in Table 9.

Category	Description
Stakeholders	Includes most stakeholder-related aspects of stakeholders such as (but not limited to) contractors, non-governmental organizations (NGOs), government, clients, financiers and residents/communities
Finance & resources	Financial arrangements for projects, distribution of resources like funding, staffing, man power and labor during the execution are examples of factors included in this category
Organization	A broad category covering different layers of management in organization, as well as the project team (temporary organization) responsible for managing the project
Legal aspects	Contracts between stakeholders, (municipal) permits, governmental regulations
Risks & external influences	Covers (unexpected) risks (opportunities and threats) and other external factors influencing projects.
Objective & scope	The objective and scope cover the functional requirements and the technical specifications, as well as the business case (including planning and budget)
Technology	The technological component in LCPs, concerning technical innovations and uncertainty regarding properties of materials and everything in between
Processes	The arrangement of procedures like decision-making, information sharing, troubleshooting and communicating benefits
Safety & health	This category covers the safety and health of people and the environment in contact with a project

Table 9: Description of the categories

After all factors have been categorized according to the process described in appendix B, the results are displayed in Table 10. Out of the 578 factors, 118 qualify for two categories.

Category	Factors
Organization	165
Objective & scope	149
Stakeholders	135
Processes	87
Finance & resources	54
Legal aspects	51
Risk & external influences	48
Technology	28
Safety & health	28

Table 10: Categories and their frequencies

IPM-role model

After the categorization the basis has been laid to formulate Control Indicators. Since the amount of factors is too large to consider them all for formulating CIs, a selection of categories is made. Certain categories match (roughly) with roles defined in the IPM-role model. These categories are used for formulation the CIs. By focusing on these categories scoping is combined with maintaining relevance of the CIs for PACER. Each Control Indicator has, just like each factor, a code; the CIs start with either PM, PB, OM, TM and CM, corresponding with each role of the IPM-model from Table 11.

Role	Responsibilities and description	Matching category
Project manager (PM)	Responsible for achieving good project results. The project should be finished within schedule, budget and according to quality.	Organization
Manager Project Control (PB)	Responsible for identifying and control possible risks that could occur within the project.	Risk & external influences
Environment manager (OM)	Responsible for contact with the environment of a project and maintain a good relation with stakeholders such as residents.	Stakeholders
Technical manager (TM)	Responsible for technical and other project-related input. Manages the risks regarding the project organization.	Objective and scope
Contract manager (CM)	Responsible for managing contracts of involved parties and this way manage risks between the client and the market.	Legal aspects

Table 11: Description of the IPM-roles according to Rijkswaterstaat (Rijkswaterstaat, n.d.)

The category 'organization' is the largest and appeared to be (upon closer examination) to contain broadly formulated organizational factors (figure 17). Since project management performance is the main focus of this research, only the organizational factors related organizational levels of project management success and product success are taken into account (Figure 19: Organizational levels across the multiple dimensions of success).

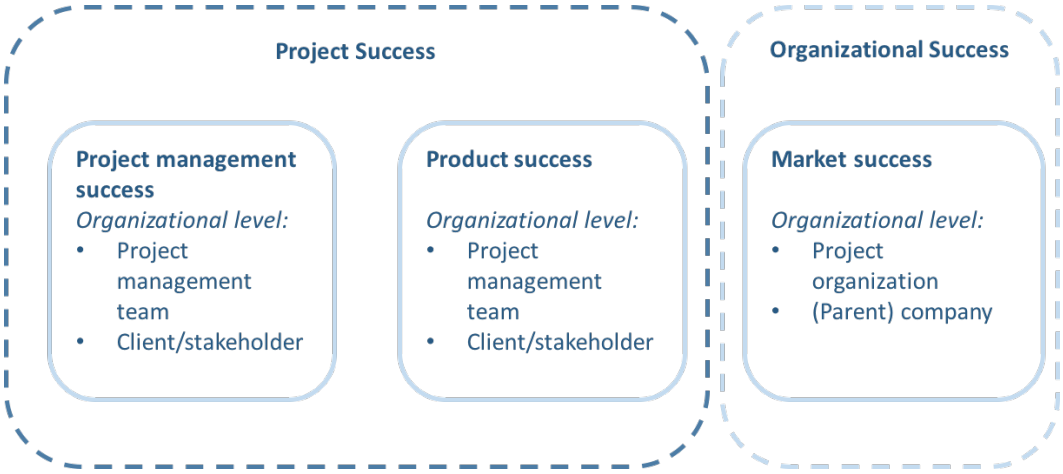


Figure 19: Organizational levels across the multiple dimensions of success

4.3 Formulating the Control Indicators

In appendix B the categorization is explained. This section elaborates on how the Control Indicators are formulated. Table 12 contains an overview of the categories and their amount of factors, how many are used and the amount of CIs this resulted in.

Category	Factors	Factors used	Control Indicators
Organization (after selection)	76	55	15
Objective & scope	149	70	29
Stakeholders	135	69	23
Legal aspects	51	34	17
Risk & external influences	48	13	10
Total	459	241	94

Table 12: From factors to Control Indicators: the numbers

It should be noted that factors can contribute to multiple CIs. As can be concluded from Table 12: From factors to Control Indicators: the numbers, not all factors lead to Control Indicators; roughly one CI is identified per five factors. This is caused by the fact that not all factors are useful: some are too vague, too broad, double/overlapping with other factors or not leading. The latter is important for the formulation of CIs: as stated in section 4.1, CIs are only effective if they are:

1. Associated with performance and success (or failure) of projects
2. Leading indicators, allowing project management to respond to them

The first criterion is satisfied, since the factors are formulated based on literature and interviews into factors influencing project management performance. When formulating the CIs, the second criterion is crucial for their effectiveness.

The following process is conducted for each of the categories:

1. Identify high-level themes within the category
2. Formulate a Control Indicator based on one or more factor that can be measured (qualitative and quantitative)
3. Describe based on the factor (and its context) how this Control Indicators is leading
4. Determine how the Control Indicator can be measured
5. Track the factors that contributed to the formulation of the Control Indicator per CI (to maintain the traceability discussed in 4.1.3)

The result of repeating this process for the different categories is a set of 94 CIs that are validated in the Expert Panel workshop. Although the categories are chosen to reflect the IPM-role model, not all CIs connect seamlessly to the IPM-roles. Therefore, the responsibilities of each of the IPM-roles are compared to the CIs; this results that each CI is fitted with an IPM-role in addition to a category (assigned in 4.2). Through this additional information the CIs can be assigned to the panel members in the Expert Panel that are specialized in the corresponding roles.

4.4 Expert Panel workshop

This section briefly describes the methodology of the Expert Panel workshop and its results and conclusions. For an extensive explanation appendix D should be consulted.

Goal and methodology of the Expert Panel workshop

The Expert Panel workshop is conducted for two purposes:

1. Feedback on and validation of Control Indicators
2. Receive input for the design of the Monitoring/feedback-system

Project management consultants from PACER with different backgrounds are selected to take part in the panel in order to include as much knowledge as possible from different perspectives (contract-, technical-, environment managers, manager project control and systems engineer). The panel members have been informed in advanced on the topic of the workshop and have been given 'homework' to stimulate them to think about the workshop in advance and this way improve the usability of the output. The entire meeting was recorded for deeper analysis to extract as much information as possible. In appendix D an overview is presented of all the remarks from EP members that are considered relevant for the workshop. These remarks are numbered and linked to the conclusions in order to be able to trace back the conclusions to the workshop output.

In order to achieve both goals, the workshop is divided in two parts: the validation of Control Indicators and the input for the Monitoring/feedback-system. The first part started with an introduction to this thesis and Control Indicators and a discussion regarding possible CIs. The validation happened through handing out sheets with the formulated Control Indicators (including the method of measuring and how the CIs are leading) on which the experts provided feedback. A short break followed and the workshop continued with a presentation on project monitoring. In appendix D a detailed description of the workshop setup is available.

Results and Conclusions

In this section the results of the workshop are briefly discussed. In appendix D the complete abstraction of the workshop and detailed description of important expert feedback is provided.

The result of the first part (feedback on Control Indicators) is that some CIs have been dropped; others are altered in order to meet the proper definition of CI. The rest of the CIs is validated and eight additional Control Indicators emerged from the EP workshop.
Part two of the Expert Panel workshop resulted in parameters that should be taken into account such as personal privacy (the extent to which information can be communicated to higher levels of management) and organizational privacy. There was a consensus among the experts regarding the fact that support of the management team and transparency of the use of the MFS is crucial for its success. The experts pointed out that project managers have different management styles, which should be taken into account when monitoring.

It can be concluded that Expert Panel workshop achieved its goals: The Control Indicators are validated and useful input for the MFS was gained from the second part. Although the meeting did not go completely according to the schedule, it can be concluded that the important parts were executed and was successful. A more detailed description of the workshop can be found in appendix D.

4.5 Reflecting upon Control Indicators

This section concludes the chapter on Control Indictors. First will be reflected upon how Control Indicators are different from Key Performance Indicators in terms of what they reflect and how they relate to each other. Section 4.5.2 provides examples of monitoring CIs versus monitoring traditional indicators.

This research resulted in a list of Control Indicators, which is too cumbersome to include in the main text. So only a few examples of CIs (including their codes and traceability) are presented in 4.5.3; the rest can be found in appendix E.

4.5.1 Process versus Project

Project management success (Figure 20) is broken down into two parts: process and project. The project performance related outcome is to what extent schedule, budget and quality/scope are met: Key Performance Indicators. The process aspects reflect how we get there, which is the performance on project management processes: Control Indicators.

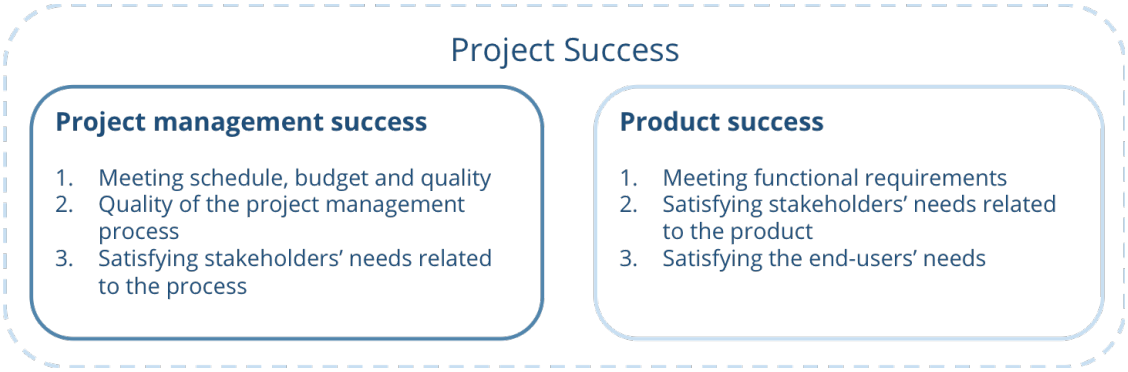


Figure 20: Criteria for success

The relationship between project/process and KPI/CI is visualized in Figure 21. Bad performance on KPIs can be caused by flaws in the process. The disadvantage of finding out bad performance through KPIs instead of CIs is that as KPI it has already manifested itself in the project. Moreover, the cause of the bad project performance could be related to the process. Since problems could emerge earlier on in processes then in outcomes, monitoring Control Indicators and responding to them could result faster controlling efforts.

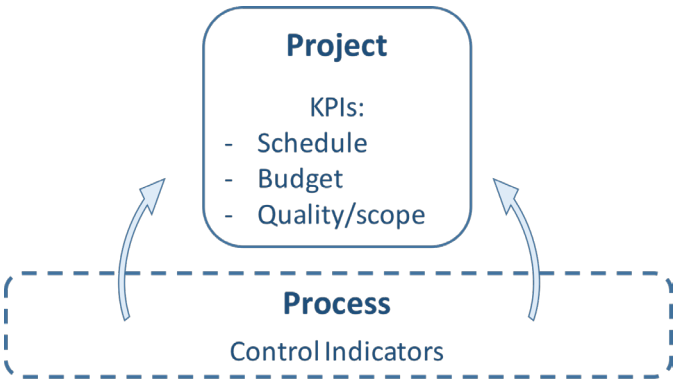


Figure 21: Indicators for project and process

The next section elaborates on the differences between monitoring Control Indicators and measuring traditional indicators used to assess project performance on KPIs such as schedule, budget and quality/scope.

4.5.2 Control Indicators versus traditional indicators

The reason why the term Control Indicators is established is that there is ambiguity regarding the definition of (Key) Performance/Result Indicators since they require to be linked to a definition of success. Therefore, Control Indicators are "leading indicators for the performance of 'project management success' which can be acted upon by the project management". The benefits of the Control Indicators stem from three important aspects which make them worth monitoring: they have leading properties, reflect processes and they are based on factors associated with success and failure. All aspects are discussed and provided with a fictional example in which the Control Indicators are compared to traditional indicators.

Control Indicators differ from traditional indicators because they are:
1. Leading instead of lagging
2. Reflect processes in projects outside of time, cost and scope
3. Based on factors associated with project success/failure

First of all, traditional monitoring focusses mainly on the criteria schedule, budget and quality/scope (point 1 from Figure 20), which are lagging indicators (outcomes). By comparing the initial schedule and budget with the realization, projections are made regarding the performance of the project. But because of the fact that these projections are based on work that already has been

performed, they are more lagging than leading. So the performance on schedule, budget and quality/scope as well as the prediction of future performance are lagging indicators. In example 1 traditional indicators are explained and Control Indicators are suggested.

Example 1

Traditional indicators: comparing 'budgeted cost of work performed' (BCWP) to the 'actual cost of work performed' (ACWP). The realization of a certain work package is half way and its budget is depleted for 90%. This means in 'Earned Value Management'-indicators that the ACWP is higher than then the BCWP. This requires further investigation to find out what caused these cost overruns. Whether the cause is found or not, it is unlikely that these overruns will be offset within this work packages.

Control Indicator: monitoring the CI 'Number of schedule updates' (PB14) is advantageous in two ways: 1) requiring regular updates reduces the chance that schedules are not updated and 2) a low number of updates could indicate little progress is made or there is an incentive to deliberately not update the schedule. 'Number of budget/contract meetings' (PB01) has the same two types of advantages: a lack of meetings could expose a lack of focus on budget/contract and organizing these meetings reduces the chances of budget/contract issues. Monitoring and requiring these meetings, does not avoid problems, but they are less likely to accumulate since the process is measured regularly.

In the example all indicators correspond with practices performed by the project controller. If the number of meetings and updates are monitored and fail to meet their predefined values (e.g. twice a month update and meeting), then action should be taken in order to find the causes before the budget/schedule overruns start. In this case the Control Indicators are not a substitute for Earned Value Management, but they could expose problems sooner.

The second point is that Control Indicators reflect project management processes. CIs reflecting processes has two advantages: processes are often leading for the outcome and provide insight in the performance of processes. As displayed Figure 20, project success consists of project management success and product success. When thinking about project success often only the product (like a bridge or a highway) comes to mind. In addition to product success there is also project management success: completing the product within budget, schedule and according to scope/quality, all while the quality of the process is maintained. The project management process can be considered as how the product is realized. Following this line of reasoning, indicators for the success of the project management process are leading for how the eventual

product is realized. It must be noted that it is possible a product is a success although the process is not, but that does not mean that the project performs well in achieving project management success (the success dimension the Control Indicators are designed for). It seems logical, however, that measuring and controlling project management processes can contribute to project success (Figure 21). An illustration is provided in example 2.

Example 2

Problems within the project team has been named as source for bad performance. If people dislike each other due to professional or personal conflicts, this affects the way they communicate and their professional attitude. By monitoring Control Indicators such as 'Compatibility project team' and 'Rating teamwork participants' these problems would be likely to surface and can be dealt with, or at least can be taken into account. If the same conflict would occur and it would not be monitored, there is a chance that this conflict would manifest itself in the product: two people disagreeing on certain quality standards and not conceding to each other could cause discrepancies in work instructions or even executed work.

The third point in which CIs differ from traditional indicators is that all CIs have been formulated based on factors derived from literature or interviews. These factors are all associated with project success or failure. If certain factors come up in the research and are found to cause problems or benefit projects, capturing this information in a CI for monitoring could predict performance. This is illustrated in example 3

Example 3

Project controllers perform cost, schedule and scope management by keeping dashboards that monitor the project progress; but stakeholder management is not included in the dashboard while the following factors point out that it is important:

- Effective consultation with key stakeholders (F1017)
- Key stakeholders informed of and satisfied with project progress (F0711)
- Effective consultation with project stakeholders (C0707)
- Regular updates stakeholders (I0104)
- Unclear expectations among project participants (I0132)

Although most projects probably include some form of stakeholder management, by explicitly monitoring CIs regarding stakeholders and stakeholder processes, the performance of stakeholder management could be monitored and improved.

4.5.3 Examples of Control Indicators

This section provided examples of Control Indicators, the definitive list of 93 CIs can be found in appendix E. Examples of how the traceability from factors to CIs works are illustrated Table 13. This traceability is explained in 4.1.3.

Code	Control Indicator	Source
PB11	Number of rescheduled activities	F0708: Activities carried out as scheduled (Khang & Moe, 2008)
PM01	Clearly defined objectives formulated by the client	F0130: Client's ability to make decisions(A. P. C. Chan et al., 2004) F0132: Client's contribution to design (A. P. C. Chan et al., 2004) E0139: Define objectives in interaction with stakeholders (Staal-Ong et al., 2016)
PM05	Number of scope/ contract meetings	I0115: Managing differences contract and scope (interview, appendix A) E0137: Tight arrangements should be in place for scope management and control (Staal-Ong et al., 2016)
OM10	Number of (timely) meetings with authorities	F1609: Technical approval authorities (Kog & Loh, 2012) E0175: Communicate with authorities proactively (Staal-Ong et al., 2016) K0421: Policy or law of government (Ali et al., 2013)
PM12	Qualifications personnel	C0802: Skilled designers (Alias et al., 2014) F1023: Competency and experience of the project personnel (Ofori, 2013) F1033: Lack of experienced staff (Ofori, 2013)
PM34	Number of unanswered inquiries/requests	EP08: Could Control Indicators be: lack of response, lack of interaction, missed deadlines, missing input from participants (remarks #3 from section 4.4.2, expert panel workshop)

Table 13: The traceability of Control Indicators

The Control Indicators are based on certain sources; all these sources can be linked through their code back to literature or research results (interview/expert panel). Each CI can be traced back to its source, thus providing the scientific foundation of the indicator.

In the next chapter the Monitoring/feedback-system is discussed. This is the system which aids the selection of the Control Indicators and provides a step by step process description of how the CIs should be monitored and how they can be used by project management professionals to respond to the project.

5 The monitoring/ feedback-system

5. The Monitoring/feedback-system

In order to use the Control Indicators, a system has to be in place where the CIs are embedded in and that allows project management/managers to respond to them; that system is the Monitoring/feedback-system (MFS). A proactive approach to project monitoring as described in chapter 2.7 requires:

1. Leading Control Indicators which can be acted upon
2. A system that aids in selecting, monitoring and displaying the CIs

The first point is discussed in the previous chapter, the second point is discussed in this chapter. Section 5.1 will concern the functional requirements derived from literature, interviews and the Expert Panel workshop as well as the implications from the CIs. In section 5.2 the design of the MFS is discussed. Section 5.3 elaborates on the use of the MFS which is illustrated with two possible applications. Section 5.4 concerns the validation of the MFS. This chapter is structured according to Figure 22.

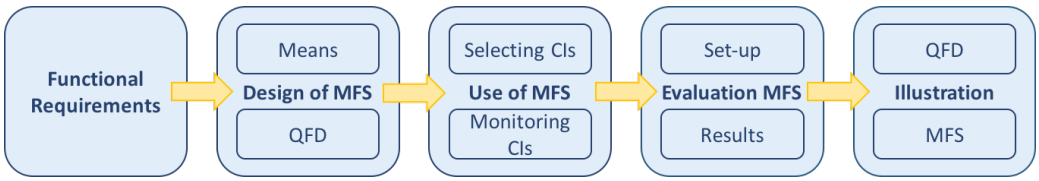


Figure 22: Structure of the chapter

5.1 Formulating the functional requirements

In this section the functional requirements for the Monitoring/Feedback-System are formulated. The functional requirements are used as leading guidelines in designing the MFS, and formulating this list is therefore a crucial part in this thesis (as illustrated in Figure 23).

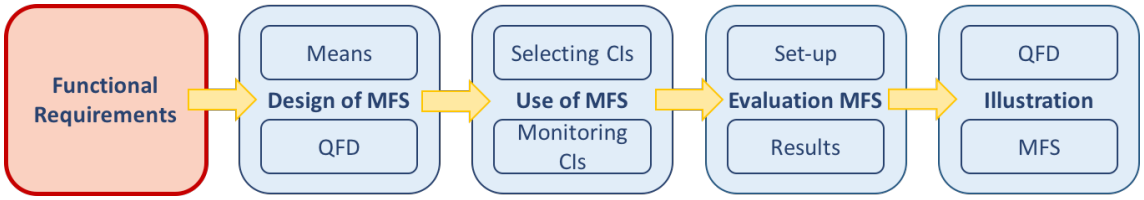


Figure 23: Functional requirements in the process of building the Monitoring/feedback-system

According to Dym, Little and Orwin, functions are "those things a designed device or system is supposed to do" (Dym, Little, & Orwin, 2014, p. 72). The input for formulating the functions of the MFS originates from four different sources (Figure 24) and discussed in this section.

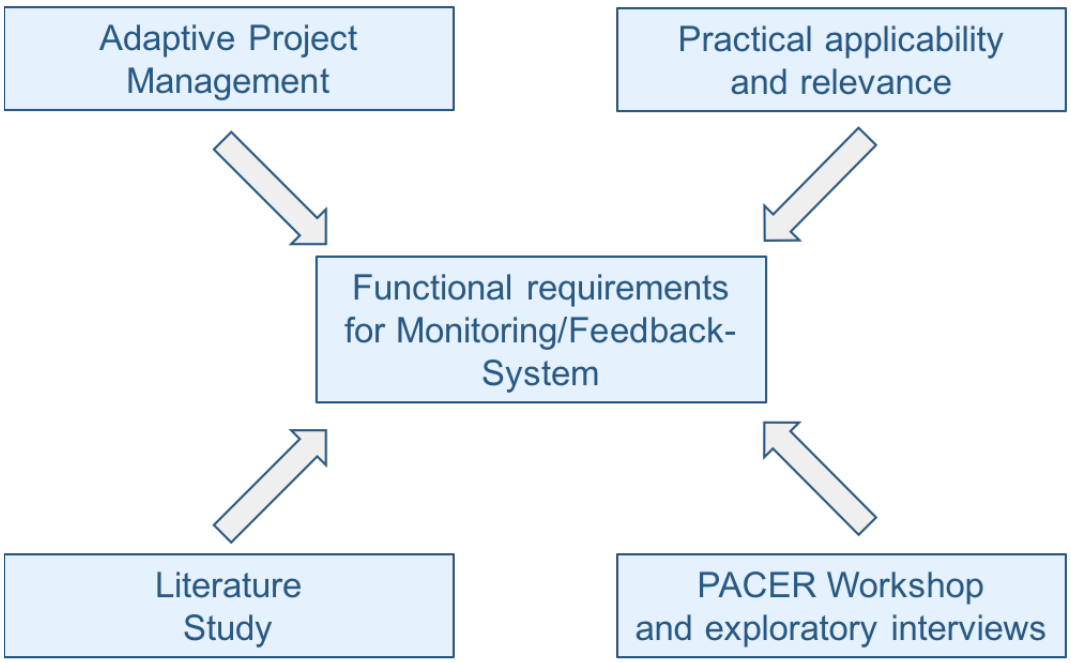


Figure 24: Input for functional requirements of the Monitoring/feedback-system

In section 5.3 the functional requirements are translated to possible designs and applications. In section 5.4 the evaluation of the MFS is discussed. The Control Indicator selection tool is illustrated in 5.5 and the practical differences between the current situation and the use of the MFS is explained using two fictional examples in section 5.6

Proactive Project Management

The most important difference between traditional project management as described in PMBoK and Proactive Project Management proposed in the introduction, are the monitor and control practices. Although both methods have parts in place to track problems or irregularities and controlling processes in place to deal with these problems.

So what would be the added value of Proactive Project Management (PPM)? The answer to this questions lies in the nature of PPM that is built around the Control Indicators which are both qualitative and quantitative. Whereas quantitative monitoring takes in account only the iron triangle (or even more often only budget and schedule), CIs quantify performance of sub processes, process related metrics (communication and cooperation) and other leading indicators. The term 'leading' is the reason why PPM is different from traditional monitoring and controlling; by monitoring CIs, irregularities should be noticed earlier which reduces the intensity and urgency of controlling efforts. By focusing more on leading than lagging indicators, controlling shifts from reactive towards proactive management.

The 'hybrid' nature of CIs (Figure 25) is also an effort to find a compromise between the trade-off between qualitative methods (pro: detailed information with context; con: small sample space, time and money consuming) and quantitative methods (pro: general lines and broad view; con: limited diagnostic value).

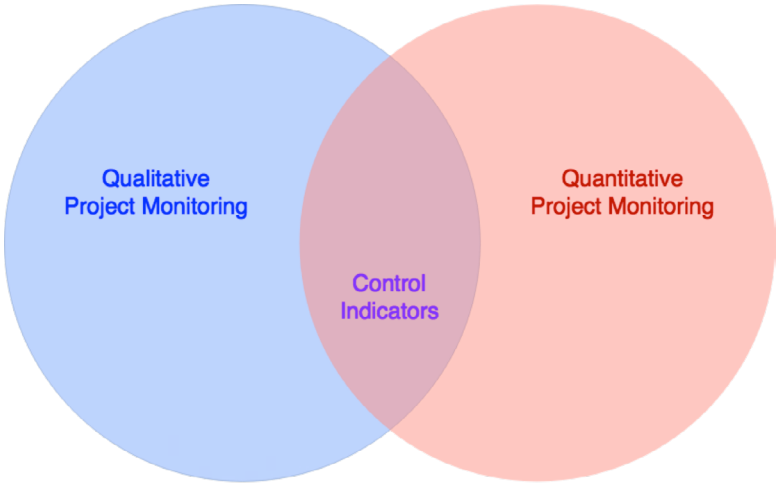


Figure 25: Control Indicators in relation to traditional monitoring

PPM is briefly described in this section due to the fact that the use of CIs has implications for the functional specifications of the MFS. Since there is a large amount of CIs, monitoring them all would be an administrative burden that project participants are not willing to bear or do not want to be bothered with. Different CIs have to be monitored with different frequencies, in different phases and different processes. Finding CIs that are compatible when measuring could reduce the burden of monitoring. This results in the following functional requirement:

- The Monitoring/Feedback-System must indicate which Control Indicators are suitable to be measured together

Practical applicability and relevance

In chapter two the concept of Large Construction Projects (LCPs) is defined, along with the necessity for Proactive Project Management in managing these projects. One of the arguments is that every project is unique: different stakeholders (residents, contractors, governments/municipalities, project organizations), different projects (construction, infrastructure) and other variables such as timespan, complexity and size.

The diversity of LCPs causes that not all Control Indicators are applicable or desirable to monitor in every LCP. Therefore, CIs have to be structured in order be able to effectively search for CIs. This results in the following requirement:

- The Monitoring/Feedback-System must apply structure to the Control Indicators

PACER Workshop and exploratory interviews

During the exploratory interviews and Expert Panel Workshop PACER professionals were asked for their opinion on monitoring in projects (the results can be found appendix D). An important conclusion that could be drawn from the workshop was regarding the properties of CIs and the project manager; not every project manager is interested in every CI and even if they were, they would not be able to monitor everything. Therefore, project management should be able to make a selection of CIs relevant to its management style based on the categories and attributes assigned to the CIs, resulting in the requirement:

- The Monitoring/Feedback-System should provide project managers with a tool to select the Control Indicators relevant and suitable for the management style and preferences

Literature study

The Project Management Body of Knowledge (PMBoK) is used as reference project management method throughout this thesis. The project monitoring process is described as an activity for which certain inputs are necessary in order to reach the desired output by executing available tools and techniques. This information is provided per monitoring process (risk/scope/schedule/quality).

The Monitoring/Feedback-System is a different approach to monitoring and requires its own process description in order to execute the monitoring effectively, resulting in the following requirement:

- The Monitoring/Feedback-System must provide a description and explanation for its process

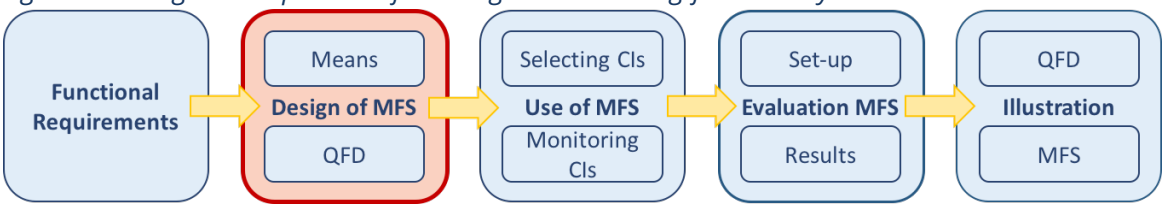
Concluding: based on the concept of Proactive Project Management, practical applicability in LCPs, the experience of PACER employees and a literature study conducted into project management, the following requirements are formulated:

1. The Monitoring/Feedback-System must indicate which Control Indicators are suitable to be measured together
2. The Monitoring/Feedback-System must apply structure to the Control Indicators
3. The Monitoring/Feedback-System should provide project managers with a tool to select the Control Indicators relevant and suitable for the management style and preferences
4. The Monitoring/Feedback-System must provide a description and explanation for its process

5.2 Design of the Monitoring/Feedback-System

The functional requirements formulated in the previous section form the basis for the design of the Monitoring/Feedback-System which is discussed in this section. Every function of the MFS is linked to a mean in order to get from the input of the MFS to its output (Table 14).

Figure 26: Design in the process of building the Monitoring/feedback-system



In section 5.2.1 the first three means are discussed separately. How they fit together and are combined into the Quality Function Deployment is discussed in 5.2.2. The use of the Monitoring/feedback-system along with the fourth mean, the flowchart, is discussed in 5.3.

No.	Requirements	Means in place
1	The Monitoring/Feedback-System must apply structure to the Control Indicators	Categorization of CIs
2	The Monitoring/Feedback-System must provide project managers with a procedure to select the Control Indicators relevant and suitable for the management style and preferences	Multi criteria analysis procedure for selecting relevant CIs
3	The Monitoring/Feedback-System must indicate which Control Indicators are suitable to be measured together	Compatibility matrix of Control Indicators
4	The Monitoring/Feedback-System must provide a description and explanation for its process	Flowchart for the monitoring process

Table 14: Functional requirements of the Monitoring/Feedback-System

5.2.1 Means to fulfill the functions

The Control Indicators are formulated from factors, which have their basis in the literature study and interviews with project management professionals. CIs are the result of capturing the factors and are predictive of project management performance; the Monitoring/Feedback-System is the system in which the CIs are embedded. The CIs are the contents of the MFS: the project manager should be able to enter his preferences and receive a set of CIs that could be monitored.

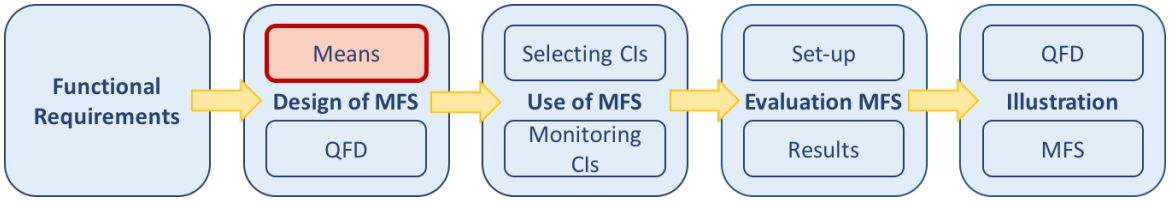


Figure 27: Choosing means in the process of building the Monitoring/feedback-system

In this section the first three means (Table 14) are discussed and how they contribute to the process to turn 'raw CIs' to a dashboard with metrics tailored to a project managers' management style. For each of the means is discussed what function they need to fulfill, why this mean is chosen and how this mean will achieve its goal.

Categorization

The Monitoring/Feedback-System should provide structure to the CIs. Since there are 94 CIs, a basic distinction based on monitoring properties provides oversight and simplifies the selection process. This distinction can be made based on different aspects: a score on a certain scale (1-5), hierarchical relations or classical categorization. In this research, the latter is used, meaning that the CIs are categorized based on certain properties or aspects. The reason this type of categorization is chosen is because the goal is to differentiate them on certain aspects and divide them into different categories

This categorization should result in manageable categories and a manageable amount of categories. Therefore, CIs are divided along two mutually exclusive axes: 'type of data' (either quantitative or qualitative) and 'theme of data' (either project & process data or human data). Assigning CIs to these axes results in four categories (Table 15). Although a certain CI could be expressed with a value (quantitative) or direction (qualitative), one cannot be both at the same time and will therefore be assigned to highest level of detail possible. Table 15 contains an example of each of the different categories. The complete list of CIs, along with their categories can be found in Appendix C.

Examples of Control Indicators	Process & project data	Human data
Quantitative	Lead time change requests (days)	Project team compatibility (% compatible)
Qualitative	Contract type	Qualification personnel

Table 15: Examples of the categorization of Control Indicators

Multi-criteria analysis for selecting Control Indicators

When choosing a mean to decide which Control Indicators should be used, two options emerge: a single-criteria or multi-criteria analysis (MCA). Since a single-criteria analysis would not be able to assess a CI on different criteria and thus will always result in one single optimum, a multi-criteria analysis is used. There are different varieties of multi-criteria analyses to choose from: the effect table, score card and SMART-model (TU Delft, 2014). The functional requirement formulated in Table 14 is as followed: The Monitoring/Feedback-System must provide a procedure for selecting CIs based on the users' preferences. This requirement is twofold:

1. The Control Indicators need to ranked according to preferences; therefore,
2. Control Indicators need to be rated on different attributes to allow comparison

Regarding the first part of the requirement: The effect table and the score card are not suitable for this purpose since they do not provide a function in which weight factor can be assigned to the different criteria; which is possible with the SMART-Model. This model is a multi-criteria tool that allows the user to compare (through standardization) different alternatives on criteria with different units of measurement, for example: cost (€/km) and rating (++/+/0/-/--). Although standardization is not necessary since the attributes (criteria) of the CIs (alternatives) are all measured on the same scale as explained later in this section, the SMART-Model is the MCA of choice.

For the second part of the requirement, attributes are assigned to the CIs. Whereas the categories are of a nominal nature, the attributes are formulated as objective for the CIs with a desired direction. The attributes of the CIs are based on the literature study, exploratory research and the Expert Panel workshop. Assigning attributes and scoring the CIs on these attributes allows the MFS to prioritize the CIs. Project managers have different management styles and preferences; the ability to assign different weights to the attributes makes it easier to select CIs best suitable for the management style.
The attributes are:

1. Measurability (effort)
2. Measurability (time)
3. Communicability
4. Insensitivity information (organizational)
5. Reliability
6. Insensitivity information (privacy)

The different attributes are explained in Table 16. Three different types of attributes have been formulated: operational attributes (how and how often is the CI monitored), organizational attributes (what could and should be done with the data) and human attributes (personal implications for sharing information).

Attribute	Type	Definition and scales
Measurability (effort)	Operational	This attributes indicates measurability in terms of the effort it costs to monitor a CI; the higher the number, the easier it is to monitor the attribute 1. Meeting or interview with an actor 2. Survey/questionnaire that has to be conducted 3. Information inquiry costs little effort (phone call, searching in database/ system) 4. Automated monitoring is possible and has low impact on actors 5. Data is already monitored and can be retrieved from that system
Measurability (time)	Operational	Certain CIs have to be monitored with a higher frequency than others. A low number of required updates makes a CI less time consuming to track. The higher the required frequency, the lower the scale. 1. Daily updates 2. Weekly updates 3. Monthly updates 4. Semi-annual updates 5. No updates required
Communicability	Organizational	This attribute indicates for what purposes the monitored data will be used. This scale is defined from the perspective of the project manager (PM): being allowed to use the data for more purposes is useful and thus desired. 1. Data can be communicated to limited actor for which it is relevant 2. Data should be kept to the project management team 3. The data can be communicated to higher management within the organization 4. The data can be communicated to project participants (contractors, client) 5. Data can be communicated to anybody (residents, press, municipality)

Insensitivity information (organizational)	Organizational	This attributes indicates how sensitive the CIs is in terms of organizational information. The higher the number, the lower the sensitivity 1. Highly sensitive 2. Sensitive 3. Medium sensitive 4. Slightly sensitive 5. Not sensitive
Reliability	Human	Certain CIs are more likely to be reported incorrectly or corrupted by participants. The lower on the scale, the more the CI could be subject to corruption. This scale does not include the likeliness of corruption; it merely states the possibility hereto. 1. Very sensitive to corruption 2. Sensitive to corruption 3. Medium sensitive to corruption 4. Slightly sensitive to corruption 5. Not sensitive to corruption
Insensitivity information (privacy)	Human	This attributes indicates how sensitive the CIs is in terms of privacy. Highly sensitive personal information is linked to a low rating on the scale. This attribute only indicates the privacy invasiveness of data collected, it does not include the integrity of the project manager or handling of information. 1. Personal information regarding the stakeholders, traceable 2. Personal information regarding project, traceable 3. Non-personal information on general project aspects, traceable 4. Non-personal information on general project aspects, not traceable 5. No invasiveness, no opinion/privacy involved

Table 16: The attributes assigned to Control Indicators in order for the Monitoring/ Feedback-System to prioritize them

The distinction between the different types of attributes is made since they share certain properties. Operational attributes are related to the ways of measurement; different methods and frequencies could be used, depending on the user. The organizational attributes reflect (to some degree) organizational values; depending on the organization, sharing information can be seen as a problem. Public organizations need to be transparent to some extent (for governmental accountability reasons), whereas private companies might not want to share information. The human factors are highly dependent on to what extend people are engaged to monitoring CIs. Limited engagement could result in unwillingness to cooperate in sharing sensitive information (according to the members from the Expert Panel).

Compatibility matrix of Control Indicators

The Monitoring/feedback-system will contain different CIs that are monitored. Since CIs are measured in different ways and indicate different trends in projects, it is important to select a group of compatible CIs. The MCA exposes the CIs that are most relevant or preferred by a project manager; this could result in a set of CIs that are either closely related (inefficiency) or require different methods of measuring (laborious). Therefore, the CIs are reciprocally tested regarding their compatibility using a Compatibility Matrix.

The Compatibility Matrix should ideally be consulted after the MCA, since selecting CIs on compatibility without taking into account the managers' preferences would be undesirable; using compatibility as first criterion and their scores on the attributes as second criterion would be inefficient. Certain CIs can be measured simultaneously (compatible), others paint a complete picture together (complementary) or are redundant and measure roughly the same values; to provide an overview of these relations a Compatibility Matrix is build. Building a sensible Compatibility Matrix containing all CIs would be very time consuming (assessing 3200 relations) while the results could still be debatable and vary from project to project; by including only the CIs of one category in each Compatibility Matrix no unnecessary work is performed and a clear representation of the Compatibility Matrix can be maintained.

5.2.2 The Monitoring/Feedback-System: building the House of Quality

The Proactive Project Management approach does not prescribe a linear predefined path that should be followed, but it does provide the project management team or the project manager with a set of Control Indicators that can be used to intervene in the project. The implications for the means that fulfil the functions is that these means are flexible and allow the input to be altered.

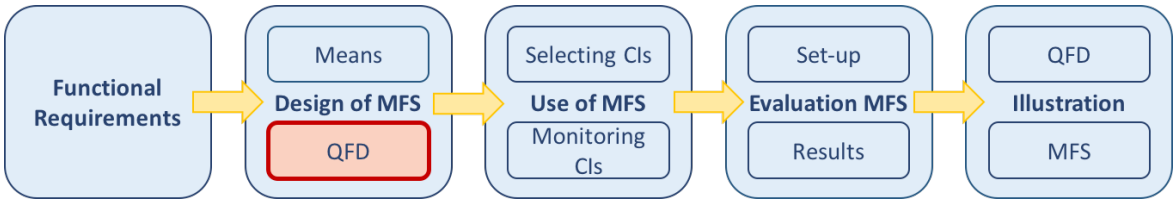


Figure 28: Building the House of Quality in the process of building the Monitoring/feedback-system

If the goal of PPM is to provide project management professionals with leading indicators to respond to the project, monitoring a certain CI or a set of CIs can be seen as an alternative. Compatibility among these alternatives (compatibility matrix) and their scores on attributes, combined with the fact that weight factors are assigned to the attributes by a certain actor (SMART-Model MCA), echoes the House of Quality, formally known as Quality Function Deployment. In the book 'Total Quality Management' is stated that the QFD is "basically a planning process with a quality approach to new product design, development, and implementation driven by customer needs and values" (Kiran, 2017, p. 426).

This description of the QFD fits the explanation of the MFS along with its purpose well; the 'customer needs' are defined by the project properties and the 'customer values' are defined by the project managers' style and preferences. The QFD used for product engineering as proposed by Dym, Little and Orwin can be seen in Figure 29.

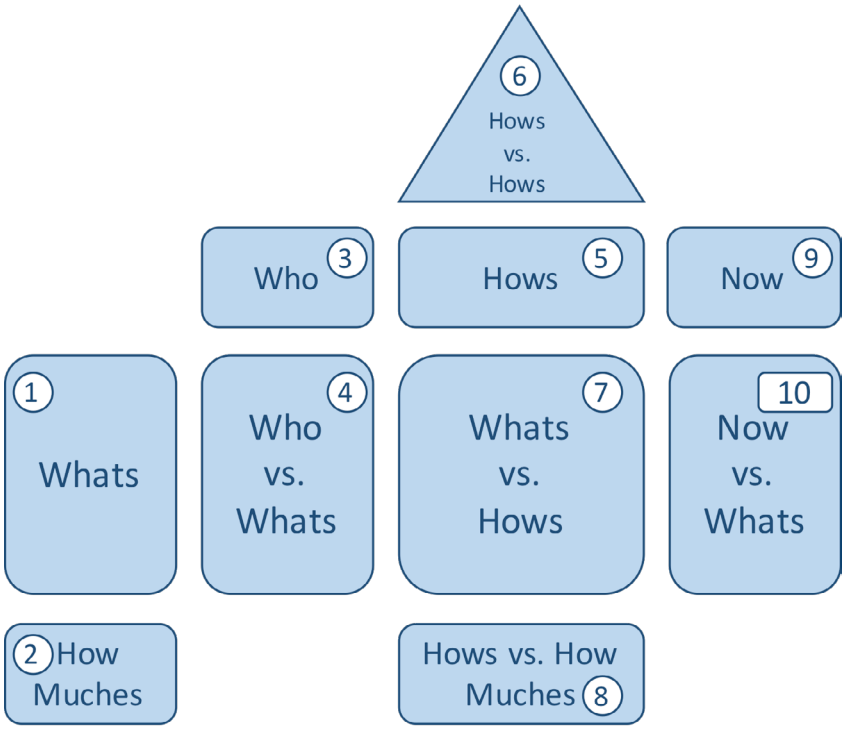


Figure 29: House of Quality (QFD) by Dym, Little and Orwin (Dym et al., 2014, p. 87)

First the QFD as used in product engineering is explained. The QFD as selection tool for Control Indicators is discussed in section 5.3.

Quality Deployment Function as product design tool

The QFD as displayed in Figure 29 "relates stakeholder interests, design attributes, measures, targets and current products" (Dym et al., 2014, p. 87). It helps designers to explore the relationships among these concepts. In Table 17 the different parts are explained including the application for this thesis.

No.	Function in product design according to Dym, Little and Orwin	Function in Monitoring/feedback-system
1	Contains the objectives/functions that have to be fulfilled or wishes formulated by users	Contains desired properties of CIs from the users perspective
2	The targets set for the entries in 1	Not used, there are no targets set
3	Stakeholders who prioritize the objectives formulated in 1	Multiple stakeholders could be included, but this is limited to the project manager or the management team for now
4	Contains the weight factors formulated by different stakeholders (3) to prioritize and assess the 'whats' from 1	These are the weight factors assessed to the attributes of the CIs. The weight factors are integers from 1 to 3
5	'Hows' indicates how the 'whats' are going to be realized; the 'hows' are the metrics to the objectives	Monitoring is the goal (achieved through the 'whats'), which requires 'hows', in this case the 'hows' are the different Control Indicators
6	Indicates the relation between different metrics/specifications	Contains the reciprocal relations between CIs (compatibility matrix) and whether they are: • Compatible • Complementary • Redundant
7	In this part the 'hows' are scored on the objectives formulated in 1	The CIs are assessed on the different properties/attributes and scales described in table 15.
8	Describes the relation between the targets (2) and the hows (5)	In the case of the MFS no targets are set. However, this part contains the average of the weighed scores of the CIs on the different attributes
9	Contains the systems, products are processes currently in place and serves as benchmark	Not used since the CIs are formulated to monitor different aspects than the current systems
10	The current products are scored on the different objectives and serves as benchmark	Not used since the CIs are formulated to monitor different aspects than the current systems

Table 17: Quality Function Deployment purpose versus the use in the Monitoring/feedback-system

In the next section is described how the QFD should be used in order to select CI compatible with the project managers' preferences.

5.3 Using the Monitoring/Feedback-System

In this section is described how the Monitoring/feedback-system is used. The description consists of two different parts:

1. The process of using the Quality Function Deployment to select Control Indicators
2. The MFS process description after the Control Indicators are selected

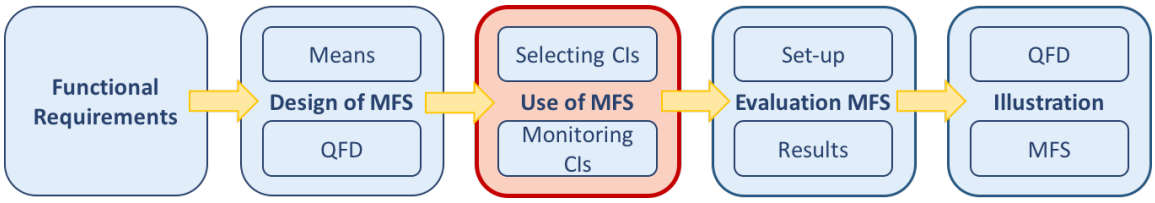


Figure 30: Using the Monitoring/feedback-system

First the process of selecting the Control Indicators is explained in 5.3.1. In section 5.3.2 is elaborated on the monitoring of CIs and how they could be responded to.

5.3.1 Selecting a set of Control Indicators

In this section the process of selection Control Indicators is explained. This is step is succeeded by an explanation of how CIs should be monitored (Figure 31).

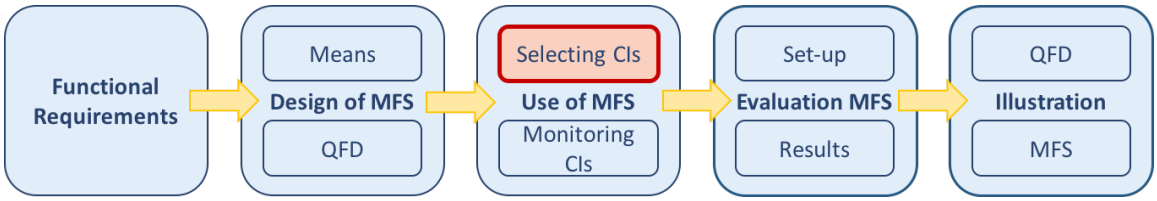


Figure 31: Selecting Control Indicators for the Monitoring/feedback-system

In order to provide a clear explanation on the process of selecting Control Indicators a tool from Systems Engineering is used: The Structured Analysis and Design Technique (SADT). It is used for analyzing activities taking into account the input, controls, output and mechanisms (Figure 32).

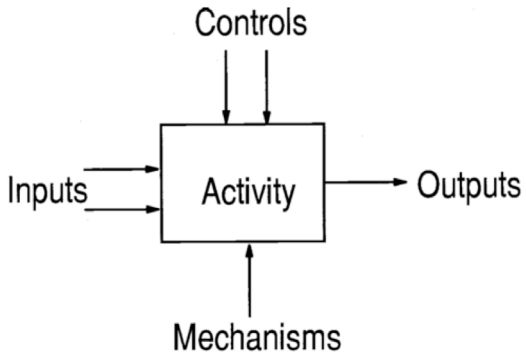


Figure 32: SADT building block according to Sage & Armstrong (Sage & Armstrong, 2000, p. 133)

The input is the data that is necessary for the activity; the output is the product. Controls are the conditions/rules that influence the activity and the mechanisms are the tools used to perform the activity. In Figure 33 the selection process for CIs is approached through the SADT perspective. Table 18 describes the different parts of the SADT.

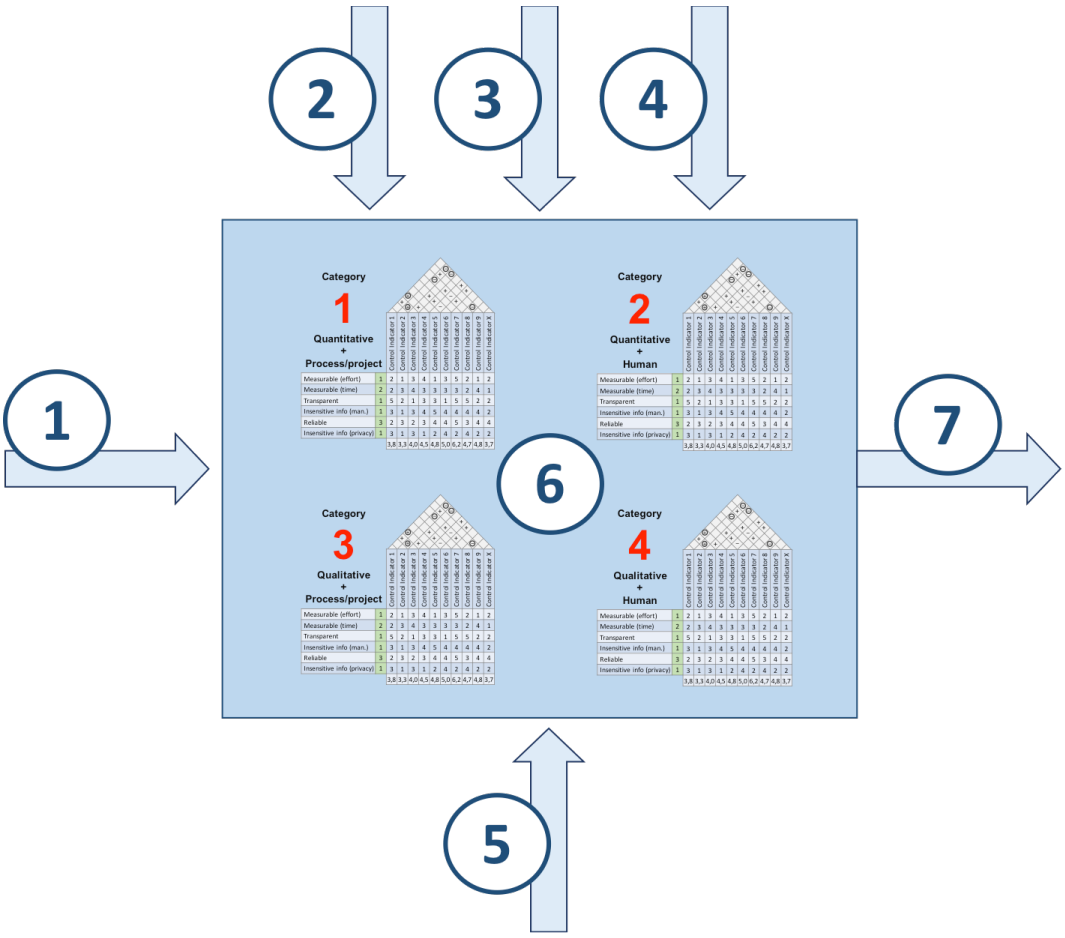


Figure 33: Selecting Control Indicators from a SADT perspective

No.	Type	Description
1	Input	Consists of four sets of preferences (weight factors) for each of the QFDs (one QFD per category)
2	Control	Set of Control Indicators
3	Control	Scores of the Control Indicators on the attributes
4	Control	Reciprocal compatibility of the Control Indicators
5	Mechanism	Multi criteria analysis (the average of the scores taking into account the weight factors)
6	Activity	Applying the users' preferences in each of the QFDs
7	Output	Ranked Control Indicators per category

Table 18: Explanation of the SADT

Entering the preferences

The weight factors that are entered in each of the single QFDs serve the purpose of ranking the Control Indicators on the different attributes: measurability in terms of effort and time, communicability, insensitivity of the information (organizational and personal) and reliability. It is advised that when entering the preferences, the user/ project manager takes into account the preferences of their own organization and management team in order to be able to create support more easily.

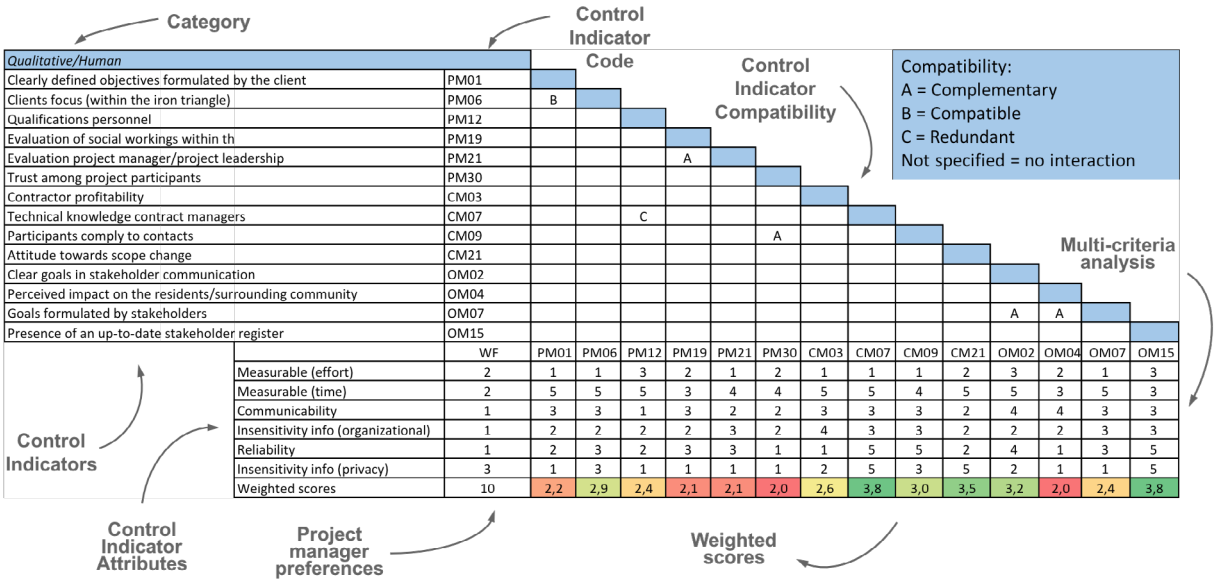
Weight factors can be assigned as integers within the range from 1 to 10. The higher weight factors the heavier the attribute weighs on the score of the Control Indicator. When assigning weight factors to these attributes, the user should ask him/herself to which degree they agree to the statements from Table 19. If the user fully agrees with the statement, the attribute should be assigned a 10; if the user fully disagrees it should be awarded with a 1. Anything in between should be graded according to the extent to which the user agrees or disagrees.

Attribute	Statement
Measurability (effort)	I think it is important that it take little effort to collect the data on the Control Indicator
Measurability (time)	The lower the measurement frequency the better.
Communicability	I want to be able to use the data that results from measuring the Control Indicator to anyone I want
Insensitivity (organizational)	I do not like collecting data that might be sensitive to the organization
Reliability	I want to collect data that cannot be manipulated by people
Insensitivity (privacy)	I do not like collecting data that might be sensitive to stakeholders involved in the project

Table 19: Determining the weight factors

Interpreting the output

The input that is required from the user are the weight factor (preferences) and the output is four different QFDs. An example of how one of these QFDs would look like can be seen in Figure 34.



Qualitative/Human															
Clearly defined objectives formulated by the client	PM01														
Clients focus (within the iron triangle)	PM06	B													
Qualifications personnel	PM12														
Evaluation of social workings within th	PM19														
Evaluation project manager/project leadership	PM21				A										
Trust among project participants	PM30														
Contractor profitability	CM03														
Technical knowledge contract managers	CM07			C											
Participants comply to contacts	CM09						A								
Attitude towards scope change	CM21														
Clear goals in stakeholder communication	OM02														
Perceived impact on the residents/surrounding community	OM04														
Goals formulated by stakeholders	OM07												A	A	
Presence of an up-to-date stakeholder register	OM15														

	WF	PM01	PM06	PM12	PM19	PM21	PM30	CM03	CM07	CM09	CM21	OM02	OM04	OM07	OM15
Measurable (effort)	2	1	1	3	2	1	2	1	1	1	2	3	2	1	3
Measurable (time)	2	5	5	5	3	4	4	5	5	4	5	5	3	5	3
Communicability	1	3	3	1	3	2	2	3	3	3	2	4	4	3	3
Insensitivity info (organizational)	1	2	2	2	2	3	2	4	3	3	2	2	2	3	3
Reliability	1	2	3	2	3	3	1	1	5	5	2	4	1	3	5
Insensitivity info (privacy)	3	1	3	1	1	1	1	2	5	3	5	2	1	1	5
Weighted scores	10	2,2	2,9	2,4	2,1	2,1	2,0	2,6	3,8	3,0	3,5	3,2	2,0	2,4	3,8

Figure 34: The QFD which incorporates the MCA, Project management preferences and CI compatibility

The legend on 'compatibility' has four options: complementary (A), meaning that two CIs monitored together have synergy (rating client by project manager and vice versa) and could be measured together. Compatible (B) means that are compatible in terms of monitoring method. If CIs are redundant (C) the roughly monitor something similar which would be inefficient. If a cell is empty, there is no particular relation between the CIs.

In the case of Figure 34, CM07 and OM15 have the highest scores (3,8) but no particular synergy with other CIs. The second and third highest ranked CIs are CM21 (3,5) and OM02 (3,2). OM02 might not have the highest score, but is complementary with OM02 and OM04. In this case the project management has to decide which CIs should be monitored. If the other three QFDs already resulted in six CIs to monitor and the project manager does not want to monitor more than seven CIs, CM07 would be a better choice; if this category is preferred by the project manager and there is enough capacity to monitor a few more CIs, monitoring Control Indicators OM07, OM02 and OM04 could be a useful addition.

The amount of CIs that should be monitored is up to the user. Parmenter states in his book on KPIs that he uses the 10/80/10-rule: 10 KRIs, 80 PIs and 10 KPIs (Parmenter, 2007). Monitoring all 93 CIs is possible, but could result in an administrative burden on the project management team. Since the CIs are formulated on their leading properties and divided into four categories, monitoring two to three CIs per category should give a decent ratio 'coverage' to 'monitoring efforts'. The more CIs are monitored; the more overlap eventually will occur and the marginal yield of monitoring extra CIs decreases.

Adjusting the model

Whereas the input consists of six weight factors per QFD, the controls consist of more than 93 Control Indicators, all rated on the six attributes and assessed on their reciprocal compatibility. The QFDs are made in Excel and changing the preferences alter the scores of the Control Indicators; all the other information that supports this process are the controls. These controls carefully formulated based on the results of the literature study and the opinions from PACER professionals.

An important point that has to be made is that although the compatibility and the assessment of CIs on the attributes is done as informed as possible, the actual compatibility and attributes may differ per situation. Depending on monitoring methods in place, organizational maturity and various interpretations of CIs, the compatibility and scores on the attributes could be altered, but this is a more fundamental procedure. An analogy to explain the difference: in a car the seats and mirrors can be adjusted before driving away (input), but changing the summer tires for winter tires requires more effort and changes the behavior of the car (control).

For altering these controls, more effort and knowledge of CIs and their compatibility is necessary and requires detailed action on the most operational level of the Monitoring/feedback-system. There is no easy way to reassess these relations between CIs and there scores on the attributes. Therefore, the user of the MFS could alter these values when using the model, but this is not presented as an input function since this falls outside of the scope of the thesis.

Concluding: The input for the model are four (different) sets of weight factor with as output four QFDs of each category from which the user can select Control Indicators. The models' controls can be altered to the preferences of the user but requires reassessment of all the assumptions and decisions made when all the CIs were tested on compatibility and attributes scores. Selecting around ten CIs from the four different categories provides the most coverage compared to the monitoring efforts.

5.3.2 Monitoring and responding to Control Indicators

After a set of Control Indictors is selected they have to be monitored and responded to where necessary. In this section is described how the monitoring system in which the CIs are embedded should be used (Figure 35).

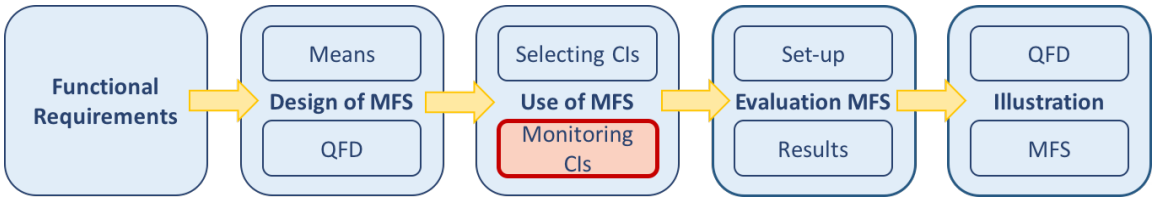


Figure 35: Monitoring Control Indicators in the Monitoring/feedback-system

The fourth mean (Table 14) is a guide that provides information on how to use the Monitoring/feedback-system. In this thesis, the flowchart (Figure 36) is used as a method to describe the process, since it provides a step by step approach that the user (the project manager) could follow. The blue ovals represent terminals: these are the beginning and end points of the chart. The green squares with two lines are predefined processes or activities (a detailed description of these processes is provided in Table 21) and the black squares are the ones represent processes as described in the square. The red diamonds are decision making moments to which the answer can be either yes or no. The yellow parallelograms represent input or output.

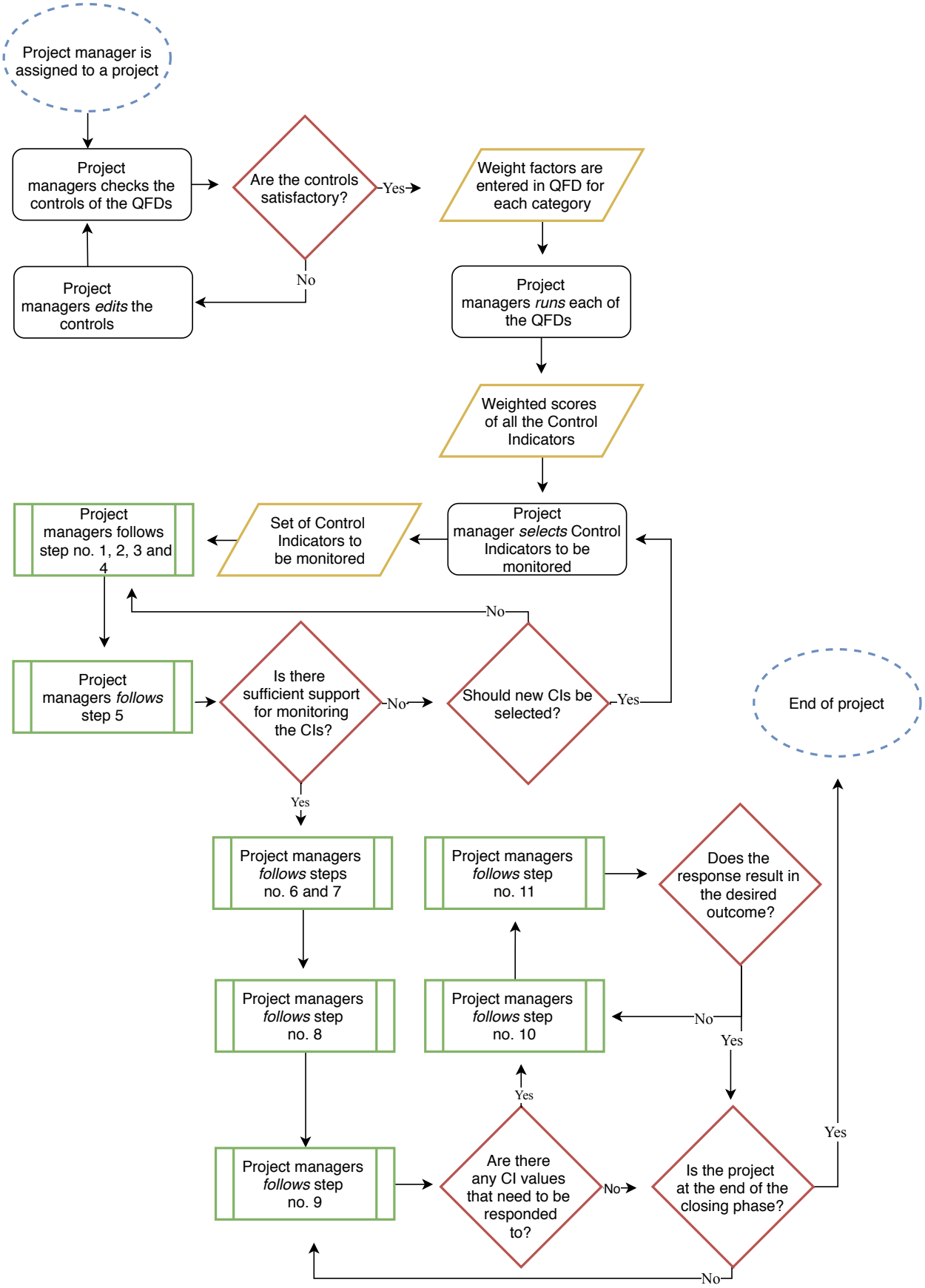


Figure 36: Flowchart describing the use of the Monitoring/feedback-system

The output of the QFD are weighted scores on different Control Indicators and their compatibility. Just like every project, every project management team is unique. It is near to impossible to describe all combinations of different CIs; taking into account the decisions that are going to be made based on the output of the QFDs makes it even more complicated. In order to ensure that the Monitoring/feedback-system is effective, a guide is designed on how its monitoring function can be performed without knowing the CIs in advance. Certain CIs score different on measurability effort than others: using a survey for measuring client satisfaction costs more effort than automatically measuring the lead time of change requests. These attribute score estimations are made based on the suggested monitoring method that comes along with each CI. The manner in which these CIs are monitored could be a choice of the project manager: it might as well be that change requests are not automatically monitored and that the project organization already has client surveys in place, resulting in a shift of the effort put in measurability. Therefore, it is imperative that the user of the MFS always uses it in light of their organization and specific situation. After a set of CIs is selected, the project manager should go through the phases as described next.

The monitoring and controlling process

Since the Control Indicators that will be monitored are not yet known the procedure has to maintain a sufficient level of abstraction. The steps up to “Project managers selects Control Indicators to be monitored” from the flowchart (Figure 34) have been discussed. The course of action that should be followed after selecting CIs is explained in Table 20. An elaboration of each step can be found in Table 21. The steps are clustered together in phases for later reference.

No.	Phase	Step
1	1	Identify the first moment of monitoring (phase of the project)
2	1	Formulate the frequency of monitoring (updating)
3	1	Draw a monitoring timeline
4	1	Establish to what extend the CIs can be communicated
5	2	Create support within the management team for monitoring CIs
6	2	Design a dashboard
7	2	Define action with certain values and trends of CIs
8	2	Assign person responsible to monitor and report certain CIs
9	3	Monitor the CIs and analyze the data
10	3	Respond to the monitored CIs
11	3	Evaluate whether the action has resulted in the desired outcome

Table 20: Steps in using the Monitoring/feedback-system

Step 1 – 4 (Phase 1)

The first three steps after the selection of CIs contribute to a monitoring timeline: it contains the information on the monitoring moments and frequency of the CIs. The sensitivity (organizational and privacy) of the information has to established and to what extent this could be communicated towards other stakeholders. After the first four steps the (preliminary) monitoring plan is finished. After Table 21 an example of a monitoring timeline and plan is presented.

Step 5 – 8 (Phase 2)

The monitoring plan is necessary to create support from both the organization and management team. Having a monitoring plan that can be presented makes it easier to create support among the management team or to receive feedback. As soon as the plan is accepted a dashboard should be designed (step 6) which contains all information on the monitored CIs, including sensitivity of the information, targets, trigger values and trends (step 7). The project manager bears the final responsibility regarding the dashboard, but he could delegate monitoring practices and keeping it up to date to other management team members (8). After Table 21 an example of the dashboard is presented.

Step 9 – 11 (Phase 3)

During the project the CIs should be monitored according to the monitoring plan (unless there are clear reasons to deviate from the plan). If during the monitoring (step 9) a CI reaches a value which requires action, an intervention is necessary (step 10). The last step is only used if an intervention was necessary: this is the evaluation of the response and whether this has resulted in the desired outcome. After Table 21 the process for responding to CIs is presented.

An important note is that these steps elaborate on what should be done and the reason it is important. Given the time constraint for this thesis, defining actions and means to reach the goals of these steps is not taken account. Moreover, these steps should be a general guideline taking into account the diversity of projects and its people. Allowing project management professionals to apply their own experience from the field in performing these activities provides them with discretionary space to maintain their own management style.

No.	Step
1	**Identify the first moment of monitoring (phase of the project)** It is important to determine the first moment of monitoring to make sure monitoring moment are not skipped and the monitoring practices start timely.
2	**Formulate the frequency of monitoring (updating)** In order to monitor CIs effectively the (desired) update/monitoring frequency has to formulated. CIs that are time consuming to monitor will probably be monitored less frequent than automated measurement techniques.
3	**Draw a monitoring timeline** A monitoring timeline provides oversight of the monitoring practices. Combining this timeline with other schedules or a GANTT-chart could create synergy and improve the output of monitoring data. Monitoring contractor satisfaction before and after a certain work package is passed on another contractor could provide useful information in their communication or quality of delivered product.
4	**Establish to what extend the CIs can be communicated** The sensitivity (both managerial and personal privacy) of the collected data should determine the communicability. Peer reviews (anonymized or not) could contain sensitive information and should be handled discretely: should it be used to enhance the performance of the project team, or should these personal rating be communicated to higher management levels? The outcome of this step also influences the next one: sensitive information should not be monitored by people who handle it without care or could pass it on to competitors.

5	**Create support for monitoring CIs** The project manager should create support for the MFS in two directions: • To the (project) organization: if there is no support from the project organization it is difficult to justify the monitoring efforts. • To the management team: if there is no support among the project management team for monitoring CIs, the MFS will not work. Especially surveys and peer reviews will not be a success if the management team does not see the potential benefits of monitoring certain CIs. The project manager could create support for the MFS by communicating to the project organization that monitoring certain CIs is beneficial for the project performance and the development of the management team. Providing the project organization with the options to monitor CIs that push their agenda (focus on excellent service or extensive risk management) can also create support for the MFS. The management team should be explained that monitoring CIs is beneficial for project performance to create engagement. Explaining that the MFS has the support from the organization could also create support, else the MFS could be seen as 'just another tool used by the project manager'. Providing the management team with a moment to provide feedback on the monitoring timeline adds to the support.
6	**Design a dashboard** The project manager should design a dashboard which contains all the data on the CIs that should be monitored. It should also contain the values of the CIs measured earlier in the project. The dashboard should support a function that data can be qualified in terms of privacy and organizational sensitivity; this should prevent that classified information of the CIs is communicated through parties who should not have access to this information.

7	**Define targets/limits on certain values and trends of CIs** Although not every CI could have predefined trigger values (values that require follow-up action), formulating conditions under which CIs should be responded to makes it easier to act on them. Instead of hard values, certain trends can also be formulated as triggers (e.g. a 50% increase in change request lead time). Depending on whether the CI is quantitative or qualitative different kind of targets and limits should be defined: **Qualitative Control Indicators** CIs of a qualitative nature have can on either a nominal or ordinal scale. Those on a nominal scale such as "type of contract" are one-time-measure CIs that could predict certain forms of behavior from participants. On the ordinal scale are CIs like "evaluation of social workings within the team" and "qualifications personnel" of which scores could be ranked (cooperation rated from bad to excellent; no education to highly educated). Based on earlier projects, project managers' preferences, clients' wishes or organizational standards it is possible to formulate a minimum/maximum value to which every monitoring moment has to be benchmarked. Falling under the predefined value should trigger a corrective response. If it is not possible to formulate clear values due to a lack of baseline, monitoring the trend becomes a better way to assess the value of the CI. **Quantitative Control Indicators** Since quantitative CIs are expressed in a 'hard' value they are easier to compare than qualitative CIs. Another advantage is that there is less bias in CIs such as "the number of budget/contract meetings", since these meetings either happened and are counted or they did not happen. Quantitative CIs are more likely to be measured in automated systems, which makes it easier to automatically import them in a dashboard and calculate trends. Regarding formulating limits and thresholds of CIs, goes the same as for their qualitative counterparts: earlier experiences or stakeholders demands could be the basis for these values.
8	**Assign person responsible to monitor and report certain CIs** Chances are that if no one is responsible for monitoring certain CIs, monitoring will not happen at all. Therefore, a person has to be made responsible for monitoring and reporting the CIs. The project manager is the person who is responsible for the dashboard, that it is updated and that action is taken when the CIs indicate an intervention is necessary. Responsibility in this sense does not mean that the project manager does everything alone; he could delegate tasks to management team members or other rely on other actors to provide data or to intervene where necessary.

9	**Monitor the CIs and analyze the data** The CIs can be monitored (automated or not) with different frequencies. Regardless of these properties, the project manager should analyze (or have analyzed) the data regularly in order to ensure that the signs of the CIs are not missed. This analysis could include for examples trends over time or extreme values for lead times.
10	**Respond to the monitored CIs** Each project manager has his/her own management style and practices to control projects. As long as the response to a certain CI value results in either a further analysis or successful intervention the project management should act however it seems fit. Since a CI does not necessarily mean that a problem has occurred; it could also indicate that a process is not being carried out properly or that tension between two project participants is increasing. The proposed course of action is described in 'phase 3' after this table.
11	**Evaluate whether the action has resulted in the desired outcome** If a CI indicates a problem and an intervention has taken place, it should be evaluated whether its goal is achieved. The CI should change in the desired direction: if a conflict between the client and the project managers is resolved the reciprocal rating should improve compared to the rating during the conflict. If this does not happen, a new intervention might be necessary.

Table 21: Description of each of the steps after selection Control Indicators

Phase 1

The monitoring timeline from step three can be made after the CIs that could be monitored are selected and their first moment of monitoring and monitoring frequency are determined. In Figure 37 an example of such a monitoring timeline is displayed.

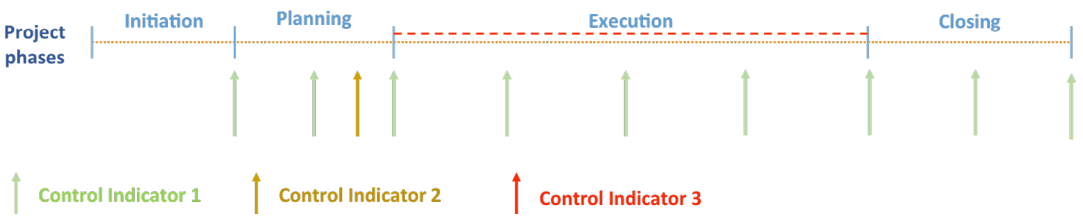


Figure 37: Possible monitoring/feedback timeline

In the case of Figure 37, Control Indicator 1 is a half yearly peer review of the project team members, Control Indicator 2 is the identification of the type of contracts as procured to contractors and Control Indicator 3 is the continuously automatically monitored lead time of change requests. Figure 37 provides an examples of what a monitoring timeline could look like; in practice this highly dependent on the project manager and the project itself. Designing this timeline along a GANTT-chart allows the project manager to identify important milestones and link these to a monitoring or CI-evaluation moment in order to maximize the result from the MFS.

Since the monitoring planning has to be presented towards the organization and the management team, the level of privacy (both organizational and personal) has to be established before support can be created. The management team would not be opposed if a peer reviews is used to improve co-operation of the team; they probably would oppose it if the project managers shares these reviews with higher management, which could have more serious consequences.

Phase 2

The dashboard (Figure 38) contains the basic information of the monitoring plan, including the predefined trigger values. Triggered values in the dashboard are marked red; indicating action is required.

Organization: PACER
Project: Example
Project manager: M. Anager
Last update dashboard: 11/03/18

		Dec-17	Jan-18	Feb-18	Mar-18
Evaluation project manager/project leadership	Rating	6,8	6,9	7,6	7,5
Measuement method	Survey				
First measurement	Start execution phase: december 2017				
Frequency	Monthly				
Trigger value	< 7				
Defined action	Organize meeting management and team				
Communicability	Involved parties: project manager and team				
Responsible for monitoring	Project manager				
Presence of an up-to-date stakeholder register	Amount of updates/month	3	2	4	4
Measurement method	Inquire at Environment Manager				
First measurement	Start execution phase: december 2017				
Frequency	Weekly				
Trigger value	Amount of updates falls under 3 per month				
Defined action	Organize meeting with Environment Manager				
Communicability	Organization, management team and client				
Responsible for monitoring	Enviromental Manager				
Number of change requests	Number CRs to be examined	3	4	6	9
Measurement method	Automated				
First measurement	Start execution phase: december 2017				
Frequency	Weekly				
Trigger value	If the number of CRs increases 3 months in a row				
Defined action	Organize meeting with stakeholders who filed CRs				
Communicability	Organization, management team, client, contractors				
Responsible for monitoring	Contract Manager				

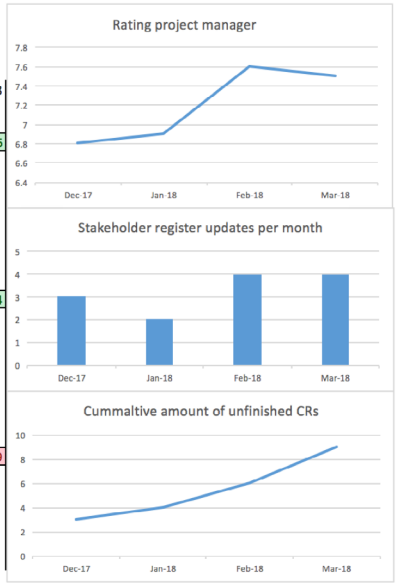


Figure 38: Dashboard containing three Control Indicators

The dashboard from Figure 38 is monitored only four months. As the project progresses more data is gathered, added to the dashboard and displayed in the graphs.

Phase 3

The Monitoring/feedback-system has to provide a mechanism which allows the user/project manager to monitor and respond to 'red flag'-values (triggers) of Control Indicators. The proactive policymaking approach by Haasnoot, Kwakkel, Walker, & ter Maat (2013) is a continuous cycle designed to improve policy and make it more robust. This framework is used as basis for the monitoring/ response/evaluate phase (step 9, 10 and 11 from Table 21).

There are some differences between policymaking and Large Construction Projects: the proactive policymaking framework is a continuous cycle, whereas LCPs are linear with a clear beginning and end. Moreover, LCPs are physical structures, whereas formulated policy is not (or not yet). By adapting the policymaking framework, it could provide a useful guide for project management as proposed in this thesis. The adapted framework (Figure 39) is an abstraction of the project management phases as described in PMBoK (2008). The initiation, planning, execution and closing phase are simplified in the adapted framework and the focus lies on monitoring and controlling (which is also the focus of this thesis).

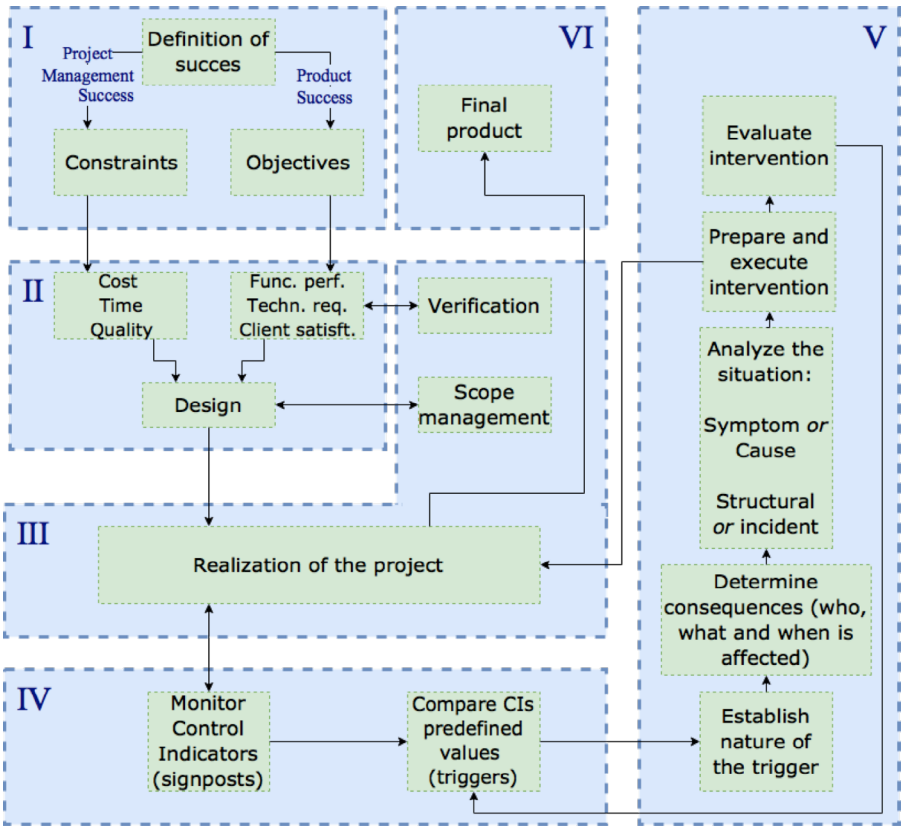


Figure 39: Responding to Control Indicators in projects

The numbers in the corners represent the project phases formulated in PMBoK in their respective order initiation, planning, execution, monitoring, controlling and closing (Project Management Institute, 2008). During the execution phase

(the realization of the project in particular), Control Indicators are continually monitored. The dashboard (designed in step 6) tracks the CI values and compares them to the predefined trigger values (defined in step 7). By falling under a certain value or passing a limit the CI requires a response: this is the start of the 'controlling'-effort (V).

First the nature of the trigger has to be established: is it due to communication problems, technical issues, stakeholder conflicts, malfunctioning processes or external influences? If the nature of the trigger is clear, the stakeholders that are involved will be known. The follow-up action should be determining who, what and when is or will be affected. By determining the consequences, the effects of not responding to the CI on the project or stakeholders is made explicit. Before responding to the trigger, the situation should be analyzed whether this is a one-time event or part of a more structural trend. It might be the case that the trigger is not the problem but merely a symptom of a more fundamental cause. The next step is executing the intervention which should contribute to controlling and improving the processes the CI reflected. The intervention should be evaluated afterwards and a follow-up measurement of CIs should be performed to ensure that the problem has been tackled.

The model for responding to monitored CIs is not validated or evaluated due to time constraints. This form of project control is further discussed in the recommendations (section 7.4).

Concluding: The Control Indicators that are selected from the output of the QFDs are accompanied by suggestions on how to monitor the CI, but should this should always be reevaluated by the user given organizational and project-related factors. After selecting the Control Indicators, the next ten steps as described in the flowchart should be followed. The flowchart contains a step by step explanation of how the MFS should be used.

5.4 Evaluation of the Monitoring/feedback-system

The previous sections elaborated on the use of the Monitoring/feedback-system; in order for the MFS to be applicable in practice it has to be evaluated. The reason that in this research an evaluation is chosen over validation is due to various constraints discussed in 6.2.3. In order to maintain the practical applicability without validating the MFS, an expert evaluation is conducted.

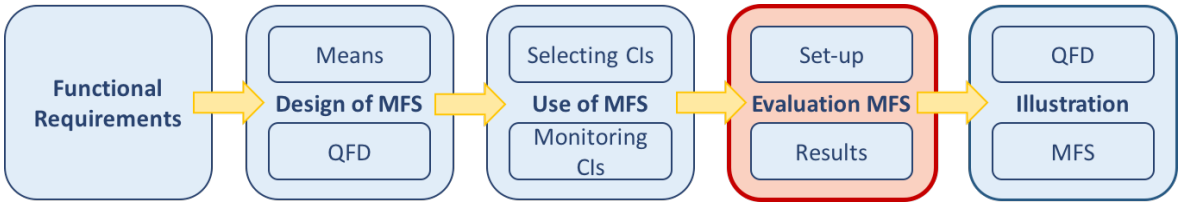


Figure 40: Evaluation of the Monitoring/feedback-system

This section describes this evaluation; in section 5.4.1 the goal and set-up of the evaluation is discussed. Section 5.4.2 elaborates on the results of the evaluation and the changes made to the MFS in response to the feedback.

5.4.1 Set-up and goal of evaluation

Since the evaluation of the Control Indicators happened in a separate session and are 'as-is', they are not being discussed in this meeting. The goal of this evaluation is followed:

1. Receive feedback on the use of the Control Indicator selection tool (QFD)
2. Receive feedback on the flowchart (and thus the process after the CI selection) on its logic and completeness

These goals are achieved by performing the activities with the corresponding numbers in Table 22. The reason this evaluation is conducted with a project management professional from PACER is to improve the practical applicability of the MFS and improve its value. The expert from within PACER is chosen based on his experience with dashboards and monitoring in projects.

For the meeting a time of two hours was reserved and involving only the researcher and the PACER expert. The meeting was not recorded and the notes were taken by the author himself. Since it was a bilateral meeting there was enough time to write down important feedback and ask questions to clarify unclear remarks. The structure of the meeting is described in Table 23.

No.	Activity	Goal
	Inform expert	The expert is given a brief explanation on the research process and the way Control Indicators are formulated in order to set the context of this meeting.
1	Use the Control Indicator selection tool	Evaluate: • Whether the expert is able to use the model. • If the user also understands the model, the inputs and their meaning, its controls, the output and how to interpret the output.
2	Review the flowchart	Evaluate if executing the steps prescribes by the flowchart is sufficient to follow up on the selection of the CIs.

Table 22: Structure evaluation meeting Monitoring/feedback-system

5.4.2 Results evaluation

During the evaluation the feedback on the different parts of the CI selection tool and the flowchart are written down. In Table 23 the feedback per evaluation activity is displayed. After the meeting the proceedings of the evaluation were sent to the expert for review; the expert agreed upon the proceedings and only had some minor remarks.

No.	Activity	Feedback
1	Use the Control Indicator selection tool	Excel model (QFDs) • Provide a clear description of how the user/project manager should enter the weight factors/preferences. It was not completely clear what the attributes meant • An addition to the excel model could be that a sum of points has to be distributed among the different categories
2	Review the flowchart	Flowchart (general) • The shape was counter intuitive since it follows and 'U' shape (user starts upper left corner, goes down and ends in the upper right corner) • As an addition to the description of the steps that should be followed, a short introduction that explains how the steps are linked and why the steps are consecutive Flowchart (process) • Step 1 (creating support) should be after step 2, 3, 4 & 5 (determine first measure moment, monitoring frequency and the sensitivity of the information). This is substantiated by the following example: if a project manager proposes monitoring CIs in a project to the members of the management team, the first thing they will do is ask questions regarding step 2, 3, 4 & 5; therefore, a monitoring plan should be made before support is created. It is the project managers' task to create support for the MFS among both the project organization (internal) and the management team. • Step 7 (appoint people who are responsible for monitoring) concerns the responsibility of monitoring and updating the dashboard. The expert noted that the responsibility lies with the project managers, but tasks can be delegated to other management team members; which comes down to the following: project manager can make other people responsible for executing the tasks, but in the end the project manager is accountable. • Step 9 is the step which is described as responding to CIs. The expert explained there is no single approach in project controller (and acting on CIs). The expert described that when a problem is encounter first the cause of the problem has to be established and whether the problem is an incident or part of a more structural problem. According to the expert, projects always encounter problems due to ever changing circumstances (weather, people, unexpected events) and no two projects are the same. During this thesis the assumption was that (standardized) project control measures were widely applied, but this is not the case. Therefore, a basic response framework is developed.

Table 23: Feedback per activity

During the evaluation the expert showed a dashboard that is used in one of the projects. The dashboard keeps track of a large variety of qualitative and quantitative metrics which led to the question to what extend the MFS could contribute to monitoring in projects compared to the dashboard. The expert explained that the dashboard was complete on project controlling metrics and that it did not include metrics on technical, contract and environment management. It could also be useful for project managers who are either driven by quantitative data or qualitative data and contractors who are tendering could use the excel sheet as if it was used by the client in order to build a tender around high ranked CIs (on which they would try to outperform the other tenderers). To ensure that the expert is able to give sensible feedback the context of the Monitoring/feedback-system and Control Indicators has to be explained.

The proceedings of the session were forwarded to the expert (the proceedings consist of all the feedback from Table 23). If there had been any misunderstandings during the meeting or a rectification of the proceedings was needed, the expert was given the opportunity to do so. The proceedings had been changed slightly by the expert (choice of words, changing organization to internal organization) and were approved. The results of the expert evaluation are critically assessed and proved to be useful in improving the MFS. Except for adding the point system to the weight factor mechanism all the feedback is processed.

Concluding, the expert evaluated the MFS (consisting of the CI selection tool and the flowchart for follow-up action) and raised valid points regarding the support that has to be created both upwards (organization) and downwards (management team) and the sequence of the steps. After the meeting the proceedings were sent to the expert and were approved. All the feedback (except for the point system) is processed in the MFS.

5.5 Illustration of the Quality Function Deployment

In this section Control Indicator selection tool is illustrated using two examples of fictional project managers in specific situations. This section does not provide a monitoring plan (phase 1), a dashboard (phase 2) or an example of project controlling (phase 3).

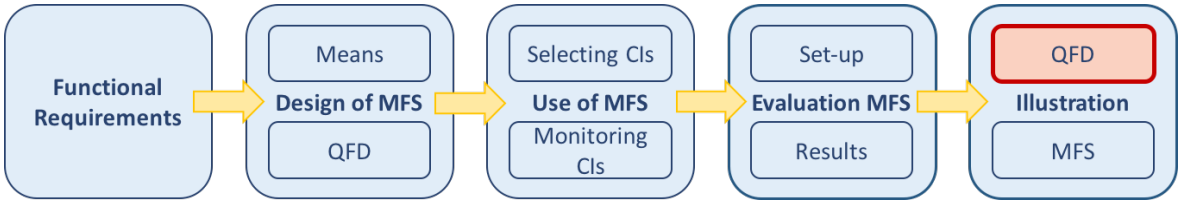


Figure 41: Illustration of the Quality Function Deployment

Attribute	Statement
Measurability (effort)	I think it is important that it take little effort to collect the data on the Control Indicator
Measurability (time)	The lower the measurement frequency the better.
Communicability	I want to be able to use the data that results from measuring the Control Indicator to anyone I want
Insensitivity (organizational)	I do not like collecting data that might be sensitive to the organization
Reliability	I want to collect data that cannot be manipulated by people
Insensitivity (privacy)	I do not like collecting data that might be sensitive to stakeholders involved in the project

Table 24: Statements to be prioritized by project managers

As described in 5.3.1, the statements in Table 24 are rated on a scale from 1 to 10 (1 = strongly disagree, 10 = strongly agree). By describing a project manager (personality, preferences) in a certain context (organization, type of project) and judging the statements from Table 24 from this project managers' perspective, different weight factors are assigned, resulting in different sets of CIs. The categories from Table 26 and Table 28 are composed of L (qualitative) or N (quantitative) and H (human) or P (process & data). It should be noted that the set of CIs are not necessarily only the highest ranked CIs; they ones with high weighted scores and are selected and combined to form a coherent set.

5.5.1 Illustration 1: Quantitative and improvement-driven

The following description is used to draw up a set of weight factors for a fictional project manager.

Project manager 1

Is working in a large organization for five years now and is highly ambitious; in order to show his competence to the organization he wants to show that his experience causes his performance to improve over time, even within projects. He prefers quantitative data since these results are unambiguous and comparable with the performance of his colleagues. He wants to focus on managing instead of measuring and collect reliable data. In his opinion people's privacy is subordinate to that of the organization.

Attribute	Qualitative/ Human	Qualitative/ process & project	Quantitative/ Human	Quantitative/ process & project
Measurability (effort)	10	10	6	6
Measurability (time)	3	3	3	6
Communicability	8	8	10	10
Insensitivity (organizational)	10	7	7	7
Reliability	10	5	5	1
Insensitivity (privacy)	1	1	1	1

Table 25: Weight factors assessed based on the description of Project Manager 1

Table 26 displays the selection of Control Indicators is made based on the assigned weight factors by project manager 1.

Code	Control Indicator	Category
CM09	Participants comply to contacts	LH
PB13	Assessment of scope control mechanism	LP
OM08	Time spent on stakeholder management per change request	NH
PM07	Number of mismatches between customer demands and functional requirements	NH
PM13	Frequency of evaluations of project team members	NH
CM13	Amount of defects	NP
OM09	Number of permits timely acquired	NP
PM33	Response time	NP
PB14	Number of schedule updates	NP

Table 26: The set of selected Control Indicators based on the description of project manager 1

The project manager is focused on quantitative data; seven out of nine indictors are quantitative. This CI-set can be monitored regularly and improve over the project and show his dedication to ever improve on communication and reduce mistakes and defects.

5.5.2 Illustration 2: Manage through people and soft skills

Based on the following description of project manager 2, the weight factors are assessed and displayed in Table 27. In appendix F the four Quality Function Deployments are displayed, containing project manager 2's preferences. Table 28 contains the proposed set of CIs.

Project manager 2

She is currently employed at a medium-sized company, but she has worked in different organizations as project manager for twenty years: she has seen it all. She knows the people within the organization, has a talent for consensus building and knows how to get stuff done. Her experience is that whenever people are able to communicate they get along better which in turn benefits the process and thus the project. In her opinion the project manager should facilitate project participants to do their job and not actually tell them what to do. 'Trust over control' is her slogan.

Attribute	Qualitative/ Human	Qualitative/ process & project	Quantitative/ Human	Quantitative/ process & project
Measurability (effort)	7	7	3	7
Measurability (time)	3	3	7	3
Communicability	5	1	5	1
Insensitivity (organizational)	1	7	1	7
Reliability	1	1	1	1
Insensitivity (privacy)	1	3	1	3

Table 27: Weight factors assessed based on the description of Project Manager 2

Applying the weight factors that are based on the profile description of project manager 2 resulted in the CI set from Table 28.

Code	Control Indicator	Category
CM07	Technical knowledge contract managers	LH
OM02	Clear goals in stakeholder communication	LH
OM15	Presence of an up-to-date stakeholder register	LH
CM14	Number of feedback moments from executive layer to management	NH
PM33	Response time	NH
PB14	Number of schedule updates	NH
OM06	Number of open meetings for input for 'other' stakeholders	NH
CM02	Contractor satisfaction	NH
PM04	Number of tasks/roles and responsibilities not delegated	LP

Table 28: The set of selected Control Indicators based on the description of project manager 2

Project manager 2 has a clear preference for human data (eight out of nine). The tasks/roles that are not delegated need to be exposed as quickly as possible to ensure that the jobs are fulfilled and conflicts are avoided. Stakeholder management is an important part of maintaining support for the project and her leadership; therefore, clear goals in communication, open meeting and an up-to-date register is necessary. To stay in touch with contractors, their satisfaction is measured and there are feedback moments from contractors to the management team.

5.5.3 Reflecting on the illustrations

These two illustrations should give an indication of the different results that could stem from changing the input (the weight factors). It should be emphasized, again, that the choice of these CIs is based on the weight factors and the fictional descriptions of the project managers and their preferences.

In practice the weight factors are not only dependent on project managers and their preferences, but also on the organizational context and properties of the project. As discussed earlier, the attribute scores of the CIs and their compatibility are assigned with outmost care but could also differ per organization and situation. Altering these attributes and compatibility is possible in the CI selection tool, but outside of the scope of this research.

Concluding: Although in this thesis the distinction is made between project/process data and human data on a quantitative and qualitative scale, these Control indicators still reflect processes: whether is the assessment of the scope change mechanism or the response time of a stakeholder, they both reflect processes that can cause problems and can be responded to. The QFD aids in selecting the type of processes that should be monitored (through Control Indicators) and are line with a project managers' preferences; project management should always see the output of the selection tool in light of their project team, organization and project.

5.6 Monitoring/feedback-system versus traditional monitoring and controlling

In chapter 4 is explained what Control Indicators are: leading indicators for project management success. Control Indicators differentiate themselves from Key Performance Indicators through being leading and measuring processes behind the project. In this section traditional monitoring and controlling (including indicators) are compared to the Monitoring/feedback-system (including Control Indicators) in terms of how they are used.

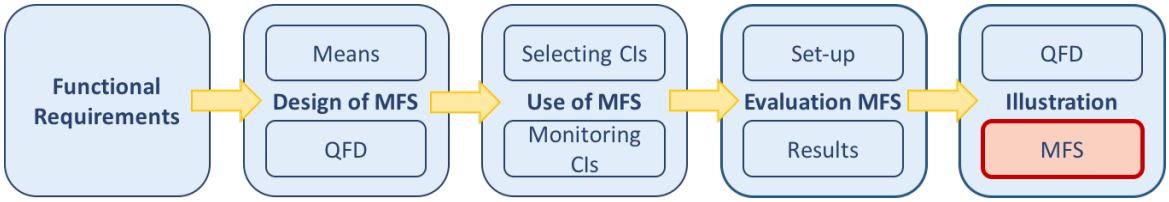


Figure 42: Illustration of the Monitoring/feedback-system

By describing two fictional cases in which a project manager uses both methods the differences between measuring leading and lagging indicators is illustrated. This will provide insight in the added value of measuring CIs instead of traditional indicators. First a fictional situation is drawn up; secondly, in 5.6.1 the use of traditional indicators is discussed and in 5.6.2 the same situation is approached through the use of Control Indicators.

Situation

A large infrastructural project, a highway, is being build. The tender for the project is won by a company named B&C. The project consists of a variety of work packages: land acquisition, earth works, roads, electric systems, water management system and over- and underpasses. Each of these work packages consists of smaller work packages: electrical systems for example include road monitoring, (lighting of) traffic signs and traffic light near exists. Not every work package is executed by B&C since they do not have all technology and expertise in house, so different contractors are hired for completing different task. The project management team is responsible for managing the project and ensure that the project is completed within time and budget and according to the scope.

The project is momentarily in the execution phase and the problem in this project is that the earth work for the under- and overpasses is not included in the contract of the work package 'earth work' nor 'under- and overpasses'. In 5.6.1 and 5.6.2 two different scenarios are described: the first using traditional monitoring and controlling and the second one using the Monitoring/feedback-system.

5.6.1 Illustrative example 1: Traditional monitoring and controlling

The project controller (who is part of the management team) is responsible for different types of management, such as cost/financial management and schedule/planning management. In order to maintain within budget and schedule, tools such as Earned Value Analysis (EVA) are used. By performing an EVA, metrics are calculated such as 'cost variance' (in € or %),' cost efficiency factor', 'estimated cost to complete', 'schedule variance' (in € or %), 'schedule efficiency' factor and 'estimated time to complete'[3].

Every quarter the project controller collects the information necessary to calculate the above mentioned metrics. The information he needs is the BCWP, BCWS and ACWP; this comes down to information on each of the work packages on how much work is performed, how much this cost, how much it is expected to cost and how much time it will cost. After the third quarter of performing the analysis, it is found out that the 'earth works' are over performing (costing less than expected), 'roads', 'electrical works' and 'water management system' are behind in schedule and 'over- and underpasses' is far behind schedule and highly over budget so far.

After nine months of the execution phase and the project is (at some points) getting behind schedule and the project controller considers the accumulating delay no longer coincidence. The conclusions drawn by the project controller are the following: 'earth works' is performing well and does not require any attention and the contractor responsible for the construction of roads should speed up in order to remain committed to the schedule. The contractor responsible for the over- and underpasses is called in for a meeting to find out why everything is taking longer than expected and why it cost more than planned.

The meeting with the contractors responsible for the construction of the over- and underpasses exposed that they were doing more work (and on a reimbursable basis) than recorded in the contract: the earth works for the under- and overpasses were executed by this contractor, while it was expected that this was performed by contractors responsible for the 'earth works'.

Upon examination of all the contracts it was found that the contract for work package 'earth works for the under- and overpasses' should be included in the 'earth works' work package, but due to miscommunications this ended up in no contract at all. The project management team expected that this would be performed by the contractors responsible for the 'earth works'; this explains why they were ahead of the project. The rest of the contractors are delayed since they are dependent on the work package 'roads' which is behind due to the delays in 'under- and overpasses'.

The solution is to intensify the efforts to finish the earth works of the under- and overpasses and reimburse the contractor that already started it; the rest of the earth works for under- and overpasses is performed on a reimbursable basis by the earth works contractor, but with high priority. The cause of the delays is found, but this took a while since the indicators were only reflecting past performance on executed work instead of leading indicators for processes.

5.6.2 Illustrative example 2: Monitoring/Feedback-System

The project manager is the head of the project management team and bears the final responsibility for the monitoring of Control Indicators. The project manager used the Control Indicator selection tool and decided that for each of the IPM-roles one CI should be selected, resulted in the following list (with corresponding CI codes)

1. Number of tasks/roles and responsibilities not delegated (PM04) – Project Manager
2. Updated risk register (PB05) – Project Controller
3. Participants comply to contacts (CM09) – Contract Manager
4. Number of (intermediate) verifications (TM04) – Technical Manager
5. Number of open meetings for input for 'other' stakeholders (OM06) – Environment Manager

[3]All these metrics are based on three values: Earned Value (= BCWP = Budgeted Cost of Work Performed), Planned Cost (= BCWS = Budgeted Cost of Work Scheduled) and Actual Cost (= ACWP = Actual Cost of Work Performed)

By selecting one CI per IPM-role, the project manager aims to focus on processes from different aspects of the project and this way cover a broad spectrum of processes. Each of the management team members is responsible for gathering the information regarding their role and reporting it to the project manager who collects it in a dashboard. Some of these Control Indicators are relatively easy to monitor (counting meetings is simple) other can be laborious (finding undelegated tasks); therefore, the CIs are updated in the dashboard every three months and discussed in the monthly meeting.

Since the project manager decided that the CIs are monitored quarterly the results are discussed during the monthly meeting of the forth month. By requiring the management team to meet their targets (such as number of meetings and verifications), the project management process is adhered to and the management team member try to satisfy these process requirements. The environment manager reports that the minimum amount of open meetings is met and that the process of managing other stakeholders is going according to plan. The technical manager has to perform at least one intermediate verifications per month; during the second verification it was noticed that none of the under- and overpasses has been realized. During the third verification it was noticed that the work package 'road' is not on schedule to reach the first deadline and the road will not be finished on time for use. The project manager checks all the work packages that have to be executed and finds that the earth work for the under- and overpasses is not delegated to any contractor. The contract manager notes that the contractors thus far all complied to their contracts, meaning that the work packages that was not been delegated is not included in the contracts.

The monitoring of the CIs of the technical, contract and the project manager expose a contract gap in the first meeting. In order to control the situation, the earth work contractor is requested to immediately perform the work packages critical for the project progress and ensure that other contractors can continue their work. Since the problem was exposed during the construction of the first under- or overpass, the delay is limited.

5.6.3 Concluding the comparison

Based on metrics described in 5.6.1, the project controller makes a projection regarding the project performance and the future of the project. These metrics are only predictive for the project performance in the sense that the current performance is extrapolated and used as a projection for the rest of the project; basically forecasting using past performance. The Control Indicators are of a more leading nature and reflect processes rather than outcomes. If for example OM06 (stakeholder meetings) would have been measured while not satisfying the required amount of meetings, this could predict that stakeholders will cause problems since they feel unheard.

In both cases the final responsibility for project management performance of projects lies at the project manager. The problem was exposed due to the

monitoring of a broader variety of indicators. In the case of the Monitoring/feedback-system, indicators are measured in processes across the IPM-role profile; in the case of traditional monitoring and controlling the main responsibility lies with the controller and does not include contract or stakeholder risks.

In these examples is illustrated that processes that seem to be performing well could contain mistakes. Certain processes regarding the procurement of work packages or the design of contracts that are responsible for the problem, should be reevaluated and checked to see if these processes were adequate and whether more mistakes are made.

This example also illustrates that there is added value not only in the results of the underlying processes and CIs, but also in the monitoring itself. If the contract manager was never required to report the number of participants that would comply to contracts, this would have been a trigger for the project manager to look into the contract management aspect of the project.

It should be noted that these examples are fictional, the Monitoring/feedback-system will not prevent all mistakes from happening, but it proposes a different way of monitoring that could be a valuable addition to the current practices by measuring process related factors instead of project output.

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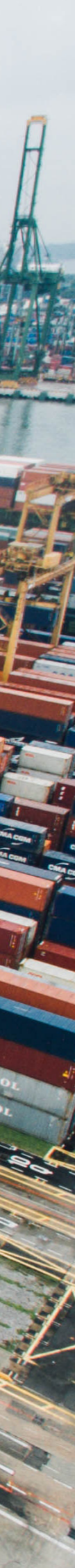
6 Discussion



6. Discussion

This chapter is divided in two sections. Section 6.1 elaborates on the findings of this research. In section 6.2 the limitations of the deliverables, the validation, the workshop and the methods for obtaining information are discussed.

6.1 Discussion of the findings

This thesis is conducted using the following types of research: literature study, exploratory interviews, an Expert Panel workshop and an expert evaluation. Each of these methods is briefly reflected upon.

6.1.1 Literature study into project success

Two different literature studies have been conducted: the first has been conducted into project success and failure. This resulted in a large collection (the factor database) of factors (related to success and failure), Key Performance Indicators and lessons learned; for the sake of simplicity they are called 'factors' from now on (once they are included in the database).

It was found that there is ambiguity among definitions such as 'critical success factors', 'success factors', 'success criteria' and 'key performance indicators'. Since there is no clear distinction and definition of either of these terms, the context determines the meaning. If a study found that a certain criterion or factor has a positive or negative influence on project performance, it was added to the factor database. Since establishing a quantitative relation between these factor and project performance fell outside of the scope of this research all factors (both qualitative and quantitative) could be included. The formulation of the factors is different per study, even if they roughly tried to describe the same phenomenon. The fact that many studies on success in projects have the basis in the same papers made it difficult to identify new material; often papers were a new take on the same success factors, a different way to categorize them/put them into perspective or factors from other studies were added.

An example of a methodology used to assess to what extent factors contribute to project success is illustrated in Figure 43.

7. There are many variables that affect the outcome of any project. Through a previous study we have been able to identify the following factors, which are a combination of different variables and has been defined in the appendix. How do you rate the extent to which these factors contributed in the outcome of the Case project?

← Extent of contribution →

−5	−4	−3	−2	−1	0	1	2	3	4	5
High				Low	No effect	Low				High

Sl.	Factors affecting the outcome of the project	Your view (please cross in the appropriate box)										
1	Project manager's competence	−5	−4	−3	−2	−1	0	1	2	3	4	5
2	Top management support	−5	−4	−3	−2	−1	0	1	2	3	4	5
3	Monitoring and feedback by project participants	−5	−4	−3	−2	−1	0	1	2	3	4	5
4	Favourable working condition	−5	−4	−3	−2	−1	0	1	2	3	4	5
5	Commitment of all project participants	−5	−4	−3	−2	−1	0	1	2	3	4	5
6	Owners competence	−5	−4	−3	−2	−1	0	1	2	3	4	5
7	Interaction between project participants – internal	−5	−4	−3	−2	−1	0	1	2	3	4	5
8	Interaction between project participants – external	−5	−4	−3	−2	−1	0	1	2	3	4	5
9	Good coordination between project participants	−5	−4	−3	−2	−1	0	1	2	3	4	5
10	Availability of trained resources	−5	−4	−3	−2	−1	0	1	2	3	4	5
11	Regular budget update	−5	−4	−3	−2	−1	0	1	2	3	4	5
12	Conflict among project participant	−5	−4	−3	−2	−1	0	1	2	3	4	5
13	PM's ignorance and lack of knowledge	−5	−4	−3	−2	−1	0	1	2	3	4	5
14	Hostile socio economic environment	−5	−4	−3	−2	−1	0	1	2	3	4	5
15	Owner's incompetence	−5	−4	−3	−2	−1	0	1	2	3	4	5
16	Indecisiveness of project participants	−5	−4	−3	−2	−1	0	1	2	3	4	5
17	Harsh climatic condition at site	−5	−4	−3	−2	−1	0	1	2	3	4	5
18	Aggressive competition during tendering	−5	−4	−3	−2	−1	0	1	2	3	4	5
19	Negative attitude of project participants	−5	−4	−3	−2	−1	0	1	2	3	4	5
20	Faulty project conceptualization	−5	−4	−3	−2	−1	0	1	2	3	4	5

Figure 43: Survey question used to identify important factors (Jha & Iyer, 2007, p. 539)

Result of the literature study: factor database

The final result of the first literature study was a factor database containing 581 factors (some reoccurring in different studies), which are categorized in order to provide structure before formulating Control Indicators. Each factor has its own code which makes it traceable back to the literature it is taken from and as what kind factor is was formulated: Critical Success Factor, Factor, KPI, Lesson learned or factor from the exploratory interviews. The Control Indicators that are formulated each have disclosed on which factors it is based to maintain traceable. This database could provide a basis for future research.

6.1.2 Literature study into project monitoring and controlling

The second literature study is conducted into monitoring and controlling practices. Monitoring and controlling are often mentioned in one breath, but are they fundamentally different. Monitoring includes practices to measure progress/scope/performance; controlling is the practice of undertaking actions to ensure that projects adheres to its goal and is basically the follow-up action on monitoring. An example of the unclear distinction between monitoring and controlling is the term 'scope management': there are practices to determine whether the scope is maintained within a project; but this 'scope management' does not include steps to control scope if it turns out the scope is unintentionally changing or if the scope should change.

The result of the study into project monitoring is an overview of a variety of (quantitative and qualitative) tools: Earned Value Management (EVM), audits, progress reports and diagnostic frameworks. PMBoK, which is used as reference throughout this thesis, proposes monitoring of project work through expert judgement from consultants, stakeholders or professionals/technicians and comparing project with its baseline and plans (which is a form of EVM).

The expectation was that this literature study would lead to an overview of standardized project controlling methods, but the conclusion is that this is not the case. The most explicit mentioning of control practices was found in PMBoK. It proposes to control (for example the schedule) by "Influencing the factors that create schedule changes" (Project Management Institute, 2008, p. 160). This is a very high level formulation and provides no description of how this should be conducted.

6.1.3 Exploratory interviews

The exploratory interviews were conducted in the first phase of the research. PACER employees were interviewed regarding their views on causes of bad or good performance in projects, on monitoring KPIs in projects and how they would measure their own performance. The interviewed PACER professionals fulfilled a broad range of functions within project management: environment manager, contract manager, project controller, Systems Engineer (technical manager) and project controller.

The most important findings from the exploratory interviews are the 39 factors derived from them (Table 29). More detailed information on the exploratory interviews can be found in appendix A.

Factors	
Clear functional specifications	Realistic planning
Attitude contractors (contract-oriented or solution-oriented)	Compatible project team
Adequate contract type	Regular updates and communication
Regular updates stakeholders	Profitability contractors
Expectation management	Skills project manager
Conflict within project team	Openness between project team and contractors
Dishonesty regarding lack of information	Insufficient organizational capacity
Holding too tight to the scope	Changing opinions or policy of stakeholders
Tension between stakes of project and organization	Flexible contracts
Personal interests of project team members	Indecisiveness of the client
Mismatch between functionality and product	Stakeholder subjectivity in project changes
Good ambiance within project team	Unclear expectations among project participants
Adequate scope management	Lacking communication
Clear scope	Project manager insufficiently instructed by the organization
Managing differences contract and scope	Project participants' unwillingness to share information
Goals contractor and client not aligned	Lack of commitment to common goal
Adequate risk analysis	Project team participants putting their own goals before team goals
Maturity and experience suppliers	Involvement of different layers of the project in decision-making (involvement is NOT influence)
Quality of contracts	Trust in project management team
Deliver proof-of-concept	

Table 29: Factors resulting from the Exploratory Interviews

6.1.4 Expert Panel workshop

The Expert Panel workshop served the purpose of validating the Control Indicators (part 1) and providing input for the requirements of the Monitoring/feedback-system through a brainstorm session (part 2). The findings are discussed separately in this section. Appendix D should be consulted for the extensive description of the methodology, results and conclusions of the Expert Panel workshop.

Part 1: Control Indicators validation

When the Expert Panel (EP) was briefed on this research, the concept of 'Control Indicators' had to be explained carefully in order to prevent them from being confused with Key Performance Indicators. After the differences were explained and the definition of 'Control Indicator' was clear the validation could commence. This resulted in a few CIs being dropped and altered. Also, new CIs have been formulated based on the workshop (Table 30).

Control Indicators
Rating processes
Process compliance
Frequency satisfactory progress reports
Trust among project participants
Number of missed deadlines (internal)
Number of missed deadlines (external)
Response time
Number of unanswered inquiries/requests

Table 30: Control Indicators derived from workshop

Part 2: Monitoring/feedback-system brainstorm

The EP was briefed on the goal of the Monitoring/feedback-system (MFS) and the members were asked regarding their experience with monitoring in projects. Some EP members had experience with dashboards and other forms of monitoring. For example, Rijkswaterstaat already rates its contractors and vice versa: these are basically process (control) indicators for the co-operation between contractor and client.

Important remarks regarding the MFS concerned the transparency and privacy of the data and to what extent it can be communicated (to the client/management team/organization). The panel was anonymous about the fact that support from the management team is necessary for the MFS to be effective. Another important aspect to take into account was the fact that different project managers have different management styles and that the MFS should be flexible enough to deal with this.

6.2 Discussion of limitations

In this section the limitations of this research and its applicability are discussed. First the limitations of the formulation of Control Indicators are discussed (6.2.1). In 6.2.2 is elaborated on the limitations of the Monitoring/feedback-system and its applicability. The lack of validation of the MFS and CIs is discussed in 6.2.3. The limitation to the validation of the CIs is discussed in 6.2.4. Section 6.2.5 briefly described disadvantages of only consulting experts employed at one company.

6.2.1 Limitation of Control Indicators

The tem 'Control Indicator' is formulated since there was an etymological vacuum between Key Performance Indicators (KPIs), Key Result Indicators (KRIs) and ambiguity regarding their leading and/or lagging properties. CIs are defined as "leading indicators for the performance of 'project management success' which can be acted upon by the project management". This statement implies that CIs have leading/predictive properties and require (predefined) trigger values in order to respond. This implication exposes two problems: their quantitative predictability and the lack of benchmark values. Both are discussed separately in this section.

Quantitative predictability

This implies that CIs are predictive for project performance. The literature on factors that influence project success is extensive, but to establish a causal relationship between a single factor and the degree to which project success is achieved is nearly impossible. Large Construction Projects are complex projects which are subject to influences from hundreds of factors that all occur at a given point in the project. When translating all these factors to Control Indicators, information got lost and factors lose their quantitative predictability. The project management professional choosing the CIs should judge the predictability of the CIs in light of the project and management team since the CI do not have the property 'predictability'. The two main causes of loss of this quantitative predictability are the measurement methods and the "direction" of factors.

Measurement methods

A practice that occurred multiple times in different scientific articles into project success was the following method: the success of a certain project was measured in the iron triangle criteria, the rating of the client or the performance assessment of the project manager or organization. Than project participants of these projects are surveyed regarding certain factors in projects and to what extent these occurred. This way correlation between factors and success can be found. Sometimes the analysis of the surveys that lead to this correlation is quantitative while the data collected was not. Surveys or research into project success were sometimes conducted just after the project is finished and in other cases reflected upon after multiple projects.

Since there are multiple methodologies used and the data is both qualitative and quantitative, all the factors are stripped from the strength of their predictive capabilities. This lead to a loss of information: the strength of the relation between certain factors and project success is not included in the Control Indicators.

Positive and negative factors

The literature study performed for this thesis takes into account all factors (positively or negatively) influencing project performance; the same goes for the exploratory interviews where is asked for both success and failure factors. All these factors are derived from different projects that are (un)successful to some degree and paint a picture in which factors can be qualitatively linked to project performance. These factors in turn are repackaged as 'neutral' Control Indicators; formulated without a desired direction.
For example: a failure factor such as 'lack of experienced staff' (F1023) combined with a success factor like 'competency and experience of project personnel' (F1033) resulted in the Control Indicators 'qualifications personnel' (PM12).

Lack of benchmark values

Another limitation of Control Indicators is the lack of benchmark values to compare it to. Whereas traditional monitoring measures performance by comparing the realization of the project with the planning or budget (that serves as baseline), Control Indicators miss this benchmark value. This could create the problem that a certain CI is measured but that it is unclear what the trigger value is or should be and when action is required. Two examples of CIs are discussed in order to explain the limitations and how the lack of benchmark values could be partially offset.

Total number of change requests

This CI reflects the total amount of change requests that have been filed, evaluated and approved or rejected. This number is highly dependent on the size of the project, the attitude of the client and project manager towards scope change, the staffing of the department responsible for the scope change, the change request itself and a number of other factors. This makes the value of the CI at a given point in the project difficult to benchmark to the CI value of other projects (if available at all). Therefore, the value of the CI without context is quite meaningless in some cases.

In order to deal with this lack of benchmark, a trigger value for the 'total number of change requests' can be seen as the upper boundary for the performance of the scope change management process. Not meeting this value would require action to improve the scope change processes.

Another option would be monitoring the trend of the Control Indicators. The unfinished change requests keep piling up and the process cannot handle the volume of the amount of change requests. This could be due to an understaffed

scope management department or a very demanding client. Or maybe the contracts are too inflexible and have to be changed often. Whatever the cause is, a steady or sudden increase in change requests could indicate problems. This trend could be telling enough on its own without using a benchmark value from other projects.

Relation project team with the client

This CI is measured by surveying the client and (for example) the project manager to evaluate their relationship. Through a system that allows reciprocal rating on different aspects the relationship is quantified. The result could be a list with grades on a scale from 1 (poor) to 10 (perfect) on different aspects (communication, performance, satisfaction).

These ratings are easier to set as trigger values since they are simple to measure. Moreover, comparing them to ratings in other projects is easy if they are surveyed the same way. Just like 'total number of change requests', a certain value could be set as threshold value for the relationship in order to maintain the quality of the process. The trend of the ratings can be monitored to identify struggles. Also, the trend could be compared to the planning to see if certain work packages match fluctuations in the ratings.

A difference between this CI and the previous example is that the rating is not objectively and subject to feelings and interpretations of the parties. One party could experience the process different than the other. The discrepancy between the ratings could be an indicator for imbalance in the process and might require expectation management or clearer communication.

Concluding: Control Indicators suffers from two weakness: the lack of quantitative predictability and the lack of a baseline or benchmark values. To get from factors to Control Indicators, a lot of information is lost. Therefore, in appendix C the complete list with factors and their sources are disclosed. Moreover, not all CIs have the same predictive value, but this is not added as attribute since there is no data available on the strength of predictability. The strength of the predictability should be, along with the effectiveness and relevance of a certain CI in a project, estimated by the project management professional responsible for selecting the CIs. The lack of benchmark can be partially offset by observing trends and approaching trigger values as objectives/ thresholds for process performance.

6.2.2 Limitations of the Monitoring/feedback-system

The Monitoring/feedback-system in which the CIs are embedded consists out of four elements:

1. Attribute scores of Control Indicators (part of QFD)
2. Compatibility Matrix (part of QFD)
3. Multi criteria analysis and weight factors (part of QFD)
4. Process description after selecting Control Indicators

The limitations of each of these parts are discussed in this section.

Attribute scores of Control Indicators

The formulation of the attributes is based on information gained during the literature study, exploratory interviews and the expert panel. These attributes are measurability (effort and frequency), communicability, sensitivity (managerial and personal) and reliability. A multi criteria analysis is only possible if the different Control Indicators can be compared on their scores on the attributes.

The scores of the CIs on the attributes dependent on how they are measured, since certain CIs can be measured in different ways. The CI 'relation project team with the client' is labeled as difficult to measure since it requires a survey, scoring low on measurability. The 'total number of change requests' is a CI that could be measured automatically, scoring high on measurability. If the organization already surveys all clients every month and the change request procedures are not standardized or automated, these CIs might swap scores in terms of measurability efforts; this could vary per organization.

The dependency of the attribute-scores of the CIs on project and organization specific aspects is not taken into account. If these attributes are not assessed correctly in light of the organization, it reduces the usefulness of the output (weighted CI scores). However, the project manager could use the QFD models to alter these values, according the own insights. The attribute-scores of the CIs can be found in appendix E. The process of reassessing the attribute-scores falls outside of the scope of this research.

Compatibility Matrix

The Control Indicators that are formulated based on the factors are categorized by assessing whether they are quantitative/qualitative and primarily reflect 'project & process' or 'human' data; this resulted in four categories. Within these categories is reciprocal assessed if the CIs are complementary (A), compatible (B), neutral or redundant (C). This assessment is based on the suggested measurement method described per CI.

Just like the attributes of the CIs, the compatibility of CIs depends on the method of measurement, which in turn is decided by the project manager (and the project organization). Before the user of the QFD makes decisions regarding the selection of CIs, the degree to which the suggested compatibility is correct should examined and taken into account. The process of reassessing the compatibility of CIs falls outside of the scope of the research.

Multi criteria analysis and weight factors

The multi criteria analysis uses the attributes of the Control Indicators and the weight factors assigned to the attributes to calculate the weighted scores of CIs. These weighted scores can be compared to determine which CIs are to be monitored, taken into account the preferences of the user. An advantage is that per category (and thus per QFD) different weight factors can be assigned. The scores are standardized by dividing the multiplication (attribute x weight factor) by the sum of weight factors; always resulting in weighted scores between 1 and 5.

The limitation of the multi criteria analysis is that the results should be viewed in the perspective of the compatibility matrix, the project and project organization. The output of the multi criteria analysis (the QFD) is dependent on the project managers, their preferences, their organization and the properties of the project.

Process description after selecting Control Indicators

The process after selection the Control Indicators is divided in three phases: development of a monitoring plan (phase 1), organize support and a dashboard (phase 2) and monitoring and operating the MFS (phase 3). It should be noted that these phases have not been validated, but have been subject to expert evaluation. In this section is briefly reflected on the limitations of each of the phases.

Phase 1

The first phase prescribes steps leading to the monitoring plan. Since it is up to the project manager to make the monitoring plan based on the chosen CIs, the project manager should also come up with a process to create support for the MFS and this specific set of CIs within the organization and the management team. The steps provide basic information on points of attention, but this is not exhaustive: the project manager should use experience, knowledge and feedback from both the team and organization to realize the MFS. The main limitation of the description of phase 1 is that it provides little details on how each step is executed since it is highly dependent on situation specific circumstances.

Phase 2
This phase prescribes steps that should lead to a dashboard that can be monitored and updated, containing up to date information, trigger/threshold values of CIs and privacy data (organizational and personal). It is up to the project manager to assign tasks, roles and responsibilities regarding the monitoring actions. The limitations of these steps are of the same nature as of phase 2: providing a detailed process description is difficult taking into account the specific situation.

Phase 3
In phase 3 the operation of the MFS is discussed. By adapting the framework by Haasnoot et al. (2013) a process is designed that can be used to respond to triggers (values of CIs). The process steps are not described in detail since every project, CI and situation is different and the response should be evaluated by the project manager. This limitation is of the same nature as phase 1 and 2.

6.2.3 Validation
The Monitoring/feedback-system has not been subject to a validation but to an expert review instead. The Control Indicators have been validated during the Expert Validation workshop, meaning that only the selection tool (the Quality Function Deployment) has to be validated, along with the process that describes the actions that have to be performed after the Control Indicators are selected. In this section is explained why the validation falls outside the scope of this thesis.

Validation is defined as: "Assessment of an action, decision, plan, or transaction to establish that it is (1) correct, (2) complete, (3) being implemented (and/or recorded) as intended, and (4) delivering the intended outcome" (BusinessDictionary.com, 2018). This definition requires that in order to label the MFS as 'validated' that a plan to establish its validity is executed and that the MFS delivers the intended outcome. Performing the validation of the MFS falls outside of the scope of this research due to the following problems:
1. Lack of 'non-intervention'-case when using Monitoring/feedback-system
2. Requires a large sample of projects
3. Timespan of the validation

Each of these problems are discussed along with a plan which could be used to validate the MFS.

Lack of the 'non-intervention'-case when using Monitoring/feedback-system

An important aspect of validation is determining whether the intended outcome is achieved. The goal of the MFS is to enhance project management performance. The MFS (including the Control Indicators) should improve monitoring and controlling in projects by indicating when CIs pass a certain threshold/trigger value and provide guidelines in responding to this trigger value.

A project goes through the usual phases (initiation, planning, execution, closing) and is monitored and controlled during the project. During this process, projects are subject to path dependence, which "... refers to a property of contingent, non-reversible dynamical processes" (David, 2000, p. 2). The final product of a project and the process of getting there is path dependent; from the moment a project is initiated there are multiple paths a project can take at any given time. After a project is closed, it is reflected upon and conclusions can be drawn based on the one path that is followed.

By tracking CIs and responding to triggers, the path of the project is altered; there is no possibility to claim with certainty that a decision to respond to a trigger was the right one and resulted in better project performance. The absence of information regarding the 'non-intervention'-case compared to the project where the MFS is used (with interventions), makes it difficult to determine within the project whether the desired outcome is achieved by using the MFS (and thus validate the MFS).

Requires a large sample of projects

The lack of this 'non-intervention'-case makes it difficult to internally validate the MFS in projects. To deal with this problem and reduce the effect of chance in one single validation, the validation of the MFS requires its application in multiple projects. The path that a project goes through is complex and subject to a tremendous amount of factors; just like the project itself. Therefore, a large sample of projects is necessary to validate the MFS.

Timespan of the validation

Large Construction Projects often take multiple years from initiation to closing. The MFS should be used at least during the complete execution phase; preferably starting near the end of the initiation and ending during the closing. The timespan covered by LCPs combined with the fact that multiple projects are required in which the MFS will be used (which are likely to start at different moments and have varying timespans) causes the validation to take at least (approximately) two years.

Validation plan

In order to validate the MFS, it is necessary to have a sample of multiple projects that is large enough to draw scientifically sound conclusions. Ideally all these projects are comparable in terms of size and complexity, have the MFS started and ended during the same phases and have similar Control Indicators monitored. It is recommended that the sample should include data on the following projects (types):

1. Projects that have their Control Indicators monitored and responded to
2. Projects that only have their Control Indicators monitored
3. Projects using 'regular' monitoring and controlling practices

The distinction between project type 1 and 2 is made in order to investigate whether the prescribed controlling process makes a difference or if monitoring (and being monitored) in projects is sufficient to enhance performance. For example: monitoring the rating between project management team and contractors could have a positive (or negative) effect; even if there is no follow-up response, behavior could be altered.

6.2.4 Expert Panel workshop

The Expert Panel serves the purpose of validating the Control Indicators. The experts reviewed CIs (as) relevant (as possible) to their function within PACER (IPM-roles). Certain CIs were flawed and dropped as Control Indicator, others were modified and new ones were added as result from the workshop.

The experts acknowledged that certain CIs already have their data available and do not require additional monitoring efforts, but it is not yet actively measured or not used as Control Indicator. The experts were also confronted with CIs which they had not yet thought of and they expected to be useful in practice.

The main limitation of the Expert Panel workshop is that although the experts validated the CIs, validation and monitoring in practice (although deemed viable by the experts) will have to be executed in projects in order to give a definitive answer on the practical validity of the CIs. Another limitation of this thesis is the fact that all project management professionals that participated in the Expert Panel are employed at PACER, which is discussed in the next section (6.2.5).

6.2.5 PACER

The methods used in this research include literature studies, explorative interviews, an Expert Panel workshop and expert evaluation. The interviews, the workshop and the evaluation are all conducted among project management professionals employed at PACER.

In order to avoid an echo chamber of opinions, PACER employees that were interviewed were not included in the Expert Panel workshop. The expert evaluation was performed by one of the interviewees since this was a professional with experience in monitoring and dashboards.

The results of this thesis would be a better reflection of reality if the interviews, workshop and evaluation would be conducted among project management professionals across different organizations. The fact that the data is only derived from PACER employees limits to which extent the results can be generalized.

7 Conclusion

7. Conclusion

The objective of this master thesis is to provide project management professionals with a monitoring system that includes leading indicators for project management success. This resulted in the following main research question:

Can traditional project management be redesigned to incorporate the monitoring of leading indicators during the project?

This chapter provides the answers to the research questions. In section 7.1 the sub questions are answered and the main research question is answered in 7.2. Section 7.3 reflects on the scientific and practical relevance of the Monitoring/feedback-system and Control Indicators. Recommendations regarding further research and the applicability of Proactive Project Management in practice are made in section 7.4.

7.1 Answers to the sub question

In this section each of the sub questions are answered. These are the most important conclusions, for more detail the report or appendix should be consulted.

Which Control Indicators can be identified and formulated?

Based on the factors that resulted from the literature study, exploratory interviews and the expert panel workshop, a list of Control Indicators is compiled, which can be found in Appendix E with detailed information regarding their codes, their corresponding IPM-role, their features that make them a leading indicator, their suggested monitoring method, their scientific basis, their category and their scores on each of the attributes.

What would the design of the Monitoring/feedback-system look like?

In order to design the Monitoring/feedback-system the functional requirements had to be specified. The sources for the functional requirements are practical applicability reasons (requirement 1), input provided by experts from the workshop (requirement 2), the theory behind the Proactive Project Management (requirement 3) and the literature study (requirement 4). The requirements are filled by means as described in Table 31.

No.	Requirements	Means in place
1	The Monitoring/Feedback-System must apply structure to the Control Indicators	Categorization of CIs
2	The Monitoring/Feedback-System must provide project managers with a procedure to select the Control Indicators relevant and suitable for the management style and preferences	Multi criteria analysis procedure for selecting relevant CIs
3	The Monitoring/Feedback-System must indicate which Control Indicators are suitable to be measured together	Compatibility matrix of Control Indicators
4	The Monitoring/Feedback-System must provide a description and explanation for its process	Flowchart for the process

Table 31: Means to fulfill the functional requirements of the Monitoring/feedback-system

The Monitoring/feedback-systems consist out of four separate Quality Function Deployments, fulfilling requirements 1, 2 and 3 accompanied with a guide how to select Control Indicators using the QFDs.

Attribute	Statement
Measurability (effort)	I think it is important that it take little effort to collect the data on the Control Indicator
Measurability (time)	The lower the measurement frequency the better.
Communicability	I want to be able to use the data that results from measuring the Control Indicator to anyone I want
Insensitivity (organizational)	I do not like collecting data that might be sensitive to the organization
Reliability	I want to collect data that cannot be manipulated by people
Insensitivity (privacy)	I do not like collecting data that might be sensitive to stakeholders involved in the project

Table 32: Statements supporting assigning weight factors

By assessing the statements from Table 32, weight factors are assigned to the different attributes creating a ranking of Control Indicators per category/QFD. The results of the weighted scores of the Control Indicators should support the selection of Control Indicators. Examples of QFDs can be found in appendix F.

The QFDs help project management professionals with the selection of Control Indicators. It is important that for effective monitoring the final selection of CIs should be made taking into account the (project) organization and other project specific factors such as size, time span and complexity.

How can the Monitoring/feedback-system be used to respond to processes reflected by Control Indicators?

The process of operating the Monitoring/feedback-system (including the QFDs for selection of CIs) is described a flowchart (chapter 5, Figure 36). The steps in flowchart along with their phase is displayed in Table 33.

No.	Phase	Step
1	1	Identify the first moment of monitoring (phase of the project)
2	1	Formulate the frequency of monitoring (updating)
3	1	Draw a monitoring timeline
4	1	Establish to what extend the CIs can be communicated
5	2	Create support within the management team for monitoring CIs
6	2	Design a dashboard
7	2	Define action with certain values and trends of CIs
8	2	Assign person responsible to monitor and report certain CIs
9	3	Monitor the CIs and analyze the data
10	3	Respond to the monitored CIs
11	3	Evaluate whether the action has resulted in the desired outcome

Table 33: Prescribed steps after selection of Control Indicators

The steps in phase 1 serve to design a monitoring plan which contains information regarding the when and with what frequency CIs have to be monitored and how communicable the CIs are in terms of organizational and personal privacy. Phase 2 includes creating support for the MFS, a dashboard containing privacy information, defining CI triggers and assigning people responsible for monitoring or reporting CIs. Phase 3 describes the steps that can be followed in to respond to processes reflected by the Control Indicators.

7.2 Answering the main research question

Large Construction Projects are complex, physical projects with many interfaces, stakeholders, uncertainty and limited possibilities to iterate and learn within the project. This thesis aimed at improving project management success of LCPs by redesigning traditional project management and making it more proactive.

Redesigning traditional project management required an artifact on three different levels: what is monitored (1), how is this monitored (2) and how should be responded (Figure 44).

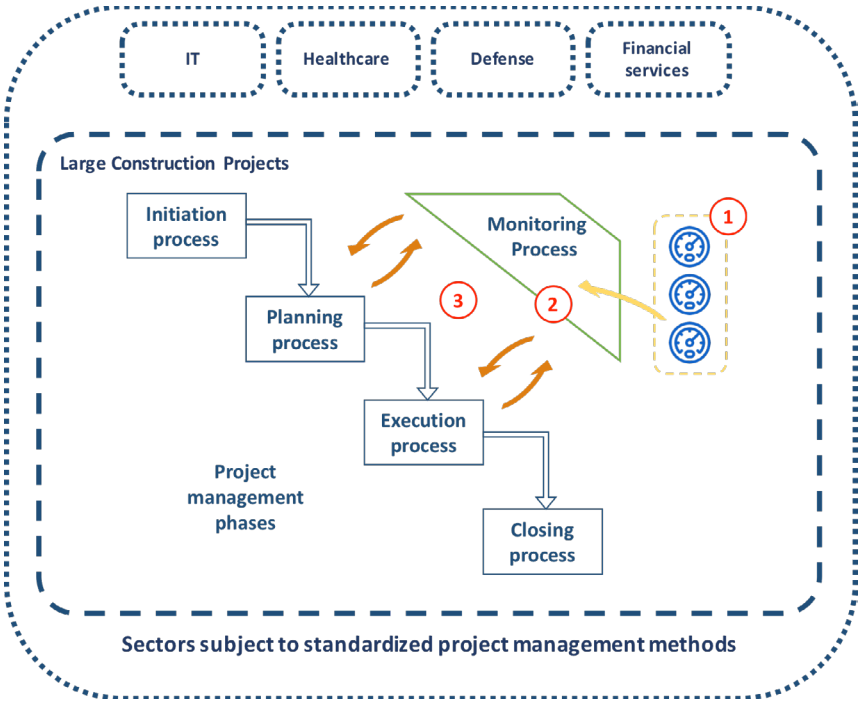


Figure 44: Sub questions related to the main research question

By identifying leading indicators (Control Indicators) for project management performance (1), embedding these CIs in a monitoring system (Monitoring/ feedback-system) to provide project managers a tool for selecting and monitoring these CIs (2) and prescribing a process to respond to processes reflected by CIs (3), project management of Large Construction Projects is partially redesigned by being provided with a tool to respond earlier to problems in projects.

7.3. Reflecting on the scientific and practical relevance

In this section is reflected on the scientific and practical relevance of Proactive Project Management. First the scientific relevance is discussed and linked to the knowledge gaps that have been identified. On the practical relevance is reflected by viewing PPM in light of its possible application in Large Construction Projects.

7.3.1 Scientific relevance: the knowledge gaps

Two knowledge gaps had been identified at the end of the literature review. The first gap was the lack of indicators for processes that are leading for project management success (Control Indicators). The second knowledge gap concerned the lack of a system with which Control Indicators could be monitored and responded to. This thesis contributes to the scientific knowledge on project management by filling these gaps in the following ways:

- A broad selection of project management literature on project success, (critical) success/failure factors and KPIs is analyzed with the addition of factors derived from expert interviews. This resulted in a dataset with over

500 factors related to project performance

- The term Control Indicator filled a vacuum in the lexicon regarding performance measurement terms such as (Key) Performance Indicator and (Key) Result Indicator.
- The identification of a set of Control Indicators, which can be monitored as an addition the current monitoring practices.
- The Monitoring/feedback-system provides a standardized approach to monitoring by developing a monitoring plan and prescribing to respond to Control Indicators

7.3.2 Practical relevance: Proactive Project Management in Large Construction Projects

In the introduction and literature review it is stated that Large Construction Projects could benefit from a more proactive form of project management to reduce the severity of budget and schedule overruns and to prevent the necessity of heavy control efforts (Figure 45).

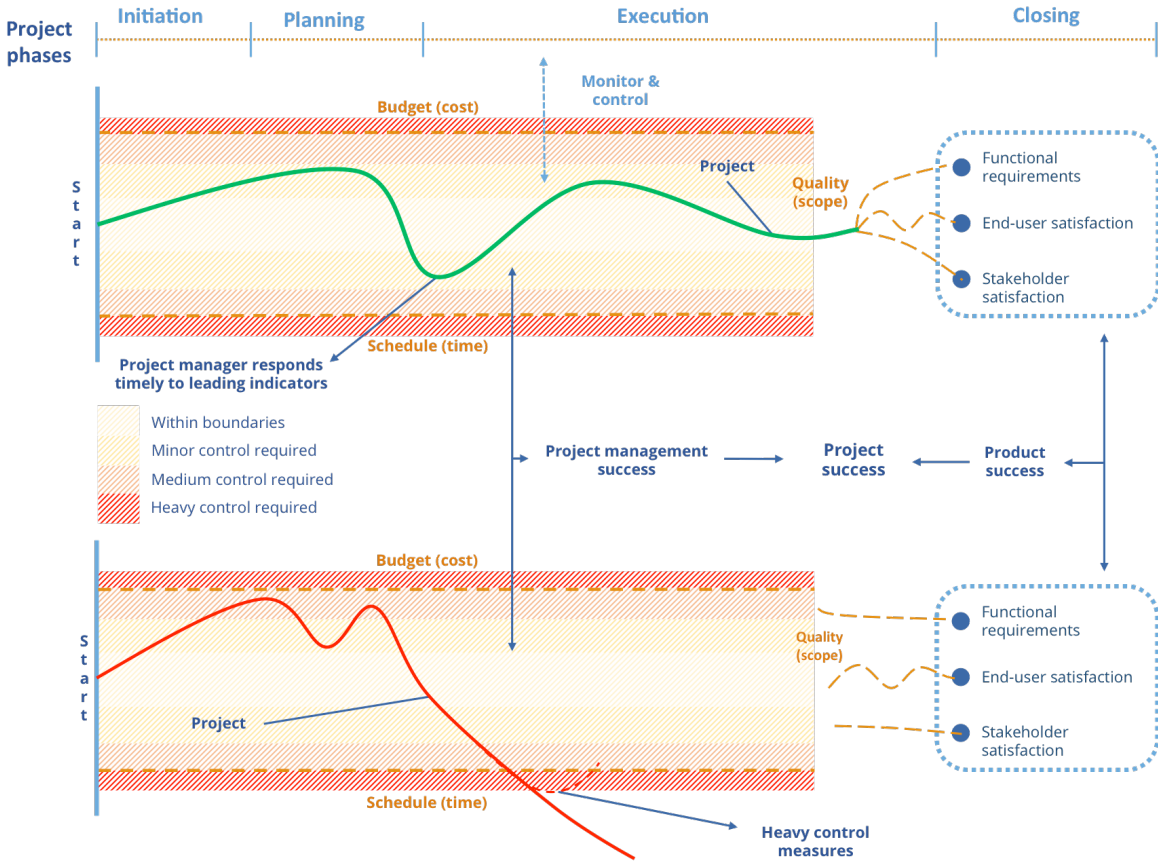


Figure 45: Controlling using leading indicators

The projects described in the introduction (Noord/Zuidlijn and Betuweroute) are both projects that experienced large overruns in budget and schedule. This is caused partially by factors that could have been dealt with by the project management, but also by factors that exceeded the level of the project and resulted from difficult economic, environmental and political decisions and

influences.Therefore, it would be an oversimplification of reality and naïve to think that Proactive Project Management alone would prevent overruns from happening in LCPs and that PPM is enough to control projects. This does not mean that the project and its performance on schedule, budget and quality/scope does not benefit from maintaining sufficient quality of project management processes (Figure 46).

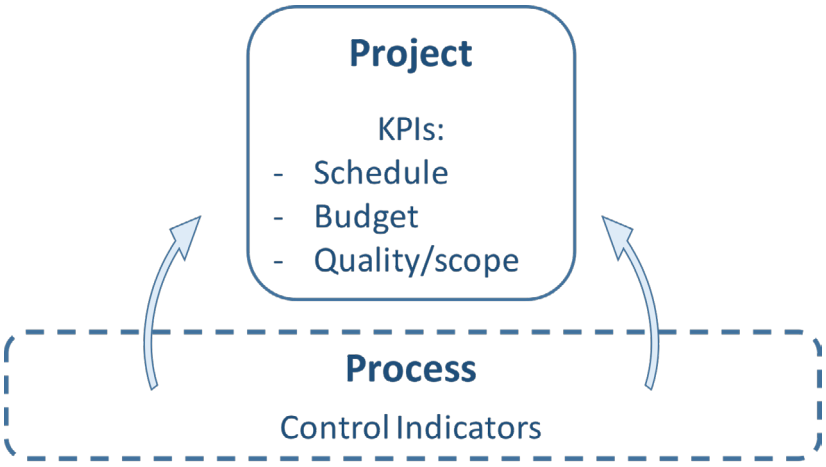


Figure 46: Project management success is achieved through

Project (Key Performance Indicators) and Process (Control Indicators) Proactive Project Management focusses on monitoring Control Indicators that reflect project management processes. Through the identification and monitoring of Control Indicators that reflect project management processes, issues in processes on different levels of the project can be exposed. Responding to CIs could mean better enforcement of existing processes, design of new processes, resolving of conflicts, rearrangement of responsibilities or other measures.

Monitoring Control Indicators and responding adequately on the process level that is reflected by the CIs, contributes to meeting the 'process' aspect of project management success and thus contributing to project success. It can be concluded that although PPM is not validated in practice, it could contribute to the improvement of monitoring and controlling of LCPs by improving the process aspect of project management success.

7.4. Recommendations

This section elaborates on the recommendations that are made based on the findings of this research. In section 7.4.1 suggestions regarding possible further research are made. Recommendations concerning the application of the Monitoring/feedback-system, Control Indicators and Proactive Project Management are made in section 7.4.2.

7.4.1 Further research

Aside from the scientific contribution that is delivered, this research also encountered certain limitations which require further investigation. In this section recommendations are made regarding possible further research.

Validation

The Control Indicators that have been identified are theoretically validated and the Monitoring/feedback-system is evaluated by a PACER professional and assessed on its practical application in theory. In order to find out whether the MFS and CIs actually enhance project management performance it has to be applied in practice in multiple projects (as described in 6.2.3). Performing a validation study is complex and could take more than two years and fell outside of the scope of this research; therefore, a validation study is recommended.

Standardized Project Controlling

An important knowledge gap that was identified during the second literature study (into monitoring and controlling practices) was the absence of standardized project controlling practices. This was unexpected since detailed monitoring practices into schedule and budget exist. In contrast to the monitoring practices are the follow-up controlling practices meagerly described. A study into the development of a standardized project controlling method is recommended.

Control Indicators

The Control Indicators that have been identified reflect project management processes performance, are leading for project management success and have their basis in documented literature and research performed during this study. The list of CIs that is provided is not exhaustive (not all categories have been used) and new CIs should be added. Providing project managers (or organizations) with a tool to develop their own Control Indicators would improve the practical applicability of the MFS and CIs. Other information that is missing regarding CIs is their baseline value: a study into CIs such as 'client/project manager rating', 'project team compatibility' and 'maturity of scope change processes' could provide baseline values which can be used to define triggers, limits and threshold values for CIs.

The formulation of Control Indicators is based on lessons learned in LCPs, Key Performance Indicators and (critical) success/failure factors that have been identified in the literature and interviews. Since Control Indicators reflect processes, another basis for CIs could have been processes indicators for either ISO-norms (a form quality management) or process management processes in general. Therefore, an additional study into the identification of Control Indicators is recommended.

7.4.2 Recommendations regarding Proactive Project Management

This research resulted in the identification of many factors associated with project success and Control Indicators. The Monitoring/feedback-system can be used to select CIs based on user preferences and is accompanied by a process that prescribes how CIs could be monitored and responded to: Proactive Project Management (PPM). This section suggests different applications for PPM.

Integrating project and process monitoring and controlling

Project controlling efforts mainly focus on scope, cost and time management. Project controlling could cover a broader spectrum of the project if (for example) contract management is included in monitoring and controlling practices such as dashboards.

As explained by one of the experts consulted for this research: dashboards are occasionally required in projects and used for monitoring indicators relevant for project controlling; adding Control Indicators from environmental-, contract-, technical- and project management could improve the coverage of these dashboards.

These types of management could set their own goals and monitor their own Key Performance Indicators, just as scope management, cost management and time management. Achieving these goals is important since it is not all about the process. But using Control Indicators to monitor processes subordinate to these goals could improve the process of achieving the goals and scores on the KPIs itself. The combination of measuring both KPIs and CIs could lead to more effective controlling efforts.

Using Control Indicators to improve your process

Organizations have different ways to separate themselves from competition. Whereas some companies gain an edge over others by being cheap and delivering fast, other organizations separate themselves by providing the best service. A project organization could use Control Indicators to tailor their services to their clients' needs and focus on processes that are favored by the client.

Managing through project management processes

Project management professionals (from specializations as described by the IPM-model), contribute in projects due to their expertise in certain project related aspects. This thesis delivers a set of Control Indicators and a tool that can be used to select them based on user preferences.

Instead of measuring the project, the MFS and CIs could equip project management professionals with the ability not only manage their project specialization, but also the processes involved with their field of expertise. By consciously monitoring project processes using the CIs, they could distinct themselves from other project management professionals.

8 Personal reflection

When I started my graduation project at PACER, I still had to finish my research proposal. I knew I wanted to do 'something' with improving project management, but I did not have a clear idea of how exactly I was going to realize this. In the end, it took me more than a month to finish my research proposal and I had to postpone my kick-off meeting with two weeks. This most difficult part of the process of writing my thesis.

Now, seven months later, I am concluding my thesis. Looking back, I wonder why I struggled more with the proposal than I did with my thesis. The most important feedback I received on the rejected proposals was that it was not clear and concise enough. By postponing important decisions regarding the scope of my research I also postponed making progress. In the beginning I had a hard time reiterating since I did not like to make decisions in the first place. Learning to make these decision is the most valuable lesson this thesis as taught me.

Since there is abundant literature on project success and failure, project management performance and lessons learned in construction projects, I wondered how it was possible that projects still suffered from budget and schedule overruns and unsatisfying results. I thought that if I found out what factors all well managed projects have in common and ensure that these factors occur in new projects, these projects would succeed. Eventually, this would result in formulation of Control Indicators. An important aspect of these Control Indicators would be that they should be leading and predictive for project performance, as opposed to other indicators that are, as the Dutch saying goes, mosterd na de maaltijd.

The Control Indicators I formulated based on the factors were a reflection of how well certain project management processes perform. But due to the fact that I approached this research from a 'success/failure factor'-perspective instead of a 'project management process'-perspective, I did not include some process related literature such as 'process management' and ISO-norms; which in hindsight I would have used.

From time to time it was a bit frustrating that some days I did not write anything. Or worse, I wrote a few pages and had to discard it the next day. When I got stuck and needed to boost my productivity I visualized concepts and relations in order to gain better understanding and create oversight. Looking back at the whole process I like to believe that I managed my own process well, since there were no indicators that triggered heavy control measures.

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Appendices

Appendix A: Exploratory Interviews

This appendix contains the structure and summaries of the exploratory interviews. The interviews were conducted semi-structured, meaning that a set of questions or topics has been formulated in advanced that do not necessarily require answering. There are certain themes that the interviewee is asked about where they might have no experience with while other themes are their specialization; this produces very different results in in the interviews. Since the interviews are of an exploratory nature, the semi-structured set-up is ideal for investigating the perimeters of the subject. The factors that resulted from the exploratory interviews are displayed in Table 34.

Factors		
Clear functional specifications	Clear scope	Insufficient organizational capacity
Attitude contractors (contract-oriented or solution-oriented)	Managing differences contract and scope	Changing opinions or policy of stakeholders
Adequate contract type	Goals contractor and client not aligned	Flexible contracts
Regular updates stakeholders	Adequate risk analysis	Indecisiveness of the client
Expectation management	Maturity and experience suppliers	Stakeholder subjectivity in project changes
Conflict within project team	Quality of contracts	Unclear expectations among project participants
Dishonesty regarding lack of information	Deliver proof-of-concept	Lacking communication
Holding too tight to the scope	Realistic planning	Project manager insufficiently instructed by the organization
Tension between stakes of project and organization	Compatible project team	Project participants' unwillingness to share information
Personal interests of project team members	Regular updates and communication	Lack of commitment to common goal
Mismatch between functionality and product	Profitability contractors	Project team participants putting their own goals before team goals
Good ambiance within project team	Skills project manager	Involvement of different layers of the project in decision-making (involvement is NOT influence)
Adequate scope management	Openness between project team and contractors	Trust in project management team

Table 34: Factors derived from exploratory interviews

Before starting the interviews, the interviewees were not briefed on what Control Indicators were; they were asked for Key Performance Indicators (a concept that was explained when necessary). Table 35 contains the introduction of the interviews along with the questions that were formulated in advance. The results of the interviews are structured according to the questions that were asked or the subject that has been discussed. As mentioned earlier, the interviews are semi-structured which (in a few cases) resulted in skipped questions. When the interviewees were asked questions, their answers were written down when relevant for this research. The interviewees were sent the results of their interviews afterwards and approved or rectified were necessary. Since the interviews were of exploratory nature, information had to be very irrelevant to this thesis in order to be not included in the notes.

Table 36 provides the notes produced by the interviewer. The answers of the interviewees are structured according the first row in Table 36. The reason the results are structured per topic instead of per question is that due to the unstrained nature of the interview the topics switched quickly. For example: when discussing KPIs interviewees often mentioned success factors or other factors that influence project performance.

There is a tendency that the question regarding KPIs quickly shifts to factors influencing performance, which could indicate that it is hard to quantify (their own) performance indicators. The same trend is observed in the literature: there is abundant literature on factors, but less so on KPIs (especially the ones not derived from schedule and budget).

Semi-structured interviews

Introduction

Research points out that LCPs underperform at the 'iron triangle' promises

- There has been a lot of research conducted into why projects fail, how is it possible that it seems that LCP performance does not increase?
- Project should avoid going 'out-of-control' [show difference between in- and out-of-control situations]
- The core of the thesis is measuring certain metrics (then still referred to as KPIs) and designing a dashboard that could be used by project managers to have overview of these metrics

Questions

1. Could you give me your job description and responsibilities?
2. What are the reasons for bad project performance on the iron triangle?
3. Which project management aspect is causing the most problems? (if the previous questions did not yield any information)
4. What kind KPIs are already measured?
5. Who should be responsible for these KPIs?
6. Which parties influence these KPIs
7. Which KPIs would you use to assess your own performance
8. Are you completely in control of your performance on these KPIs?
9. What are the requirements of KPIs of a system that monitors these KPIs?
10. 10. Do you feel like I forgot to ask questions, tips/tops or other remarks?

Table 35: Set-up of the interview

Causes of bad performance:	[the causes of bad performance as mentioned by the interviewee]
Other remarks:	[other miscellaneous remarks made by the interviewee that are worth mentioning, such as recommended literature, contacts or other tips/tops]
Analysis:	[interpretation, background and context of remarks. If relevant, the results from the interview are compared or linked to findings from the literature]
Summary:	[the most important takeaways from the interview, as well as the factors, KPIs or monitoring system requirements that resulted from the interview]

Results interview of interviewee 1

Causes of bad performance: validation of functional specifications (ambiguity on contracts and requirements and how contractors deal with this ambiguity), quality (trade-off between high quality and low maintenance and vice versa) and stakeholders (keeping them informed expectation management)

KPIs: When asked about possible KPIs the interviewee suggested the following KPIs:
- Percentage permits on time (include possible delays into your planning)
- Number of necessary permits requested
- Number environmental research (avoid appeals)
- Number neighborhood meeting (avoid appeals and create commitment/ expectation management)

Other remarks: Rijkswaterstaat already sets goals regarding satisfaction. They use surveys to monitor service, accessibility and satisfaction. KPIs are already monitored in safety: incidents, material damage and (deadly) casualties.
Analysis: The interview explained (using examples) the tension between contactor and client in the contract type that he is used to work with: DBFM (design, build, finance, maintain) contracts. The contractual problems that could arise from the insufficiently specified functional requirements is something that also is mentioned in the literature. It is not clear what the client really wants; or at least it is not sufficiently captured in the requirements. The attitude contractors have is mentioned by other interviewees as well in the sense that some contractors make money out of loopholes or vague requirements in contracts: adequate contract types could reduce negative effect. Expectation management is mentioned as success factor in multiple sources in the literature study and is formulated as 'expectation management' and 'regular updates stakeholders' in the factors. The KPIs are formulated after efforts that could be undertaken to manage the environment of a project.

Summary:
Factors
- Clear functional specifications
- Attitude contractors (contract-oriented or solution-oriented)
- Adequate contract type
- Regular updates stakeholders
- Expectation management

KPIs
1. Percentage permits on time
2. Number of necessary permits requested
3. Number community/neighborhood meetings
4. Grades of satisfaction surveys

Results interview of interviewee 2

Causes of bad performance: aspects that cause problems: objective & scope, stakeholders and organization & management. Problems often stem from human factors such as interfering with other people's work fields and dishonesty, unrealistic expectations such as a 'fixed' scope and misalignment of goals (like organization vs project, personal vs project). Tension between project participants often goes at the expense of the ambience of the working environment.

KPIs: the interviewee made efforts in designing a dashboard which tracks certain metrics. Interviewee shared some useful documents after the interview. Try including how much 'fun' project members have along with other more human elements. RWS has surveys in which client and contractor rate each other.

Other remarks: Interviewee provided information on the IPM-model (Expertgroep Projectmanagement, 2008) as used by Rijkswaterstaat. Project managers do not want to be bothered with more bureaucracy like keeping track of lists and dashboards.
In governmental projects expenses have to be justified extensively (= only spending that DIRECTLY serves a clear purpose is allowed). Projects should focus more on the group instead of on themselves: trust and facilitate.
The need for configuration management, functional requirements and object do sometimes not align which results in holes in contracts.

Analysis: After explaining the research question of this thesis the interviewee explained what human factors (from his point of view) contributed to bad project performance. He showed efforts that already had been made in displaying certain metrics: for example, a dashboard with both qualitative and quantitative information and an excel sheet in which different metrics could be tracked.

The human factors that were discussed were (generally) more specific than the factors described in the literature. Mismatch between functionality and product is a reoccurring theme in both the interviews and literature. The tension between the stakes of the project and organization and the personal interest versus the project teams' interest are trends that is also observed in the literature review in the section of KPIs and KRIs on different levels and varying definitions of success.

Summary:
Factors
- Conflict within project team
- Dishonesty regarding lack of information
- Holding too tight to the scope
- Tension between stakes of project and organization
- Personal interests of project team members
- Mismatch between functionality and product
- Good ambiance within project

Monitoring system
- Example of a dashboard

Results interview of interviewee 3

Causes of bad performance:
Scope management: often scope is not clear in advance. This requires thorough questioning: what do really want? Problem with scope is that expectations change, contracts do not. Not everything is clear, but a lot of problems are foreseeable.
Information: there is a trade-off between how much research is conducted and when the risk is acceptable.
Objective & scope: project managers have the important task to manage the tension between client and contractors: what is within the scope of the project and what is not.

KPIs:
For own evaluation, not project: hours/job (are you effective?) client feedback, being able to communicate a risk plan, making predictions that turn out to be true. People need space to learn, although this often happens through negative experiences. Capturing everything in a contract does not always work well with contractors, you sometimes should give them space and trust them.
For project monitoring: automated dashboard that is synced with some sort of system. Try formulating KPIs in risk management and communicate these from mid-management to higher management in quarter-annual reports that include mitigated and residual risks.

Other remarks: suppliers are a source of risk: are they mature? Self-audits of suppliers are randomly checked: are these very detailed. Risk management has to be performed by suppliers, if their risk analysis is thorough they put money, time and expertise in it.
Reducing risks in projects: proof-of-concept. When building 10 houses, build 1 completely, then the other 9. Instead of directly building 10 foundations and so on.
Feedback loops (System Dynamics nature) are difficult to predict in projects and can result in large budgetary and schedule overruns.
Project governance: kill your darlings when projects get to expensive
Comments on project managers: planning is essential, therefore, good planners are too. Planning is telling how managers see their project; is there spare time or is it a tight schedule?

Analysis: This interview showed that scope management and contractual arrangements are closely related since the contract is the legal enforceable agreement on the work that has to be done. Therefore, a clear scope and managing the differences between contract and scope are important factors. Aligning the goals of contractors and the client reduces the problems that result from a change in scope since both benefit from reaching their shared goal.

Managing risks is important for success in projects, therefore adequate risk analysis is necessary. Risk is reduced with the right incentives in contracts, mature suppliers and delivering proof-of-concept. A tight schedule might be appealing since the time to complete a project is shorter, but minor setbacks can have a large impact on the schedule and cost of a project. Therefore, a realistic planning reduces risks compared to an over-optimistic planning.

Summary:
Factors
- Adequate scope management
- Clear scope
- Managing differences contract and scope
- Goals contractor and client not aligned
- Adequate risk analysis
- Maturity experience suppliers
- Quality of contracts
- Deliver proof-of-concept
- Realistic planning

Monitoring system
- Keeping track of automated systems reduce the administrative burden of monitoring systems

Results interview of interviewee 4

Causes of bad performance: when the interviewee was asked about overruns in terms of the iron triangle in projects she was a part of, she did not recall projects not meeting their promises.

KPIs: the interview named the following possible KPIs that could be used to evaluate own performance

- Number of change request that could have been avoided
- Reaching targets, goals and milestones on time
- Quality of cooperation with contractors

Other remarks: since the interviewee was generally positive about projects, she was asked about what the success factors in projects were according to her experience:

- Compatible project members, preferably people who are working full-time on a project
- Small teams which enables fast communication
- Good contractors: they are more committed when they are able to realize a project with profit
- The type of tender and contract depends on whether the project is complicated or not (focus on either price or quality)
- Project manager and contract manager should be a 'match'
- Good cooperation with contractors (fun at work, openness, respect each other's interests, common goal despite different interests
- One project which was completed within the constraints but had some struggles:
- The project team had problems working together
- Project managers followed a course and tried applying it, but it came across unnatural: 'oh, the manager followed a course'

Analysis: This interview consists of the two parts: first factors were discussed associated with projects

Summary:
Factors

- Compatible project team
- Regular updates and communication
- Profitability contractors
- Skills project manager
- Openness between project team and contractors

Results interview of interviewee 5

Causes of bad performance: delays are often caused by capacity problems; too many projects for too few staff members.
Stakeholders often change their opinions and/or policies

KPIs: Different KPIs were suggested:
- Number of client requirements outside the scope
- Number of client requirements that has been argued over
- Number of client requirements that have awarded
- Number of client requirements that have declined

Also, different KPIs are suggested among different phases of the project.

Other remarks: often the relationship between clients and contractors fluctuate because of their portfolio's. Contracts need to be balanced between technical requirements and contractual incentives. Contracts remain flexible by adding functional requirements (instead of the detailed, final product).

Analysis: The lack of sufficient capacity results in to understaffing which in return could lead to bad performance. Changing opinions of stakeholders involved or changing policies require adjustment of contracts/project plans and can result in delays (which can have financial consequences). Based on the remarks some contractual room is desired (in the form of different incentives and functional requirements) flexible contracts is formulated as factor.

Summary:
Factors
- Insufficient organizational capacity
- Changing opinions or policy of stakeholders
- Flexible contracts

Results interview of interviewee 6

Causes of bad performance: The interviewee mentions the following causes:
- Indecisiveness of the client
- Everybody 'has an opinion' on certain change requests
- Unclear expectations among controllers, PPOs and contractors

KPIs: The following KPIs to measure own performance were mentioned:
- Process time of change requests
- Calls and emails send to people (have they done their job?)

Interviewee mentioned that he is dependent of other people to do their jobs: which results in managing many project participants.
When asked about managing 'soft factors', the interviewee proposes a visual board that shows the work load and mood of people.

Other remarks: Linking your to-do's to risks could help prioritizing tasks.

Analysis: Indecisiveness of the client is a remarks that was mentioned by the interviewee and formulated as such. The remark that often people feel the necessity of weighing in in change requests is translated to 'stakeholder subjectivity in project changes', since the reason that this negatively affects project performance is that often these opinions conflict among the participants. Unclear expectations among project participants includes the examples mentioned by the interviewee: PPOs, contractors and controllers.

Summary:
Factors
- Indecisiveness of the client
- Stakeholder subjectivity in project changes
- Unclear expectations among project participants

Results interview of interviewee 7

Causes of bad performance: The following causes are mentioned:

- Bad communication
- Insufficient governance from the organization to project management. This is not necessarily a choice by the organization, but could be due to:

1. Time pressure
2. Not paying attention to people's needs
3. Prioritizing (person vs organization)
4. Drive to perform (do what suits the person best, not the project)
5. No investment in team building
6. Projects are temporary organizations. Sometimes people do not want to share their information since the cooperation is temporary and the 'skill' or 'information' could be sold elsewhere.

After discussing the causes of bad performance the interview evolved into a conversation on what causes good performance:

- Project management has broad meeting that include everybody from different levels; people hear about other people's tasks which creates involvement of participants on different levels.
- Trust and availability of the people who make decisions is important. Seeing these management types on the actual projects (near the more operational levels) lowers the threshold to talk to these people which in turn results in better communication.
- Even unilateral updates from higher to lower management can contribute to project understanding.
- Regular reflection: perform tasks, show result, deliver feedback, improve. This loop can contribute to more trust between project team and contractors
- Motivation on more operational levels decrease when they have no trust in management
- The executive level should inform the higher management levels, this is important for the quality and people at the executive level are often experts/specialist in what they do.

KPIs: The interviewee told that the more standard KPIs like time and money are measurable. Measuring communication with the project environment such as residents and municipalities; this could be measured among different phases of the project.
KPIs for the organization internally: how often are interdisciplinary meetings held? It is important to include everybody in the project team (do not exclude certain functions). When asked about which levels could be subject to monitoring and controlling with KPIs, the interviewee thought from the operational to the project management team was possible. A large share of the information is required from the more operational levels.

Other remarks: When the interviewee was asked about who should be monitoring KPIs in projects, the interviewee would assign this task to the project controller rather than the project manager (they are better at monitoring in general).

Analysis: Lacking communication throughout different layers of the project causes overruns in terms of schedule and budget. Project managers often do what they think is best, but are sometimes not sufficiently briefed by their project organization which leads to decisions being made not in the interest of the project. When project participants share a common goal they operate more like a team and a more willing to share information (and thus improve communication). Involving participants of different layers of projects contributes to that people feel heard. Trust in project management is named as a factor that positively influence project performance.

Summary:
Factors
- Lacking communication
- Project manager insufficiently instructed by the organization
- Project participants' unwillingness to share information
- Lack of commitment to common goal
- Project team participants putting their own goals before team goals
- Involvement of different layers of the project in decision-making (involvement is NOT influence)
- Trust in project management team

Table 36: Results of the interviews

Appendix B: Categorizing the Factors

In this appendix the process of categorizing the factors is described. This process is important for the formulation of Control Indicators, but not sufficiently relevant to discuss in the main text. The literature that forms the basis for the categorization is displayed Figure 47 (Alzahrani & Emsley, 2013; Atkinson, 1999; A. P. C. Chan & Chan, 2004; Kaplan & Norton, 1992; Ofori, 2013; Philbin & Kennedy, 2014; Staal-Ong et al., 2016; Westerveld, 2003)

Kaplan & Norton, 1992	Atkinson, 1999	Westerveld, 2003	Chan et al., 2004	Ofori, 2013	Alzahrani & Emsley, 2013	Philbin & Kennedy, 2014	Staal-Ong et al., 2016
Customer	Iron triangle	Project results (triangle)	Project management actions	Communication	Financial	Process	Finance
Financial	Information system	Appreciation client	Project-related factors	Commitment	Management	Technology	Scope & Objective
Environment	Benefits (organizational)	Appreciation project personnel	External environment	Competency	Technical	Resources	Contracting
Learning & growth	Benefits (stakeholder community)	Appreciation users	Project procedures		Past experience	Impact	Risk management
Internal business		Appreciation contracting partners	Human-related factors		Past performance	Knowledge	Legal consent
		Appreciation stakeholders			Organization	Culture	Stakeholder
		Leadership and team			Environment		Organization & management
		Policy and strategy			Health and safety		Knowledge & Technology
		Stakeholder management					Political context
		Resources					
		Contracting					
		Project management					

Figure 47: Sources of literature used for defining the categories

Categorization is used on one hand to simplify information and reduce the highly specific context. On the other hand, the categorization provides more insight in what are the most important aspects of project management. This means that a fine balance has to be maintained when defining these categories, with as most important guidelines: the categories could have some overlap (although preferably not) and a factor should qualify for at least one category with a maximum of two. In Table 37: Description of the categories the different categories are explained.

Category	Description
Stakeholders	Includes most stakeholder-related aspects of stakeholders such as (but not limited to) contractors, non-governmental organizations (NGOs), government, clients, financiers and residents/communities
Finance & resources	Financial arrangements for projects, distribution of resources like funding, staffing, man power and labor during the execution are examples of factors included in this category
Organization	A broad category covering different layers of management in organization, as well as the project team (temporary organization) responsible for managing the project
Legal aspects	Contracts between stakeholders, (municipal) permits, governmental regulations
Risks & external influences	Covers (unexpected) risks (opportunities and threats) and other external factors influencing projects.
Objective & scope	The objective and scope cover the functional requirements and the technical specifications, as well as the business case (including planning and budget)
Technology	The technological component in LCPs, concerning technical innovations and uncertainty regarding properties of materials and everything in between
Processes	The arrangement of procedures like decision-making, information sharing, troubleshooting and communicating benefits
Safety & health	This category covers the safety and health of people and the environment in contact with a project

Table 37: Description of the categories

Since there is abundant literature on factors and frameworks for assessing factors, there are many different views on the categorization of factors. Figure 47 contains the categorizations used in different academic sources. When comparing the categorization from this thesis and the ones from the literature, the resemblance with Staal-Ong et al (2016) is the most significant. The document where the categorizes are derived from is a large collection of lessons learned in the construction sector across different companies and countries. Given the large (time) scale of both this document (Lessons Learnt and Challenges Ahead 10 Years of Managing Large Infrastructure Projects in Europe) and the literature study conducted, this categorization seems most fit, although some adjustments were made.

Although nearly every aspect of project management also has the 'process'-side to it, a new category "processes" had to be created in order to cover miscellaneous process are not clearly covered by other fields. It could be argued that 'stakeholder management' is a process, and rightly so. Processes in this case, does not cover managing the stakeholders, nor does it cover 'technology management' since that also is covered by another category, namely 'Technology'. The literature also exposed different processes which have not been discussed, such as benefit management, trouble shooting and information sharing, which are included in this category.

External influences are source of uncertainty in projects, which requires anticipation. Managing the possible threats and opportunities and their impact on projects is done through risk management (which is the process-side to risks).

An important difference is between 'stakeholders' and 'organization': the former are actors mostly external to the project organization and the latter are internal, but could be consisting of a wide variety of actors. The reason to make the distinction this way is because a hard internal/external divide causes confusion whether it applied to the project team, project organization or the project as whole. Upon discussing the categories with PACER consultants, a distinction between internal/external would be too harsh (also this distinction is not made in any literature) since in LCPs there could be stakeholders within the same organization with different goals and incentives and "stakeholders sitting on both sides of the table". Clients are seen as stakeholders instead of as part of the organization, since the client want something done, hands this to a developer, which in turns tenders it to a project organization who will execute the project. This does not mean that the client cannot participate in the project organization.

'Finance & resources' and 'Objective & scope' appear difficult to separate: the former concerns financing of projects and the distribution of resources. But the latter is responsible for adherence to the agreed upon schedule and budget. On the other hand: access to financial aid when dealing with budgetary overruns during the execution phase of the project falls under the category 'finance & resources'.

In order to consequently assign factors to a category they have to be subdued to the same process. Each factor has to be assigned to at least one category and have a maximum of two. The first questions that has to be asked is: "does the factor have a strong component that clearly fits one of the categories?". If that is the case, it will be assigned directly. The second question will be: "does the factor qualify for a secondary category?". If this is the case, it will be assigned. For elaboration on what the different categories mean, the previous section should be consulted.

Appendix C: List of Factors

This appendix (Table 38) contains a list of all factors, their source, their code and their category or categories (if applicable). This categorization is conducted with the context of the literature in mind, therefore this overview should be viewed in light of the literature also.

Code	Factor	Cat. 1	Cat. 2
	L1 Chan, Scot, Chang 2004		
F0101	Communications system	Process	
F0102	Control mechanism	Process	
F0103	Feedback capabilities	Process	
F0104	Planning effort	Process	
F0105	Developing an appropriate organization structure	Organization	
F0106	Implementing an effective safety program	Safe/health	
F0107	Implementing an effective quality assurance program	Process	
F0108	Control of subcontractor's work	Process	
F0109	Overall managerial actions	Process	
F0110	Procurement method	Legal	Process
F0111	Tendering method	Legal	Process
F0112	Economic environment	Risk/ext.	
F0113	Social environment	Risk/ext.	
F0114	Political environment	Risk/ext.	
F0115	Physical environment	Risk/ext.	
F0116	Industrial relations environment	Risk/ext.	
F0117	Technology advanced	Technology	
F0118	Type of project	Obj&scope	

F0119	Nature of project	Obj&scope	
F0120	Number of floors of the project	Obj&scope	
F0121	Complexity of project	Obj&scope	
F0122	Size of project	Obj&scope	
F0123	Client's experience (sophisticate or specialized client?)	Stakeholders	
F0124	Nature of client (private/public)	Stakeholders	
F0125	Size of client's organization	Stakeholders	
F0126	Client's emphasis on low cost	Stakeholders	Obj&scope
F0127	Client's emphasis on (high) quality	Stakeholders	Obj&scope
F0128	Client's emphasis (short) time	Stakeholders	Obj&scope
F0129	Client's ability to brief	Stakeholders	
F0130	Client's ability to make decisions	Stakeholders	
F0131	Client's ability to define roles	Stakeholders	
F0132	Client's contribution to design	Stakeholders	
F0133	Client's contribution to construction	Stakeholders	
F0134	Project team leaders' experience	Organization	
F0135	Project team leaders' Technical skills	Organization	
F0136	Project team leaders' Planning skills	Organization	
F0137	Project team leaders' Organizing skills	Organization	
F0138	Project team leaders' Coordinating skills	Organization	
F0139	Project team leaders' Motivating skills	Organization	
F0140	Project team leaders' Commitment to iron triangle	Organization	Obj&scope
F0141	Project team leaders' Early and continued involvement in the project	Organization	Process
F0142	Project team leaders' Adaptability to changes in the project plan	Organization	Process
F0143	Project team leaders' Working relationship with other	Organization	Process
F0144	Project team leaders' Support and provision of resources from parent company	Resources	Organization
L2 Cooke-Davies 2002			
F0201	Adequacy of company-wide education on the concepts of risk management.	Organization	Risk/ext.
F0202	Maturity of an organisation's processes for assigning ownership of risks.	Organization	Risk/ext.

F0203	Adequacy with which a visible risk register is maintained.	Organization	Risk/ext.
F0204	Adequacy of an up-to-date risk management plan.	Risk/ext.	
F0205	Adequacy of documentation of organisational responsibilities on the project.	Legal	
F0206	Keep project (or project stage duration) as far below 3 years as possible (1 year is better).	Process	
F0207	Allow changes to scope only through a mature scope change control process.	Obj&scope	Process
F0208	Maintain the integrity of the performance measurement baseline.	Resources	
F0209	Portfolio- and program management	Organization	
F0210	Program and portfolio metrics	Organization	Process
F0211	An effective means of "learning from experience" on projects	Organization	Process
L3 Al-Tmeemy, Abdul-Rahman & Harun 2011			
C0301	Adherence to quality targets	Obj&scope	
C0302	Adherence to schedule	Obj&scope	
C0303	Adherence to budget	Obj&scope	
C0304	Customer satisfaction	Stakeholders	Obj&scope
C0305	Functional requirements	Obj&scope	
C0306	Technical specifications	Obj&scope	
C0307	Revenue and profit	Stakeholders	Organization
C0308	Market share	Organization	
C0309	Reputation	Stakeholders	Organization
C0310	Competitive advantage	Stakeholders	Organization
L4 Atkinson 1999			
C0401	Cost	Resources	Obj&scope
C0402	Quality	Obj&scope	
C0403	Time	Resources	Obj&scope
C0404	Satisfied users	Stakeholders	Obj&scope
C0405	Social and environmental impact	Stakeholders	Safe/health
C0406	Personal development	Organization	
C0407	Professional learning	Organization	
C0408	Contractor's profits	Stakeholders	
C0409	Capital supplies	Resources	

C0410	Content project team	Organization	Safe/health
C0411	Impact surrounding community	Stakeholders	Safe/health
C0412	Information system	Organization	Process
C0413	Information quality	Process	
C0414	Improved effectiveness and efficiency of organization	Organization	
C0415	Increased profits	Resources	Organization
C0416	Organizational-learning	Organization	
L5 Jha & Iyer 2007			
F0501	Commitment of all project participants	Stakeholders	Organization
F0502	Owner's competence	Stakeholders	
F0503	Good coordination among project participants	Organization	Process
F0505	Conflict among project participants	Stakeholders	Organization
F0506	Project manager's ignorance and lack of knowledge	Organization	
F0507	Hostile socio-economic environment	Stakeholders	Risk/ext.
F0508	Indecisiveness of project participants	Organization	
F0509	Top management support	Organization	
F0510	Favorable working conditions	Risk/ext.	Safe/health
F0511	Harsh climate condition at site	Risk/ext.	
F0512	Aggressive competition during tendering stage	Process	
F0513	Project manager competence	Stakeholders	
F0514	Top management support	Organization	
F0515	Owners competence	Stakeholders	
F0516	Interaction between project participants – internal	Organization	
F0517	Interaction between project participants – external	Stakeholders	
C0501	Commitment	Organization	
C0502	Competency	Organization	
C0503	Coordination	Organization	Process
L6 Clarizen 2015			
F0601	Poor communication	Organization	Process
F0602	Lack of alignment with a team	Organization	
F0603	Ineffective leadership	Organization	
F0604	Lack of participation	Stakeholders	Organization
C0601	Communication	Process	

C0602	Complexity	Obj&scope	
C0603	Project visibility	Obj&scope	
C0604	Organizational change	Organization	
L7 Khang & Moe 2008			
F0701	Addressing relevant needs of the right target group of beneficiaries	Obj&scope	
F0702	Identifying the right implementing agency capable and willing to deliver	Stakeholders	
F0703	Matching policy priorities and raising the interests of key stakeholders	Stakeholders	Process
F0704	Approval of, and commitment, to the project by the key parties	Stakeholders	
F0705	Sufficient resources committed and ready to be disbursed	Resources	
F0706	Core organizational capacity established for project management	Organization	
F0707	Resources mobilized and used as planned	Resources	
F0708	Activities carried out as scheduled	Obj&scope	
F0709	Outputs produced meet the planned specifications and quality	Obj&scope	
F0710	Good accountability of resources utilization	Resources	
F0711	Key stakeholders informed of and satisfied with project progress	Stakeholders	Process
F0712	Project assets transferred, financial settlements completed and dissolved to the satisfaction of key stakeholders	Obj&scope	
F0713	Project end outputs are accepted and used by target beneficiaries	Obj&scope	
F0714	Project completion report accepted by the key stakeholders	Stakeholders	Obj&scope
C0701	Clear understanding of environment by funding and implementing agencies and consultants	Risk/ext.	
C0702	Competencies of project designers	Stakeholders	
C0703	Effective consultations with primary stakeholders	Stakeholders	
C0704	Compatibility of development priorities of the key stakeholders	Stakeholders	Process
C0705	Adequate resources and competencies available to support the projects plan	Resources	
C0706	Competencies of project planners	Stakeholders	

C0707	Effective consultation with key stakeholders	Stakeholders	
C0708	Compatible rules and procedures for PM	Process	
C0709	Continuing support of stakeholders	Stakeholders	
C0710	Commitment to project goals and objectives	Stakeholders	Obj&scope
C0711	Effective consultation with key stakeholders	Stakeholders	
C0712	Adequate provision for project closing in the project plan	Process	
C0713	Competencies of project managers	Stakeholders	
C0714	Effective consultation with key stakeholders	Stakeholders	
L8 Alias, Zawawi, Yusof, & Abra, 2014			
C0801	Support from senior management	Organization	
C0802	Skilled designers	Organization	
C0803	Skilled project managers	Organization	
C0804	Troubleshooting	Process	
C0805	Project team motivation	Organization	
C0806	Commitment of all project participants	Stakeholders	Organization
C0807	Strong/detailed plan effort in design and construction	Obj&scope	
C0808	Adequate communication channels	Process	
C0809	Effective control, such as monitoring and updating plans	Process	
C0810	Effective feedback	Process	
C0811	Adequate financial budget	Obj&scope	
L9 Pinto & Slevin 1987			
C0901	Communication	Process	
C0902	Project mission	Obj&scope	
C0903	Top management support	Organization	
C0904	Project schedule/plan	Obj&scope	
C0905	Client consultation	Stakeholders	Obj&scope
C0906	Personnel recruitment, selection and training	Organization	
C0907	Technical tasks	Technology	
C0908	Client acceptance	Stakeholders	
C0909	Feedback and monitoring	Process	
C0910	Troubleshooting	Process	

L10 Ofori 2013			
F1001	Project understanding	Organization	Obj&scope
F1002	Information and Communication	Process	
F1003	Project mission/common goal	Stakeholders	Obj&scope
F1004	Competent project team	Organization	
F1005	Realistic cost and time estimates for the project	Obj&scope	
F1006	Adequate project control	Process	
F1007	Adequate resources	Resources	
F1008	Client involvement	Stakeholders	
F1009	Project ownership	Stakeholders	Organization
F1010	Authority of project manager/leader	Organization	
F1011	Problem solving abilities	Process	
F1012	Risk management	Risk/ext.	
F1013	Monitor performance and feedback	Process	
F1014	Planning/controlling	Process	
F1015	Clarity of missions and goals	Stakeholders	Obj&scope
F1016	Effective communication	Process	
F1017	Effective consultation with project stakeholders	Stakeholders	Process
F1018	Well-laid out specifications	Obj&scope	
F1019	Top management support and commitment	Organization	
F1020	Adequate resources for the project	Resources	
F1021	Commitment to standards and regulations to ensure quality	Legal	
F1022	Commitment to client/beneficiary satisfaction	Stakeholders	
F1023	Competency and experience of the project personnel	Organization	
F1024	Use of superior and appropriate technology for the project	Technology	
F1025	Good leadership	Organization	
F1026	Teamwork	Organization	
F1027	Monitoring and feedback	Process	
F1028	Client involvement	Stakeholders	
F1029	Stakeholders not consulted	Stakeholders	
F1030	Lack of support/finance	Resources	

F1031	Lack of commitment, communication and coordination	Organization	Process
F1032	Bureaucracy in government institutions	Risk/ext.	
F1033	Lack of experienced staff	Organization	
C1001	Clear mission & goals	Stakeholders	Obj&scope
C1002	Adequate resources	Resources	
C1003	Top management support & commitment	Organization	
C1004	Competency of project personnel	Organization	
C1005	Effective communication	Process	
C1006	Well-laid out specifications	Obj&scope	
C1007	Leadership	Organization	
C1008	Client acceptance/ satisfaction	Stakeholders	
C1009	Client involvement/ consultation	Stakeholders	
C1010	Teamwork	Organization	
C1011	Monitoring & feedback	Process	
C1012	Realistic cost & time estimates	Process	
C1013	Appropriate technology	Technology	
C1014	Standards & regulations	Legal	
L11 Dvir, Lipovetsky, Shenhar, & Tishler, 1998			
C1101	Functional specifications	Obj&scope	
C1102	Technical specifications	Obj&scope	
C1103	Schedule goals	Obj&scope	
C1104	Budget goals	Obj&scope	
C1105	Meeting acquisition goals	Obj&scope	
C1106	Meeting the operational requirements	Obj&scope	
C1107	Product entered into service	Obj&scope	
C1108	Reached the end-user on time	Obj&scope	
C1111	User is satisfied with product	Stakeholders	Obj&scope
L12 Remington, Zolin, Turner 2009			
C1201	Meeting project's overall performance (functionality, budget, timing)	Obj&scope	
C1202	Meeting user requirements	Obj&scope	
C1203	Meeting the project's purpose	Obj&scope	

C1204	Client satisfaction with project results	Stakeholders	
C1205	Reoccurring business with the client	Organization	
C1206	End-user satisfaction with the project's product of service	Stakeholders	
C1207	Suppliers' satisfaction	Stakeholders	
C1208	Project team's satisfaction	Organization	
C1209	Other stakeholders' satisfaction	Stakeholders	
L13 Westerveld 2003			
F1301	Human factors	Stakeholders	
F1302	Human parties	Stakeholders	
F1303	Use of managerial skills	Organization	
F1304	Project definition	Obj&scope	
F1305	Control and monitoring	Process	
F1306	Politics and social factors	Risk/ext.	
F1307	Relations with client	Stakeholders	
F1308	Politics	Risk/ext.	
F1309	Finance	Resources	
F1310	Use of technology	Technology	
F1311	Resources preliminary estimates	Resources	
F1312	Legal agreements	Legal	
F1313	Contracting	Legal	
F1314	Scheduling, design	Obj&scope	
F1315	Project administration	Organization	
F1316	PM Efficiency	Organization	
F1317	PM Scheduling	Obj&scope	
F1318	Schedule urgency	Obj&scope	
F1319	Schedule duration	Obj&scope	
F1320	Objectives	Organization	
F1321	Factors related to project manager	Organization	
F1322	Project team members	Organization	
F1323	Factors related to the project	Obj&scope	
F1324	Factors related to the organization	Organization	
F1325	Availability of resources	Resources	
F1326	External environment	Risk/ext.	

C1301	Pofit	Stakeholders	Organization
C1302	Client acceptance	Stakeholders	
L14 Gomes & Rao 2016			
C1401	Scope control	Obj&scope	
C1402	Top management support	Organization	
C1403	Team engagement	Organization	
C1404	Resource availability	Resources	
C1405	Risk management	Risk/ext.	
C1406	Business opportunity	Risk/ext.	
C1407	Market impact	Organization	
C1408	Financial resources	Resources	
L15 Alzahrani & Emsley 2013			
F1501	Safety and quality	Safe/health	
F1502	Past performance	Organization	
F1503	Environment	Safe/health	
F1504	Management and technical aspects	Technology	
F1505	Resource	Resources	
F1506	Organization	Organization	
F1507	Experience	Organization	
F1508	Size/type of previous projects	Organization	
F1509	Finance	Resources	
L16 Kog & Loh 2012			
F1601	Constructability	Technology	
F1602	Adequacy of plans and specifications	Legal	Obj&scope
F1603	Realistic obligations	Legal	
F1604	Clear objectives	Obj&scope	
F1605	Economic risks	Risk/ext.	
F1606	Project manager competency	Organization	
F1607	Project manager commitment and involvement	Organization	
F1608	Contractual motivation/incentive	Legal	
F1609	Technical approval authorities	Legal	Technology
F1610	Construction control meetings	Process	
F1611	Pioneering status	Process	

F1612	Schedule updates	Obj&scope	
F1613	Site limitation and location	Safe/health	
F1614	Adequacy of funding	Resources	Legal
F1615	Budget updates	Obj&scope	
F1616	Risk identification and allocation	Risk/ext.	
F1617	Site inspection	Safe/health	
F1618	Contractor team turnover rate	Stakeholders	
L17 Livesey 2016			
F1701	Team members' communication needs	Organization	Process
F1702	Stakeholders' goals and resultant agendas	Stakeholders	
F1703	Scope changes as the project progresses	Obj&scope	
F1704	Building a cohesive team	Organization	
F1705	Lack of a clearly defined project scope	Obj&scope	
F1706	Develop rapport with stakeholders	Stakeholders	
F1709	Stakeholders communication needs	Stakeholders	Process
F1710	Team member changes	Organization	
Interview results			
I0101	Clear functional specifications	Obj&scope	
I0102	Attitude contractors (contract-oriented or solution-oriented)	Stakeholders	
I0103	Adequate contract type	Legal	
I0104	Regular updates stakeholders	Stakeholders	
I0105	Expectation management	Process	
I0106	Conflict within project team	Organization	
I0107	Dishonesty regarding lack of information	Process	
I0108	Holding too tight to the scope	Organization	Obj&scope
I0109	Tension between stakes of project and organization	Organization	
I0110	Personal interests of project team members	Organization	
I0111	Mismatch between functionality and product	Obj&scope	
I0112	Good ambiance within project team	Organization	
I0113	Adequate scope management	Obj&scope	
I0114	Clear scope	Obj&scope	
I0115	Managing differences contract and scope	Legal	Obj&scope

I0116	Goals contractor and client not aligned	Stakeholders	
I0117	Adequate risk analysis	Risk/ext.	
I0118	Maturity and experience suppliers	Stakeholders	Organization
I0119	Quality of contracts	Legal	
I0120	Deliver proof-of-concept	Legal	Risk/ext.
I0121	Realistic planning	Obj&scope	
I0122	Compatible project team	Organization	
I0123	Regular updates and communication	Process	
I0124	Profitability contractors	Stakeholders	Organization
I0125	Skills project manager	Organization	
I0126	Openness between project team and contractors	Organization	
I0127	Insufficient organizational capacity	Organization	
I0128	Changing opinions or policy of stakeholders	Stakeholders	
I0129	Flexible contracts	Legal	
I0130	Indecisiveness of the client	Stakeholders	
I0131	Stakeholder subjectivity in project changes	Stakeholders	Obj&scope
I0132	Unclear expectations among project participants	Stakeholders	
I0133	Lacking communication	Process	
I0134	Project manager insufficiently instructed by the organization	Organization	
I0135	Project participants' unwillingness to share information	Stakeholders	Process
I0136	Lack of commitment to common goal	Process	
I0137	Project team participants putting their own goals before team goals	Organization	
I0138	Involvement of different layers of the project in decision-making (involvement is NOT influence)	Organization	
I0139	Trust in project management team	Organization	
E1 Staal-Ong, Kremers, Karlsson, & Baker, 2016			
E0101	Define objectives in interaction with stakeholders;	Stakeholders	Obj&scope
E0102	Formulate a vision	Obj&scope	
E0103	Translate objectives into scope, work packages and milestones;	Obj&scope	
E0104	Assess and authorise scope changes	Obj&scope	
E0105	Use configuration management to assess the impact of scope changes;	Obj&scope	

E0106	Implement a variation (scope change) procedure;	Obj&scope	
E0107	Organise adequate expertise to be able to deal with scope changes	Obj&scope	
E0108	Stakeholders are very important to project delivery organisations in terms of achieving the consents and approvals for work to commence	Stakeholders	Organization
E0109	An open approach to stakeholders helps build credibility of a project team	Stakeholders	
E0110	A proactive liaison with key influencers and obtainers of legal consents is essential	Stakeholders	Legal
E0111	Wide stakeholder support throughout the project is important for sustaining political support	Stakeholders	
E0112	Categorise stakeholders according to their impact on the project	Stakeholders	
E0113	Project branding gives the project a very clear identity	Obj&scope	
E0114	Sustaining the relationships and measuring the effectiveness of communication with stakeholders can yield strong benefits for a disproportionately low amount of time and expenditure.	Stakeholders	Process
E0115	Even though stakeholder management is a key to project success, still many projects fail or are extremely challenged by project stakeholders	Stakeholders	
E0116	The global request for considering sustainable development increases the need for project stakeholder management even more	Stakeholders	
E0117	Practitioners and researchers alike need a deeper understanding of how to practice stakeholder management to support benefits creation	Stakeholders	Process
E0118	Stakeholders are better organized	Stakeholders	
E0119	Stakeholder groups are becoming more vocal and are better informed	Stakeholders	
E0120	In some countries, stakeholders expect to be involved in the design process	Stakeholders	Obj&scope
E0121	Management of expectations is undervalued	Process	
E0122	The influence of new media	Technology	
E0123	The use of new media. Realistic and risk based communication with stakeholders is required	Risk/ext.	Technology
E0124	The European Commission focusses more on corridors rather than on individual projects	Risk/ext.	

E0125	There is an increasing need for (cross- border) cooperation	Risk/ext.	
E0126	Use proper calculations to support decision-making	Process	
E0127	Search for financing and funding possibilities	Resources	
E0128	Control costs and budget in relation to scope	Obj&scope	
E0129	It is essential that major infrastructure projects are properly defined against a specific output requirement and strategic purpose. Projects should be developed, assessed and prioritized in relation to the extent to which those defined outputs contribute to the solution of transport, economic or social problems	Obj&scope	
E0130	A clear set of appraisal guidelines for projects should be issued on a national or possibly a European basis so that effective comparisons can be made to inform choices of both priority and affordability. This would help mitigate the risk of projects proceeding because they were the particular 'babies' of certain politicians or parties;	Legal	Risk/ext.
E0131	A best practice relates to the use of levels of optimism bias, i.e. making an extra allowance in the appraisal to recognize that there are many elements at early stages of a project which have yet to be quantified or indeed identified. As the project proceeds and the levels of definition improve, the percentage of optimism bias is reduced, until, at the 'go ahead' stage, this is replaced by a risk margin within the overall project costs. It was a helpful practice in some projects to quote a price range at early stages of project development	Obj&scope	
E0132	Major Projects take many years to implement, usually much longer than the length of governments and a clarity of purpose and business case justification is vital if projects are not to be hampered by changes in government, either from a change of party or of key individuals. Equally, it is helpful to seek as much as possible "all party support" to ensure that the project is widely understood to be of national importance and is not a point of controversy between political groups	Stakeholders	Obj&scope
E0133	Several of the smaller projects studied formed part of a longer term strategic plan for development of a network of routes. This is best practice – the appraisal and consideration of a main network being completed enables an overall goal to be achieved in sections as affordability considerations allow	Stakeholders	

E0134	Clear project objectives, if defined at the early stage, can be very helpful for the project organization in defining design parameters and project specification as well as in undertaking consultation and staff communication	Organization	Obj&scope
E0135	The project objectives should be clearly translated into a functional output specification. The functional specification should be translated to required technical outputs, scope of work, work packages and milestones.	Obj&scope	
E0136	The roles of the client/sponsor and PDO need to be clearly defined and the interfaces between them correctly managed	Stakeholders	Organization
E0137	Tight arrangements should be in place for scope management and control;	Legal	Obj&scope
E0138	There needs to be an informed and aware client organization in place, with sufficient authority, resources and capability to lead the project	Resources	Organization
E0139	The client needs to be consistent and effective and should create the right framework for identifying and resolving issues.	Stakeholders	
E0140	Communication and stakeholder management should not be regarded as a separate function but should be fully integrated in the tasks of key project team members	Stakeholders	Process
E0141	The PDO should be tailored to meet the particular needs of the phase of the project	Stakeholders	
E0142	Project management is more than a technical construction process. Interface management should be a key part of mature project management	Process	
E0143	The project team should be aware of new threats, opportunities and changes during the implementation and delivery phases of the project when there is a natural tendency to be internally focused.	Risk/ext.	
E0144	Neglecting of the internal stakeholders, managing the project team, no linking of investor and contractors workforces, little consideration of employee satisfaction	Organization	
E0145	Lack of suitable training for sponsors and project teams for large projects	Organization	
E0146	Challenge of human resource retention near project completion	Resources	Organization

E0147	The soft skills and taking time for discussing together what is happening (principles of High Reliability Organizations)	Process	
E0148	Even though there are enough tools in place for scope, financial, risk, permits and quality management; the organizational aspects of managing team members is difficult in a project organization that is operating under a line organization that has been given a 20% redundancy target and forbids the contracting of external specialists. It is also challenging to form a team when team members all work part time on the project	Organization	
E0149	In line with the point above, the reorganizations of client organizations and the effects on projects;	Stakeholders	
E0150	The management of large infrastructure projects is often managed by technicians. We believe that one part that is undervalued is the organization and the people within the organization and how they are managed;	Organization	
E0151	Too little emphasis is given to the management of staff and people, their development and reward. In particular, in the UK civil service, staying with a project from start to end can be career limiting;	Organization	
E0152	The biggest challenge for the future is managing projects cooperating in new structures with other public governments.	Legal	Risk/ext.
E0153	Position the responsibility for risk analysis within an independent group	Risk/ext.	
E0154	Do not forget to identify opportunities	Risk/ext.	
E0155	Share risk analyses with contractors and before tendering	Organization	Risk/ext.
E0156	Include risks and risk reservations in cost estimations	Risk/ext.	
E0157	Use a risk database	Risk/ext.	
E0158	Rank and prioritize risks	Risk/ext.	
E0159	Make risk management part of regular management routines	Risk/ext.	
E0160	Effective budgeting needs to be linked to robust contract management	Resources	Legal
E0161	Contract and commercial interfaces need to be well managed in order to be able to understand where there are potential interactions and sources of delay	Legal	

E0162	Whatever the format of the contract (DB, DBFM, Alliance), care must be taken with the contract arrangement them- selves and in managing the execution of the work through the contract to avoid soaring costs and delivery progress delays	Legal	
E0163	The size and scope of contracts needs to be carefully considered so that they may be manageable and deliverable via the market and can attract appropriate competition, financial resources and specialists	Legal	
E0164	Prize should not be the key basis of awarding contracts. It is important that pre-defined and communicated criteria including capability and quality are part of the contract award process.	Legal	
E0165	Contract Managers should have adequate technical expertise for the management of the design of physical elements of project delivery	Legal	Technology
E0166	The PDO should be aware of currency exchange risks (if project contract prices or finances are based on different currencies) and interest rates where external funding is used to provide project financing. Price indexation arrangements should be clearly defined	Stakeholders	Resources
E0167	Effective budgeting and managing contract and commercial interfaces are examples of activities that have become regular project management practice, although interface management does seem to be deemed a challenge still by some delegates. As one delegates mentioned: contract incentives are now built into the contracts, helping to manage the contract better. Designing a contract approach or format to suit the project type is also now deemed normal. Prize is no longer the only basis on which contracts are awarded in LIPs and currency exchange risks and interest rate issues seem to be under control	Legal	Obj&scope
E0168	In cross-border projects it is essential to realize you are dealing with sometimes incompatible laws and regulations and the importance of understanding the differences in culture, institutions, laws and ways of working	Legal	Risk/ext.
E0169	It is important not to drive the project delivery too far ahead of obtaining full legal consents to progress the project	Legal	
E0170	The project team needs to identify and manage the risk of changes in ecological or environmental regulations and/ or legislation to avoid long planning delays	Legal	Safe/health

E0171	Land acquisition regulations especially in Eastern Europe need to be made more effective to make the planning and delivery of major projects more efficient.	Legal	
E0172	Link legal procedures and stakeholder management	Stakeholders	Legal
E0173	Map procedures and keep them updated	Legal	Process
E0174	Ensure legal expertise is available	Legal	
E0175	Communicate with authorities proactively	Legal	
E0176	Coordinate the consents and tenders planning	Legal	Process
E0177	There is little interest in learning from projects at a more advanced stage of completion or in passing on knowledge to other projects at earlier stages of development. Project teams relish the challenge in tackling problems which are new to their experience, rather than researching solutions from elsewhere	Organization	Process
E0178	Gains in cost, efficiency and delivery could be obtained from sharing experiences and knowledge	Process	
E0179	An understanding of how to translate another experience into the context of a different project is a key requirement	Process	
E0180	If new technology or innovation is implemented in the project, manage it as a separate project within project	Technology	
E0181	Too much time pressure to make an effort to share knowledge;	Process	
E0182	Using and transferring knowledge from and to other projects is not part of the project scope	Obj&scope	Process
E0183	False modesty about any innovations	Technology	
E0184	Absence of a bird's eye view over multiple projects with steering on inter project learning	Process	
E0185	Difficulties in bringing people together	Stakeholders	
E0186	People in this sector find it hard to learn from each other and tend to reinvent everything all over again when starting a new project;	Process	
E0187	In particular the choice of materials, innovation in solutions or in problem analysis;	Technology	
E0188	Knowledge and new technology (processes and technics) should be handled as a gift from a project to the client/ mother organization. Time and benefit to anchor these "presents" are mostly secondary targets in the organization	Technology	

E0189	Knowledge management and technology are both under- and overvalued. In the latter case some people have illogical faith in new technologies	Technology	Process
E2 Chan & Kumaraswamy, 2002			
E0201	Enhance the buildability of project design, by integrating early inputs of the contractor in the design phase;	Organization	Technology
E0202	Encourage standardization, modularization and repetition in the design of building elements and construction details;	Technology	Process
E0203	Maximize the mechanization of the construction process;	Technology	
E0204	An efficient and simple construction sequence;	Technology	
E0205	A set of technical recommendations applicable for the construction sector only (very specific)	Technology	
E0206	Ensure continuous workflow for each critical resource such as tower crane, large panel form-work, pumped concrete and any other related resources e.g. site laborers to facilitate a 4-day working cycle	Resources	
E0207	Improve the effectiveness of site management and supervision to ensure a coordinated workflow among all work trades. Close liaison among all contracting parties is essential	Organization	Process
E0208	Seriously consider the appropriateness in each project scenario of alternative innovative) procurement methods, e.g. fast-track, design-and- build and negotiated contracts, as well as a `partnering' approach	Legal	
E0209	Establish appropriate overall organizational structures and integrated information communication network systems across professional boundaries throughout the construction process	Organization	Process
E0210	Clearly define the roles and responsibilities of each project participant	Organization	Legal
E0211	Increase the co-ordination of the design and construction teams at the design-construction interface	Obj&scope	Process
E0212	Clearly identify and mobilize the designated decision-makers	Stakeholders	

E0213	Provide decision aids for decision-makers, e.g. construction management decision support systems, perhaps incorporating expert systems and simulation models	Stakeholders	Process
E0214	Provide training programs and formal education for industry practitioners to better foster communication management skills through using integrated management information systems and advanced information processing technology for promoting faster information flows among the project team members.	Organization	Process
E3 Amalraj & Doucet, 2007			
E0301	Quality assurance and quality control should be managed by the parent company, not by a third party or contractor	Stakeholders	Obj&scope
E0302	Parent company should review job specific contractor quality plan before starting the project	Stakeholders	
E0303	Type of contract is important: lump sum work should be held to a higher standard of quality control then reimbursable work	Legal	
E0304	In the tendering phase it should be clearly communicated that a higher standard is upheld for lump sum then reimbursable	Legal	
E0305	Contractors should respect the planning in order to reduce starting to early; which could result in rework	Obj&scope	
E0306	Changes in plans and what actually takes place in the field should communicated to order to remain consistent in terms of plans and realization (maintain scope)	Obj&scope	
E0307	Staff needs to be professionally qualified and should be familiar with local codes, project procedures and standards	Organization	Legal
E0308	Project estimates are lowered in order to get final project approval, while the estimates should be as accurate as possible	Resources	Obj&scope
E0309	Project control and project accounting should be involved from the very beginning	Process	
E0310	A system should be in place that tracks changes in scope and forecasts additional cost due to scope change	Obj&scope	
E0311	Project management team should have regular schedule updates in order to ensure effectiveness of project controls	Obj&scope	

E0312	Standardized reporting with consistent structure ensures that information is clear and unaffected by varying ways of tracking and reporting cost and schedule	Process	
E0313	Adequate managing subtasks in order to improve oversight and reduce costs	Organization	
E0314	Lack of competition on the contractors' side, which means the client is not getting the job done for the best price, schedule and safety	Stakeholders	Risk/ext.
E0315	Depending on the market and the project, the correct contract and remuneration scheme should be selected	Legal	
E0316	The managing company does not always have the same incentives as the client, which results in bad performance. Therefore the parent company should manage the project themselves	Stakeholders	Organization
E0317	Contractors often do not have sufficient (qualified) staff in order to execute large projects	Stakeholders	Resources
E0318	Having a clear and well-defined schedule at the outset of a project helps containing cost in the long run	Obj&scope	
E0319	Unnecessarily far stretched goals contribute to delays since it requires (unlikely) breakthroughs and abnormal productivity which could lead to failing quality or demotivated staff for not achieving goals	Obj&scope	
E0320	Over-ambitious goals can be used to reduce pressure on the schedule, but is likely to increase when the goals are not achieved	Obj&scope	
E0321	The quality of imported workforce put pressure on the schedule, requires pro-active management	Resources	Organization
E0322	Reduced availability of materials affect project schedule, requires pro-active management	Resources	
E0323	Significant coordination is necessary when building an operating plant on a construction site	Technology	
E0324	Workers unions should be handled strategically in order to avoid delays	Stakeholders	
E0325	In desolate locations workers should be provided temporary housing and access to basic need to ensure their satisfaction	Stakeholders	
E0326	Extreme weather condition can be anticipated on by building extra padding into the schedule	Risk/ext.	

E0327	Shadow communities (live in the vicinity of a large project) can cause housing problems, put pressure on healthcare system, facilities and infrastructures and pay no local taxes. This requires efforts by the parent company and municipality to avoid that the local community suffers from a large project.	Stakeholders	
K1 A. P. C. Chan & Chan, 2004			
K0101	Construction time	Obj&scope	
K0102	Speed of construction	Obj&scope	
K0103	Time variation	Obj&scope	
K0104	Unit cost	Obj&scope	
K0105	Percentage net variation over final cost	Obj&scope	
K0106	Net present value	Resources	Obj&scope
K0107	Accident rate	Safe/health	
K0108	Environment Impact Assessment (EIA) scores	Safe/health	
K0109	Quality	Obj&scope	
K0110	Functionality	Obj&scope	
K0111	End-user's satisfaction	Obj&scope	
K0112	Client's satisfaction	Obj&scope	
K0113	Design team's satisfaction	Organization	
K0114	Construction team's satisfaction	Stakeholders	Organization
K2 The KPI Working Group, 2000			
K0201	Time for Construction	Obj&scope	
K0202	Time Predictability – Design	Obj&scope	
K0203	Time Predictability – Construction	Obj&scope	
K0204	Time Predictability – Construction (Client change orders)	Stakeholders	
K0205	Time Predictability – Construction (Project Leader change orders)	Organization	
K0206	Time to Rectify Defects	Obj&scope	
K0207	Cost for Construction	Obj&scope	
K0208	Cost Predictability – Design	Obj&scope	
K0209	Cost Predictability – Construction	Obj&scope	
K0210	Cost Predictability – Construction (Client change orders)	Stakeholders	
K0211	Cost Predictability – Construction (Project Leader change orders)	Organization	

K0212	Cost of Rectifying Defects	Obj&scope	
K0213	Cost in use	Obj&scope	
K0214	Defects	Obj&scope	
K0215	Quality Issues at Available for Use	Obj&scope	
K0216	Quality Issues at End of Defect Rectification Period	Obj&scope	
K0217	Client Satisfaction Product – Standard Criteria	Obj&scope	
K0218	Client Satisfaction Service – Standard Criteria	Obj&scope	
K0219	Client Satisfaction – Client-Specified Criteria	Obj&scope	
K0220	Change Orders – Client	Stakeholders	
K0221	Change Orders – Project Manager	Organization	
K0222	Profitability (company)	Organization	
K0223	Productivity (company)	Organization	
K0224	Return on Investment (client)	Stakeholders	
K0225	Profit Predictability (project)	Obj&scope	
K0226	Repeat Business (company)	Organization	
K0227	Outstanding Money (project)	Resources	
K0228	Reportable Accidents (incl. fatalities)	Safe/health	
K0229	Reportable Accidents (non-fatal)	Safe/health	
K0230	Lost Time Accidents	Safe/health	
K0231	Fatalities	Safe/health	
K3 Ahmad, Svalestuen, Andersen, & Torp, 2016			
K0301	Construction Cost	Obj&scope	
K0302	Construction Time	Obj&scope	
K0303	Predictability Cost	Obj&scope	
K0304	Predictability Time	Obj&scope	
K0305	Defects	Obj&scope	
K0306	Client Satisfaction Product	Stakeholders	
K0307	Client Satisfaction Service	Stakeholders	
K0308	Safety	Safe/health	
K0309	Profitability	Organization	
K0310	Productivity	Organization	
K0311	Project Budget Factor	Obj&scope	
K0312	Project Cost Growth	Obj&scope	

K0313	Project Schedule Factor	Obj&scope	
K0314	Project Schedule Growth	Obj&scope	
K0315	Recordable Incident rate	Safe/health	
K0316	Lost work day case incident rate	Safe/health	
K0317	Change cost factor	Obj&scope	
K0318	Total field rework factor	Obj&scope	
K0319	Planning	Obj&scope	
K0320	Organizing	Organization	
K0321	Leading	Organization	
K0322	Controlling	Process	
K0323	Design Efficiency	Obj&scope	
K0324	Human Resources	Resources	
K0325	Quality	Obj&scope	
K0326	Sustainability	Safe/health	
K0327	Supply Chain	Stakeholders	
K0328	Safety	Safe/health	
K4 Ali, Al-Sulaihi, & Al-Gahtani, 2013			
K0401	Profitability	Organization	
K0402	Quality of service and work	Obj&scope	
K0403	Growth	Organization	
K0404	Financial stability	Resources	Organization
K0405	Cash flow	Resources	Organization
K0406	External customer satisfaction	Stakeholders	
K0407	Safety	Safe/health	
K0408	Business efficiency	Organization	
K0409	Market share	Organization	
K0410	Effectiveness of planning	Organization	
K0411	Labor efficiency	Organization	
K0412	Successful tenders rate	Organization	Legal
K0413	Organization competency in management human resources	Resources	Organization
K0414	Risk control	Risk/ext.	
K0415	Managers competency	Organization	
K0416	Partnership and suppliers	Stakeholders	

K0417	Reliability of financial performance	Resources	
K0418	Innovation	Technology	
K0419	Continuous improvement	Organization	
K0420	Productivity	Organization	
K0421	Policy or law of government	Legal	
K0422	Resource management	Resources	
K0423	Internal customer satisfaction	Organization	
K0424	Number of new customers	Organization	
K0425	Investors in people	Resources	
K0426	Capital	Resources	
K0427	Technological capability	Resources	Technology
K0428	Number of high-performance professionals	Organization	
K0429	Motivation	Organization	
K0430	Investment in development of new markets	Organization	
K0431	Human resource training and development	Resources	
K0432	Value of money	Resources	
K0433	Competitors	Stakeholders	Risk/ext.
K0434	Competitive price	Risk/ext.	
K0435	Quality control and rework	Obj&scope	
K0436	Informatization	Process	
K0437	Defects	Obj&scope	
K0438	Empowered work force	Organization	
K0439	Research and development	Organization	Technology
K0440	Hassle-free relationship	Stakeholders	
K0441	Interest cover	Resources	
K0442	Staff turnover	Organization	
K0443	Impact on society	Stakeholders	Safe/health
K0444	Waste	Safe/health	
K0445	Energy use	Safe/health	
K0446	Main water use	Safe/health	
K0447	Impact on biodiversity	Safe/health	

Table 38: Complete list of all factors with the categories

Appendix D: Expert Panel Workshop

This appendix contains the methodology, results and conclusions of the Expert Panel workshop. Before the Expert Panel workshop, a set of Control Indicators is formulated based on the exploratory interviews (4.1.2) and literature study (4.1.1). The combination of a basis consisting of both literature and empirical research should have resulted in CIs that resonate with experts from the field; a statement that is put to the test in the Expert Panel workshop. The Expert Panel (EP) workshop is designed to increase the input from professionals and validate the CIs formulated in 4.3. In addition to validating CIs, the EP also serves the purpose of gathering requirements for the preliminary design of the monitoring/feedback-system (described in chapter 5). In this appendix the methodology used to perform the EP is discussed along with the results, the conclusions and the abstractions (Table 41 and Table 44). Since only relevant remarks are noted, coherently rephrased and translated to English, this appendix refers to abstractions opposed to transcript (which is a literal report of what is said).

Methodology Expert Panel Workshop

The Expert Panel serves as validation of the first research question and as input for the second research question; the two goals of the EP are formulated as followed:

1. Receive feedback on and validation of the Control Indicators that are formulated based on the exploratory interviews and literature study.
2. Receive input on the requirements and preliminary design of the monitoring/feedback-system (MFS).

In order to reach these two goals, the workshop is divided in two parts. In part 1 the CIs are validated and in the second part the MFS is discussed. This way this workshop is conducted in a scientific methodological sound manner. The EP workshop is conducted at the PACER office in Utrecht where there are possibilities to film the workshop (which all panel members gave their consent on). The video material enables the workshop organizer to fully engage in the workshop without having to take notes. It also reduces ambiguity on remarks since it provides context for remarks made by panel members. Moreover, being able to examine the workshop multiple times reduces the chance of missing important remarks. The workshop is held in Dutch since all EP members are Dutch natives and switching to English would complicate the use of jargon. The Expert Panel Workshop is discussed in this section.

Preparing for the Expert Panel Workshop

The Expert Panel consists of project management professionals who are employed at PACER. In order improve the applicability of the CI, the six experts invited to the panel have different specializations and roles within project teams (and thus different perspectives). The quality of the EP depends on how participatory the experts are. In order to engage the experts and ensure high quality output, three measures have been taken:

- Inform beforehand
- Required homework/input for the meeting
- Introduction/presentation

Firstly, after the experts are approached and agreed to participate in the EP Workshop, they received an email a few days in advance with basic information such as the subject of the thesis, the location and planning of workshop and how long it will take. In addition to the practical information, they are briefed on KPIs and performance measuring in projects.

The second measure is taken to create commitment and 'force' the experts to think about performance measuring they are instructed to prepare the following 'homework':

> [Did you recently experience a process-related event during a project that had an unexpectedly bad or good impact on the project result? In hindsight, could this event have been foreseen? What indicators or signs can you think of (in hindsight) that this event would happen? What would you do in hindsight to prevent this from happening again]

This also creates engagement since people in general like to discuss their positive and negative experiences; they can relate to each other's experience since they are active in the same field of work.
The third and last measure to maximize the relevance of the output of the workshop for this research, is a presentation on this thesis that will update the EP to the required knowledge level and understanding of certain concepts. The presentation will cover the scope of research, the results thus far, an explanation of KPIs/CIs (and their difference), the monitoring/feedback-system and what the desired output is of the workshop. This way the efforts of the experts are maximized towards the goal of this thesis and the amount of irrelevant output is reduced.

The members of the expert panel were selected in line with their experience in the field. The roles of the panel members were as following: a contract manager, technical manager, environmental manager, systems engineer and two project controllers. Not every IPM-role was represented since not all roles are available within PACER; their experience with the IPM-role model allowed the experts to give insightful information nonetheless.

Part 1: Feedback on Control Indicators

The Control Indicators are derived from the dataset that is formed on basis of exploratory interview and literature study. As can be seen in Table 39, this part of the workshop is structured in six parts:

No	Activity	Goal
Introduction and discussion of 'homework' (14:00-14:10)		
1	Brainstorm (14:10-14:20)	The goal of this brainstorm is to identify possible Control Indicators. In order to structure the brainstorm a grid is made with the different IPM-roles (which can be explained if necessary) on the row and the PMBOK project phases in the columns. The possible CIs are written on post-its and pasted in the correct quadrant.
2	Discussion (14:20-14:30)	The results of the brainstorm and (dis)agreements are discussed, as well as a recap of the definition of CIs for the participants who had a different perception of what a CI is.
3	Presentation (14:30-14:35)	Ask whether the structure (grid: phase/role) used for the brainstorm is helpful and relevant. Show the CI that resulted from this research and explain how these are CIs
4	Discussion (14:35-14:45)	Receive feedback on the formulated CIs by asking the following questions: • Has any of you ever had experience monitoring these CIs? • Which ones do you think are the most important? • Having seen these CIs, do you think this list is missing some CIs?
5	Detailed feedback (14:45-14:55)	The 86 Control Indicators that have been formulated are divided over the panel members in sets of approximately 15 CIs. The CIs were accompanied with text regarding how they would be measured and how they are leading indicators. This way it is possible to receive feedback on all the unique CIs within the workshop.
6	Conclusion (14:55-15:00)	The first part of the workshop regarding the Control Indicators is concluded.
Break (15:00-15:10)		

Table 39: Structure of the first part of the workshop (Control Indicators)

The first part is divided into two brainstorm sessions to ensure that the first brainstorm is as unbiased as possible. Directly providing the EP with the results of the research could limit and 'color' their perception of CIs and force them immediately into a direction. During the second brainstorm session the EP is more informed on possible CIs. Ideally the EP should be as uninformed as possible to avoid biased answers, but there is a trade-off between to what extend the EP is unbiased and the output of the workshop is useful; completely uninformed experts could produce output irrelevant to this research, too much information could (unconsciously) create a bias towards the already formulated CIs and result in just a slight variation on these CIs.

Part 2: Monitoring/feedback-system

The results of the literature study conducted into the current practices of monitoring & controlling are described in 2.4. The literature study combined with information on monitoring from the interviews form the basis of the (preliminary) outlines of the monitoring/feedback-system (MFS). This part of the workshop provides feedback from the experts on the list of functional requirements and the first sketches of the MFS. The second part of the workshop follows the steps described in Table 40.

No	Activity	Goal
1	Presentation (15:10-15:15)	A brief presentation of the current monitoring & controlling practice and basic idea behind the monitoring/feedback-system.
2	Discussion (15:15-15:25)	The following questions are asked to spark a conversation: • Has anybody had their performance (actively) monitored? • Do you see any added value in monitoring CIs and being confronted with them?
3	Feedback (15:25-15-35)	Show the list of functional requirements and the outlines of the monitoring/feedback-system, including the following parameters: • How to monitor? Who is responsible for monitoring/ updating? • How often should you evaluate results or update the MFS? The EP is asked if these parameters sufficiently delineate the 'design space' or if they miss certain aspects.

4	Brainstorm (15:35-15:45)	The brainstorm will serve the purpose of obtaining new (functional) requirements or constraints of the MFS. It is structured using a whiteboard with a triangle on it; each corner has one theme: • Technical/operational (e.g. "Is the MFS an administrative burden?") • Managerial (e.g. "How to communicate negative values of the MFS?") • Human (e.g. "How do people feel about the MFS?") To structure the results from the brainstorm post-its are placed within the triangle near the appropriate themes. The content of the post-it's is not limited to just single words or concepts, but includes questions that come to mind, points of attention and additional requirements
5	Discussion (15:45-15:50)	Discuss the results of the brainstorm (what and why are the most discussed themes, what are possible pitfalls designing the MFS).
6	Evaluation (15:50-15:55)	The EP is asked whether they have any thought left to share on either the CIs or the MFS and if they have other suggestions, remarks, tips/tops regarding the workshop.
7	Conclusion (15:55-16:00)	The workshop is concluded and the EP is thanked for their cooperation.
End workshop		

Table 40: Structure of the second part of the workshop (Monitoring/feedback-system)

Results Expert Panel

The result of the Expert Panel is divided in the two parts and presented as followed: first the transcript of the key findings of part 1 is presented along with the goal of part 1. Secondly, the conclusions are drawn for the separate activities based on the results of the transcripts. After these conclusions a short summary and reflection is presented on how the meeting went and whether the set goals are achieved. The same is repeated for part 2.

The transcript is the result of viewing the video material of the workshop multiple times and extracting the relevant remarks. The workshop was held in Dutch and is translated to English to be included in the thesis. Therefore, the remarks are freely translated from the video footage. The EP workshop also resulted in findings that do not serve the goals formulated in advance but is worth discussed nonetheless. This information can be found in the discussion (section 6.1.3).

Part 1

The remarks are numbered and linked to results in Table 41 (the transcript). The conclusions based on the transcript are presented in Table 42. The Control Indicators that resulted from the Expert Panel are discussed in Table 43.

No.	Remark
1	Project was not running smooth, since a 'catalyzing force' was missing for scope management. The amount of change requests was low due to problems with the change request coordinator (incompetence).
2	Clarity on job responsibility was missing
3	Could Control Indicators be: lack of response, lack of interaction, missed deadlines, missing input from participants
4	Change request process is not functioning properly. Change request process is insufficiently enforced
5	How is the relationship between client and project manager
6	Are the people who have to use certain processes also the ones that come up with them? People who come up with processes have no connection to these processes resulting in a lack of support.
7	Measure trust among participants
8	Monthly evaluations and peer review and review processes. Not only values, but trends should also be measured.
9	Do the management/project teams match, are they compatible?
10	People do not stick to their roles in the task division. People always want to give their opinion, not one person is responsible.
11	Control Indicator could be: amount of 'signatures' required for decision on change requests. This should lead to clear responsibilities.
12	Most of problems stem from vagueness regarding tasks, authority and responsibilities
13	Building a matrix to link tasks, authority and responsibilities
14	Processes should be audited
15	Control Indicator could be assessing/rating processes people use (satisfaction with process).
16	Processes should be designed and standardized before people use it, else people come up with their own processes and this is hard to changes
17	Are all critical/crucial processes defined in advance?

Table 41: Transcript of important remarks from the part 1 of the workshop

The goal of the first part of the workshop is formulated as followed:

1. Receive feedback on and validation of the Control Indicators formulated based on the exploratory interviews and literature study.

The lines between the different activities of part 1 as scheduled (Table 39) were blurred and a natural discussion followed, while maintaining the general guidelines of the workshop.

The results of the activities are summarized and described in Table 42.

No	Activityivity	Conclusions (related to the transcript)
1	Homework, brainstorm and discussion	The panel members discussed several issues the encountered in projects. Most of these problems had to do with project participants that were either incompetent (1), did not communicate well or could not get along (5). Not all tasks in projects were assigned to somebody to bear the responsibility, resulting in work remaining undone and conflicts regarding who is responsible (2,10,12). This could be tackled with a task/authority/ responsibility –matrix containing the project participants and tasks to ensure that every task is linked to a participant (13). The EP also pointed out there was a variety of problems with processes: often certain processes were missing (17); processes were not enforced or tested before (4). Processes designed by people who had no experience in using the processes themselves were experienced as inadequate (6). It was suggested that processes are audited and rated by its users (14,15). As a problem was also mentioned that certain projects do not have the necessary (standardized) predefined processes in place, which lead to participants to start it doing it their own way which than in turn is hard to change (16). An EP member noted that is important to realize is a large discrepancy between the literature/project management in theory and the application in practice.
2	Validation	The expert panel members commented on the CIs that were handed to them. The feedback varied from tips regarding monitoring practices and (in)feasibility to practical applications or inconsistencies in their formulation. More detailed information on the results of the validation of the CIs can be found in appendix B. The CIs formulated on basis of the EP workshop can be found in Table 43.
Break		

Table 42: Expert panel activities and their conclusions (part 1)

Table 42: Expert panel activities and their conclusions (part 1) During and after the presentation questions were asked regarding what exactly the difference is between KPIs and CIs. After everybody was on the same page and understood what CIs were, one of the panel members described the diagnostic character of CIs using the following analogy: When driving in a car the CIs would fulfil the function of generic/high-level lights on a dashboard, which would indicate that it is time to look under the hood and investigate what is the cause is of the flashing light and to zoom in on this. This analogy showed that the EP clearly understood what the goal is of the CIs (and the MFS) and expressed that they could see the added value of such a system.

Control Indicators	Transcript no.
Rating processes	8
Process compliance	14
Frequency satisfactory progress reports	Written feedback
Trust among project participants	7
Number of missed deadlines (internal)	3
Number of missed deadlines (external)	3
Response time	3
Number of unanswered inquiries/ requests	3

Table 43: Control Indicators formulated based on the EP workshop

Reflection part 1

The goal of part 1 of the workshop is achieved: experts gave their professional opinion on the formulated CIs. Many of the problems they encountered in projects corresponded with ones from the literature and the problems mentioned by their colleagues during the exploratory interviews. More detailed information on the results of the expert panel can be found in appendix B.

Part 2

The goal of the second part of the workshop is formulated as followed:

- Receive input on the requirements and preliminary design of the monitoring/ feedback-system (MFS)

Like the first part of the workshop, the different activities of the second part of workshop were less distinct than planned. Nonetheless, enough structure was maintained in order to generate useful input for this thesis. Table 44 contains the transcript of the second part of the workshop. The conclusions of the activities are summarized and described in Table 45.

No.	Remark
1	KPIs have been monitored, but these were mainly (technical) project KPIs like biodiversity (different sector)
2	Measuring difference between design and realization in order measure the quality of the initial design
3	Rijkswaterstaat has a certain set of risks regarding processes they manage: process guided risk management.
4	Have monthly meetings in which the results of the Control Indicators are discussed
5	Difference between input and output: • CIs are input: (who should collect them, how are they going to be measured) • Dashboard is output: share trends and results with the management team Project manager is unlikely to measure in by him/herself, this should be clearly
6	Awareness of the MFS and realizing that it can contribute to project success is important. A form of engagement and realization should be present by project managers.
7	Who has access to the MFS and the data derived from monitoring the CIs? Is the project manager allowed to communicate this to higher levels of management or it solely for the purpose of improving the management team?
8	If the information is communicated to different layers of management, there should be clear rules on how CIs are monitored, which and when CIs are communicated since unstructured communication could lead to cherry picking of data (which in term could make the MFS/CIs susceptible for strategic behavior).
9	Explain the project team which purpose and goals the MFS/CIs serve in order to create support.
10	Transparency is a requirement for support
11	The MFS does not have as goal to check project team members; this should be communicated clearly.
12	The MFS with CIs should not become a political tool or document. Therefore, it should be transparent on what and which CIs are communicated.
13	Control Indicators or not hard facts, but 'indicators'
14	MFS could provide the project manager with a tool to come up with his own Control Indicator
15	It is crucial that the project management is committed to the MFS and monitoring the CIs
16	There is a fallacy that projects that are most in need of such a system (experiencing problems) are the least likely to adopt such a system

Table 44: Transcript of important remarks from the part 2 of the workshop

No	Activity	Conclusions (related to the transcript)
1	Discussing the statement	First the EP was asked whether they had their own performance or project performance monitored. In some instances, this was the case; the response varied from technical KPIs such as biodiversity **(1)** to amount of differences between plans and realization (to measure quality of the initial designs) **(2)**.
2	Discussing	Among the EP there was a consensus that support from the project participants is crucial for the MFS to be effective **(6,15)**. The added value of openness and participation in the system contributes to its effectiveness **(9)**. Transparency towards the participants is important to maintain support **(10)**. The results displayed by the MFS (derived from CIs) have to subject to strict and clear rules and purposes **(8)**. If the project manager is responsible for communicating the dashboard's results it should display the same CIs consequently in order to avoid cherry picking data **(8)**. The project managers should also be discrete with the information and should not use it to justify decisions towards higher management (or at least not without the consent of the project team) **(6,7,11)**. The results of the MFS should not be politicized by the project management (**12)**. These constraints on use of the information are necessary when the information collected from project team members is more personal. Other remarks included that every project manager has his/her own management style and that not every CI would fit in their MFS, so a tool or guidelines for formulating their own CIs could be helpful **(14)**. Commitment from the project management is important and the MFS should be enforced in order to work **(15)**.
End workshop		

Table 45: Expert panel activities and their conclusions (part 2)

At some point in the conversation one of the experts brought the comparison between a monitoring systems and Taylorism (industrial management). This type of performance measurement is associated with KPIs and the every growing need to become increasingly efficient. The association between performance measurement in this thesis and Taylorism is a sentiment that should avoided because it reinforces the 'big brother' – feelings of being monitored constantly. This is an important remark since is stresses one of the most essential requirements of the MFS: the participants will only be open and honestly participate in questionnaires or surveys when they acknowledge the added value and understand it is not designed to squeeze empty the project team members.

Reflection part 2

The goal of part 2 is largely achieved; it was not 100% clear to the expert panel what kind of input was expected. When presented with the parameters, trade-offs and examples the input improved and the discussion resulted in useful feedback. The notions of project team commitment/engagement, the use of the information (process improvement versus justification to higher management) and the different management styles are important takeaways.

Concluding, the Expert Panel workshop largely achieved its goal. The feedback on the Control Indicators was useful; it resulted in new CIs as well as changes to existing ones. Another finding regarding the CIs was that in order to perform a "real" validation of CIs, they should be tested in practice (more on this in section 6.1.3). The brainstorm on the MFS resulted interesting aspects of the information CIs collect, such as limitation to who the information can be communicated and strict rules and formats for the sharing of information to limit abuse.

Appendix E: Control Indicators

This appendix contains the definitive list of Control Indicators, divided in three tables: the first contains their code/IPM-roles and sources (Table 46), the second contains their QFD categories and attribute scores (Table 47) and the third table contains their suggested method of measurement and how they are leading (Table 48). The codes of the Control Indicators are based on their IPM-roles: PM is project manager, PB = project controller, CM = contract manager, TM = technical manager, OM = environmental manager. The sources indicate which factors form the basis of the Control Indicators. The complete list of factors can be found in Appendix C.

Code	Control Indicators	Sources
PM01	Clearly defined objectives formulated by the client	F0130 F0132 E0139
PM02	Relation project team with the client	F1307
PM03	Number of meetings with powerful stakeholders	E0110 F0704 F0711 C0707 C0709 C0714
PM04	Number of tasks/roles and responsibilities not delegated	F0205 E0210
PM05	Number of scope/contract meetings	I0115 E0137
PM06	Clients focus (within the iron triangle)	F0126 F0127 F0128

PM07	Number of mismatches between customer demands and functional requirements	C0304 C0305 I0111 E0135
PM08	Clear scope	C0902 F1003 F1015 C1001 F1304 F1604 F1705 I0114 C0905 E0102
PM09	Feasibility planning	F1005 I0121 E0305 E0308 E0319 E0320 E0131
PM10	Rating by the client (process)	K0218 K0402
PM11	Rating by the client (project in progress)	C0905 C0904
PM12	Qualifications personnel	C0802 F1023 F1033
PM13	Frequency of evaluations of project team members	C0410 F0602 F0604 F1026 C1010 F1322 I0110 I0122 I0137
PM14	Number of undertakings to improve team building	C0410 F0602 F0604 F1026 C1010 F1322 I0110 I0122 I0137
PM15	Number of changes in the project team	F1704 F1710
PM16	Number of (acknowledged) conflicts in a project	F0516 F0602 I0106 I0108
PM17	Number of conflict-resolving efforts	F0516 F0602 I0106
PM18	Conflict to conflict-resolve efforts ratio	F0516 F0602 I0106
PM19	Evaluation of social workings within the team	C0410 C0805 C1208 C1403 F1704 I0112 I0139 K0429 K0438
PM20	Differences between goals organization to project team	I0109 I0134
PM21	Evaluation project manager/project leadership	F0134 F0135 F0136 F0137 F0138 F0139 F0140 F0141 F0142 F0143 F0506 C0803 F0603 F1010 F1025 C1007 F1303 F1321 F1606 F1607 I0125 K0415
PM22	Evaluation organizational support to project team	F0144 I0109 I0134
PM23	Rating process and project from project team	F1316 I0109 I0110 I0138 E0144
PM24	Rating process and project from contractors	I0138 E0144 K0114
PM25	Rating process and project from organization	I0109 I0138 E0148

PM26	Rating teamwork among participants	C0410 F0602 F0604 F1026 C1010 F1322 I0110 I0122 I0137
PM27	Rating processes	EP01
PM28	Process compliance	EP02
PM29	Frequency satisfactory progress reports	EP03
PM30	Trust among project participants	EP04
PM31	Number of missed deadlines (internal)	EP05
PM32	Number of missed deadlines (external)	EP06
PM33	Response time	EP07
PM34	Number of unanswered inquiries/requests	EP08
PM35	Compatibility project team	I0122 EP
PB01	Number of budget/contract meetings	E0160
PB02	Number of risk meetings (internal)	F0202
PB03	Number of risk meetings (external)	F0201
PB04	Visibility risk register	F0203
PB05	Last update (date) risk register	F0204
PB06	Standardized risk management	F1012 E0159
PB07	Risk included in budget	E0156
PB08	Independence risk analyst	E0153
PB09	Existence of risk management database and plan	F1616 I0117
PB10	Mature scope change control process within organizations	F0207 E0106
PB11	Number of rescheduled activities	F0708
PB12	Cost of scope change	E0128 E0310
PB13	Assessment of scope control mechanism	C1401 I0113 E0137 83
PB14	Number of schedule updates	F1612 E0311
CM01	Rating of contractor	I0102 I0118 E0302 E0317
CM02	Contractor satisfaction	C1207 K0114 E0325
CM03	Contractor profitability	C0408 F1618 I0124
CM04	State of the market	F0507 E0314
CM05	Contract size/scope	E0163
CM06	Incentives in contracts	F1608 E0167 E0173 E0304 E0315
CM07	Technical knowledge contract managers	E0165

CM08	Contract type	F1313 I0103 I0119 I0129 E0303
CM09	Participants comply to contacts	E0161
CM10	Type of procurement	F0110 E0164 E0208
CM11	Ratio rework to work (time)	K0206 K0318
CM12	Ratio rework to work (cost)	K0212 K0317
CM13	Amount of defects	K0214 K0305 K0437
CM14	Number of feedback moments from executive layer to management	E0306
CM15	Number of change requests (client)	I0113
CM16	Number of change requests (contractors)	I0113
CM17	Total numbers of change requests	I0113
CM18	Number of accepted change requests	I0113
CM19	Number of rejected change requests	I0113
CM20	Independence quality control/audit	E0301
CM21	Attitude towards scope change	I0108 I0131 F1703
TM01	Client satisfaction (intermediate)	C0304 C1008 C1009 C1204 K0306
TM02	Number of minutes communicated/ consulted with client	C0905 C0908 F1008 C1008 C1009 C1302 F1028
TM03	Number of mistakes in plans and specifications	F0205 F1602
TM04	Number of (intermediate) verifications clients	F0709
TM05	Number of mismatches between functional requirements and technical specifications	C0305 C0306 I0111 E0135
TM06	Presence of a clear overview of functional and technical specifications	F1018 C1006 C1101 C1102 F1602
OM01	Environmental Impact Assessment	C0405
OM02	Clear goals in stakeholder communication	F1702 F1709 E0101 E0115 E0112 E0114
OM03	Frequency of residents/stakeholder updates (external updates environment)	F1709 I0104 E0140 E0111 E0115
OM04	Perceived impact on the residents/ surrounding community	C0411 C0408 F0517 K0443 E0327
OM05	Measured impact on the residents/ surrounding community	C0411 C0408 F0517 K0443 E0327

OM06	Number of open meetings for input for 'other' stakeholders	F1017 F1029 C1209 F1702 E0115 E0109
OM07	Goals formulated by stakeholders	F1003 F1015 C0710 C1001 F1702 I0116 I0132
OM08	Time spent on stakeholder management per change request	I0131
OM09	Number of permits timely acquired	E0169
OM10	Number of (timely) meetings with authorities	F1609 E0175 K0421
OM11	Presence of impact assessment	E0170
OM12	Commitment to standards and regulations	F1021 C1014
OM13	Completeness of regulations/legislation/ procedures overview	C1014 F1312 E0168 E0172 E0173 K0421 E0307
OM14	Available information regarding the project environment	EP09
OM15	Presence of an up-to-date stakeholder register	EP10
OM16	Amount of denied or delayed permits	EP11
OM17	Amount of preparatory research (timely) requested	EP12

Table 46: Control Indicators with their codes and sources

This table contains the scores of the attributes and categories of the Control Indicators assigned for the use of the Quality Function Deployments. The categories are defined as following: either L = qualitative or N = quantitative, and either H = human or P = project & process. The scores of the attributes are assigned on a scale from 1 to 5 (which is explained in section 5.3.1).

Code	Control Indicators	Cat	M (e)	M(t)	C	S(o)	R	S (p)
PM01	Clearly defined objectives formulated by the client	LH	1	5	3	2	2	1
PM02	Relation project team with the client	NH	2	4	2	2	2	1
PM03	Number of meetings with powerful stakeholders	NH	3	3	3	4	5	5
PM04	Number of tasks/roles and responsibilities not delegated	NP	3	3	3	3	4	5
PM05	Number of scope/contract meetings	NP	1	3	3	5	4	5
PM06	Clients focus (within the iron triangle)	LH	1	5	3	2	3	3
PM07	Number of mismatches between customer demands and functional requirements	NH	3	4	3	3	4	5
PM08	Clear scope	LP	1	4	3	5	3	5
PM09	Feasibility planning	LP	1	5	3	4	3	5
PM10	Rating by the client (process)	NH	2	3	3	2	2	1
PM11	Rating by the client (project in progress)	NH	2	3	3	2	2	1
PM12	Qualifications personnel	LH	3	5	1	2	2	1
PM13	Frequency of evaluations of project team members	NH	3	3	3	5	5	5
PM14	Number of undertakings to improve team building	NH	3	3	3	5	5	5
PM15	Number of changes in the project team	NH	3	3	3	3	5	5
PM16	Number of (acknowledged) conflicts in a project	NH	2	3	3	2	2	3

PM17	Number of conflict-resolving efforts	NH	2	3	3	2	2	4
PM18	Conflict to conflict-resolve efforts ratio	NH	3	3	3	2	1	5
PM19	Evaluation of social workings within the team	LH	2	3	3	2	3	1
PM20	Differences between goals organization to project team	LP	1	4	3	3	4	3
PM21	Evaluation project manager/project leadership	LH	1	4	2	3	3	1
PM22	Evaluation organizational support to project team	LP	1	4	2	3	4	1
PM23	Rating process and project from project team	NH	2	4	2	2	2	1
PM24	Rating process and project from contractors	NH	2	4	2	3	2	1
PM25	Rating process and project from organization	NH	2	4	2	2	2	1
PM26	Rating teamwork among participants	NH	2	4	2	3	2	1
PM27	Rating processes	NH	2	4	3	3	2	2
PM28	Process compliance	LP	1	4	3	3	4	5
PM29	Frequency satisfactory progress reports	NP	3	3	4	4	4	5
PM30	Trust among project participants	LH	2	4	2	2	1	1
PM31	Number of missed deadlines (internal)	NP	3	2	3	2	5	5
PM32	Number of missed deadlines (external)	NP	3	2	3	3	5	5
PM33	Response time	NP	3	2	3	4	5	5
PM34	Number of unanswered inquiries/requests	NP	3	2	3	3	5	5
PM35	Compatibility project team	NH	2	4	2	3	3	1
PB01	Number of budget/ contract meetings	NP	1	2	3	4	5	5
PB02	Number of risk meetings (internal)	NP	3	2	2	4	5	5

PB03	Number of risk meetings (external)	NP	3	2	3	4	5	5
PB04	Visibility risk register	LP	2	3	3	3	5	5
PB05	Last update (date) risk register	LP	3	2	3	3	5	5
PB06	Standardized risk management	LP	3	4	3	3	5	5
PB07	Risk included in budget	LP	3	5	3	3	5	5
PB08	Independence risk analyst	LP	2	5	3	3	5	5
PB09	Existence of risk management database and plan	LP	3	5	3	3	5	5
PB10	Mature scope change control process within organizations	LP	3	5	3	3	5	5
PB11	Number of rescheduled activities	NP	3	2	3	3	5	5
PB12	Cost of scope change	NP	3	3	3	3	5	5
PB13	Assessment of scope control mechanism	LP	3	3	3	4	5	5
PB14	Number of schedule updates	NP	3	2	3	4	5	5
CM01	Rating of contractor	NH	2	4	3	2	2	1
CM02	Contractor satisfaction	NH	2	4	3	2	1	1
CM03	Contractor profitability	LH	1	5	3	4	1	2
CM04	State of the market	LP	2	5	5	5	5	5
CM05	Contract size/scope	LP	1	5	3	2	5	5
CM06	Incentives in contracts	LP	1	5	3	3	5	5
CM07	Technical knowledge contract managers	LH	1	5	3	3	5	5
CM08	Contract type	LP	1	5	3	3	5	5
CM09	Participants comply to contacts	LH	1	4	3	3	5	3
CM10	Type of procurement	LP	3	5	3	3	5	5
CM11	Ratio rework to work (time)	NP	3	3	3	2	5	5
CM12	Ratio rework to work (cost)	NP	3	3	3	2	5	5
CM13	Amount of defects	NP	3	3	4	2	5	5

CM14	Number of feedback moments from executive layer to management	NH	3	4	4	3	5	5
CM15	Number of change requests (client)	NP	3	2	3	3	5	5
CM16	Number of change requests (contractors)	NP	3	2	3	3	5	5
CM17	Total numbers of change requests	NP	3	2	3	3	5	5
CM18	Number of accepted change requests	NP	3	2	3	3	5	5
CM19	Number of rejected change requests	NP	3	2	3	3	5	5
CM20	Independence quality control/audit	LP	1	5	3	3	3	5
CM21	Attitude towards scope change	LH	2	5	2	2	2	5
TM01	Client satisfaction (intermediate)	NH	1	3	3	2	2	1
TM02	Number of minutes communicated/consulted with client	NH	3	3	3	2	5	5
TM03	Number of mistakes in plans and specifications	NP	3	3	3	2	5	5
TM04	Number of (intermediate) verifications clients	NP	3	3	3	3	5	5
TM05	Number of mismatches between functional requirements and technical specifications	NP	3	3	3	2	5	5
TM06	Presence of a clear overview of functional and technical specifications	LP	3	3	3	3	5	5
OM01	Environmental Impact Assessment	LP	1	5	5	2	5	5
OM02	Clear goals in stakeholder communication	LH	3	5	4	2	4	2
OM03	Frequency of residents/ stakeholder updates (external updates environment)	NH	3	3	5	3	5	5

OM04	Perceived impact on the residents/surrounding community	LH	2	3	4	2	1	1
OM05	Measured impact on the residents/surrounding community	NH	1	3	4	2	5	5
OM06	Number of open meetings for input for 'other' stakeholders	NH	3	4	5	3	5	5
OM07	Goals formulated by stakeholders	LH	1	5	3	3	3	1
OM08	Time spent on stakeholder management per change request	NH	3	2	3	4	5	5
OM09	Number of permits timely acquired	NP	3	2	3	3	5	5
OM10	Number of (timely) meetings with authorities	NH	3	2	3	3	5	5
OM11	Presence of impact assessment	LP	3	5	3	2	5	5
OM12	Commitment to standards and regulations	NP	3	2	3	2	5	5
OM13	Completeness of regulations/legislation/ procedures overview	LP	3	4	3	3	5	5
OM14	Available information regarding the project environment	LP	3	3	3	3	5	5
OM15	Presence of an up-to-date stakeholder register	LH	3	3	3	3	5	5
OM16	Amount of denied or delayed permits	NP	3	2	3	3	5	5
OM17	Amount of preparatory research (timely) requested	NP	3	2	3	3	5	5

Table 47: Control Indicators with their categories and attribute scores

Code	Control Indicators	How to measure?	How is the CI leading?
PM01	Clearly defined objectives formulated by the client	Interview client	Formulated objectives reduces indecisiveness and stimulates communication
PM02	Relation project team with the client	Client rates the team and vice versa	Negative ratings could expose problems, acting on these ratings could expose the underlying problems
PM03	Number of meetings with powerful stakeholders	Track the frequency of meetings with powerful stakeholders	A low number of meetings could indicate that powerful stakeholders are not on board with the project and cause delays later on
PM04	Number of tasks/roles and responsibilities not delegated	Assign all the responsibilities/work packages/tasks to all the involved parties	If there are more tasks than assigned to project participants, nobody is responsible which results in uncompleted task or legal conflicts
PM05	Number of scope/ contract meetings	Audit by contract expert	Since contracts are binding, contracts have to be updated for scope changes
PM06	Clients focus (within the iron triangle)	Meeting with client	If the project team is up-to-date on the client's priorities, the goals of the client are clearer: does it matter when it's done, or should it be a cheap as possible)
PM07	Number of mismatches between customer demands and functional requirements	Compare customer demands to functional requirements using a matrix	Mismatches expose either missing functionalities or unnecessary requirements
PM08	Clear scope	Have the project team explain the goal and objectives back to the client	If the project team is not able to communicate the goal and objectives to the client, there already is an ambiguity on the scope
PM09	Feasibility planning	Project team could compare the project to similar projects or prior experiences	An infeasible planning can discourage project participants, create unrealistic expectations and cause contractors to stop abiding to the schedule
PM10	Rating by the client (process)	Survey among clients	If the client is not satisfied with the process it might have to do with mismatch in scope/goal or overruns in time/budget

PM11	Rating by the client (project in progress)	Survey among clients	Intermediate consultation with the client on the progress of the plan and schedule could help create understanding of the project and possible issues
PM12	Qualifications personnel	Compare official qualifications or professional experience to the job requirements	Insufficiently qualified or experienced personnel could negatively affect the project
PM13	Frequency of evaluations of project team members	Track the amount of evaluations	Skipped evaluations could leave problems unexposed which in the end could affect the project
PM14	Number of undertakings to improve team building	Track the numbers of undertakings	Teambuilding improves openness in communication, aligns goals creates engagement and commitment
PM15	Number of changes in the project team	Track the changes since the start of the project	High amounts of changes could indicate conflicts or problems with sharing information, since changing creates new interfaces (old to new, maybe lost information from earlier phases)
PM16	Number of (acknowledged) conflicts in a project	Survey within project team	Conflicts appear in most projects, acknowledging them is the first step to reduce conflicts that cause the project to suffer
PM17	Number of conflict-resolving efforts	Survey within project team	Efforts to resolve conflicts indicates that there are conflicts, but they are acknowledged and worked on
PM18	Conflict to conflict-resolve efforts ratio	Conflict resolve efforts /conflicts	A high amount of resolved conflicts should indicate that there is a small amount of conflicts
PM19	Evaluation of social workings within the team	Survey within project team	This is a function of trust, motivation, ambiance, satisfaction and engagement; scoring high on these factors contribute to openness and effectiveness
PM20	Differences between goals organization to project team	Discuss with organization management	Difference in goals could result in a project achieving the wrong goals or feeling uninformed

PM21	Evaluation project manager/project leadership	Survey/evaluate the project manager or leadership	Since the project manager is one of the most reoccurring factor influencing success, management should be effective
PM22	Evaluation organizational support to project team	Survey project team / discuss in meetings	Negative evaluation of the project organization could be the cause of lack of resources or information, both necessary for reaching project management success
PM23	Rating process and project from project team	Survey project team / discuss in meetings	Project participants unsatisfied with the project or process could indicate friction, tension, problems or goal misalignment
PM24	Rating process and project from contractors	Survey contractors / discuss in meetings	Project participants unsatisfied with the project or process could indicate tension, unrealistic goals, narrow margins or poor coordination
PM25	Rating process and project from organization	Survey higher management / discuss in meetings	Organizations unsatisfied with the project or process could be the cause of poor communication or lacking coordination and competence
PM26	Rating teamwork among participants	Survey among the project team / discuss in meetings	Participants receiving or giving low ratings could indicate conflict or poor performance of participants
PM27	Rating processes	Survey among process users	Low rating or inadequate processes could indicate that the goals the processes serve are inadequately achieved
PM28	Process compliance	Audit processes	If certain processes are not being complied might be an indication that these processes are not adequate or participants are not fulfilling their tasks as expected
PM29	Frequency satisfactory progress reports	Monitor project control through demanding progress reports on regular intervals	Missing/too low frequency or satisfactory progress reports could indicate underperforming contractors
PM30	Trust among project participants	Survey among project participants	A lack of trust among project participants could indicate misinformation, strategic behavior and incompetence

PM31	Number of missed deadlines (internal)	Track the amount of missed deadlines of project team members	A high amount of missed deadlines could indicate too much work on certain project team members or incompetence. A sudden increase could stem from personal problems or an unexpected difficult task
PM32	Number of missed deadlines (external)	Track the amount of missed deadlines of contractors or other stakeholders	A high amount of missed deadlines could indicate too much work on certain contractors or incompetence. A sudden increase could stem from(financial/managerial) problems or an unexpected difficult task
PM33	Response time	Track time between contact and reaction	High response times could indicate overworked project team members, uncooperative contractors or incomplete information of the other party
PM34	Number of unanswered inquiries/ requests	Track the amount of times contacted parties do not respond	A high number of unresponsiveness could indicate parties need more time, are not finished with a task, do not have all information needed or indicate a 'needy' project participant
PM35	Compatibility project team	Perform personality test or survey with the project team	The test results could give an impression of which personalities and roles are more likely to get into conflicts then others
PB01	Number of budget/ contract meetings	Audit by contract expert	Effective budgeting needs to be linked to contract management
PB02	Number of risk meetings (internal)	Track the amount of risk meetings on the project (project team)	Risk meetings are important for dealing with unexpected situations
PB03	Number of risk meetings (external)	Track the amount of risk meetings from the organization	Risk meetings are important for dealing with unexpected situations
PB04	Visibility risk register	Surveys among project team members / contractors	Visibility contributes to the communication of the risks across the project participants, making them aware
PB05	Last update (date) risk register	Track the updates of the risk register	An up-to-date risk register shows that risks are actively managed

PB06	Standardized risk management	Consult project team or project organization if it is available	Having an (organizational) standardized risk management approach could reduce risks being overlooked
PB07	Risk included in budget	Find out if risks are included in budget through financial experts	If risk is included in cost estimates, projects are more resilient for financial set backs
PB08	Independence risk analyst	Does the risk analyst benefit from under/ over estimating risks?	Unnecessary risk mitigation is expensive just as insufficient risk coverage can be; therefore the risk analysis needs to be unbiased
PB09	Existence of risk management database and plan	Consult project team if one is made	Having a project controller develop and maintain a risk register including allocation in order to have an oversight of the possible risks
PB10	Mature scope change control process within organizations	Inquire whether the (project) organization has a scope change control process in place that is used before	Having experience with dealing with scope changes is a large advantage since a clear scope is named as one of the success factors in project management success (as seen in this list)
PB11	Number of rescheduled activities	Compare the original schedule with the adjusted schedule	If the reasons for rescheduling are not valid, there might be causes to this that could affect the rest of the project
PB12	Cost of scope change	Measure baseline budget versus the cost of scope change	If in the early stage of a project costs due scope change are already high, reassessment of the budget and scope is necessary
PB13	Assessment of scope control mechanism	Measure the (average) their lead time of change requests; along with a rating how their handling is experienced	If the scope control mechanism is performing poorly, the scope will blur and problems regarding contracts and responsibilities will emerge
PB14	Number of schedule updates	Track the amount of schedule updates	Failing to provide schedule updates could indicate that the project is already delaying
CM01	Rating of contractor	Experience of project team/organization	Low contractor rating might result in extra risk mitigation (closer monitoring or insurance), are the contractors solution-or contract-oriented

CM02	Contractor satisfaction	Surveys among contractors	Contractors satisfaction exposes negative or positive sentiments that can be discussed
CM03	Contractor profitability	Interview contractors	Contractors who profit from projects are more likely to reach a common goal instead of cutting costs everywhere possible
CM04	State of the market	Obtainable from CBS	Insufficient competition on the market could result in high prices or low quality
CM05	Contract size/scope	Audit by contract expert	The size/scope of the contract should be manageable: if the contract is too large it will not attract appropriate competition
CM06	Incentives in contracts	Audit by contract expert	Including incentives in contracts helps managing contracts better
CM07	Technical knowledge contract managers	Test knowledge contract managers	Contract managers should have sufficient technical knowledge in order to formulate effective contracts
CM08	Contract type	Audit by contract expert	Different types of contract have different consequences for how contractors/parties will behave
CM09	Participants comply to contacts	Audit participants	Failing to comply with contracts can result in delays or unsatisfied requirements
CM10	Type of procurement	Provided from the project organization	Procurement method could tell something about how contractors/supplier will earn money
CM11	Ratio rework to work (time)	Divide rework hours to work hours	If there is a (unexpected) high ratio of rework to work, this could indicate unclear scope, narrow/limited contracts or other underlying causes that should be discussed
CM12	Ratio rework to work (cost)	Divide rework cost to work cost	If there is a (unexpected) high ratio of rework to work, this could indicate unclear scope, narrow/limited contracts or other underlying causes that should be discussed
CM13	Amount of defects	Track the amount of defects	Defects could indicate problems with contractors, which in turn could result in poor quality

CM14	Number of feedback moments from executive layer to management	Require regular updates from executive layer to management on what/ how is done	This feedback creates confidence in the job done at the executing level and serves as early indicator whether work packages will be completed in time or not
CM15	Number of change requests (client)	Track the amount of change requests from the client	A high amount could indicate that the client is stretching the content of contracts and tries to get more then paid for
CM16	Number of change requests (contractors)	Track the amount of change requests from contractors	A high amount of change requests could indicate that the original plans were inadequate or infeasible. It also could indicate that contractors try to make money through change requests
CM17	Total numbers of change requests	Track the amount of change requests	The amount of change requests is an indicator to what extent the scope shifts away from the baseline
CM18	Number of accepted change requests	Track the amount of accepted change requests	A high amount of accepted change requests could indicate that is a lot of ambiguity in contracts or that the process for change requests not rigorous enough
CM19	Number of rejected change requests	Track the amount of rejected change requests	A high amount of rejected change request could indicate a very demanding client
CM20	Independence quality control/audit	Audit by independent party	The lack of independent quality control/audit could create an environment where contractors could underperform
CM21	Attitude towards scope change	Survey within the project team	Having a negative attitude towards scope change can cause a fixation on scope; a too lax attitude could allow scope creep
TM01	Client satisfaction (intermediate)	Interview client	If the customer is not satisfied, this could indicate that the objectives are not met or the specifications are not correct
TM02	Number of minutes communicated/ consulted with client	Project management tracks time of meetings	Too little communication could result in (the perception) of too few involvement or acceptance of the client

TM03	Number of mistakes in plans and specifications	Track the amount of mistakes in the plans and specifications	A high number of mistakes in the plans and specifications could be a symptom of careless planning. If certain aspects contain more mistakes than others, then they should be examined closer.
TM04	Number of (intermediate) verifications clients	Compare output to specifications and quality standards	Timely noticing problems with the realization of specifications can get participants communicating again; early noticing quality issues reduces rework
TM05	Number of mismatches between functional requirements and technical specifications	Compare functional requirements to technical specifications using a matrix	Mismatches expose either unnecessary specifications or missing functionalities
TM06	Presence of a clear overview of functional and technical specifications	Verification: compare each step to the succeeding one: 1) articulated vision, goals and objectives translated to 2) functional requirements translated into 3) technical specifications 4) realized in practice	Mismatches expose flaws in the different steps of translation
OM01	Environmental Impact Assessment	Environmental Impact Assessment	The negative outcome of the EIA could harm the project due to appeals of residents or damaging the client reputation
OM02	Clear goals in stakeholder communication	Set targets what it to be achieved through stakeholder communication	Being able to formulate clear goals in stakeholder communication could indicate that there has been sufficient research into the needs of different stakeholders (residents, contractors, municipality)
OM03	Frequency of residents/stakeholder updates (external updates environment)	Track the frequency of updates	Regular updates are an indication of sufficient awareness of the environment and could trigger (positive/negative) feedback from the environment (what can be acted upon)

OM04	Perceived impact on the residents/ surrounding community	Surveys	Indicates the necessity to reduce perceived impact in order to reduce appeals or other resistance
OM05	Measured impact on the residents/ surrounding community	Sound/environmental/ traffic nuisance	Provides objective measurements to what extend the surrounding community experience nuisance
OM06	Number of open meetings for input for 'other' stakeholders	Track number of these meetings	Openness in the project reduces feelings of distrust of stakeholders or residents
OM07	Goals formulated by stakeholders	Organize (separate) meetings with stakeholders	Noticing diverging goals could expose tension between stakeholders or common goals could improve cooperation; mutual exclusive goals could indicate problems (later on) in the project
OM08	Time spent on stakeholder management per change request	Track the time it costs before stakeholders agree on change requests	The time spent on a change request could indicate different things: too much time delays the project and requires streamlining; too little time could result in unwanted scope creep
OM09	Number of permits timely acquired	Track the amount required permits and the amount of permits acquired	If no permits have been requested or acquired this could indicate that the task of requesting permits is not being executed or that the client is not fully aware of the implications of his own project and could result in delay
OM10	Number of (timely) meetings with authorities	Track meetings with authorities	Consent and support from authorities is important to reduce delays
OM11	Presence of impact assessment	Check whether the responsible person requested the assessment	There needs to be an oversight of ecological/environmental regulations and legislations in order to avoid problems with permits or emissions
OM12	Commitment to standards and regulations	Compare required standards and regulations to the satisfied standards and regulations	Not committing to regulations could be an indication of people trying to make money at the expensive of others

OM13	Completeness of regulations/legislation/ procedures overview	Analysis of legal and regulatory environment	Failing to sufficiently analyzing the legal and regulatory context could result in refused permits, appeals and delays
OM14	Available information regarding the project environment	Check whether the information is requested and available to the project team	Lack of availability could stem from the fact that the information has not yet been requested/ research not conducted. The availability benefits other project team members who can also use the information (technical information about the acreage, soil, water)
OM15	Presence of an up-to-date stakeholder register	Frequently update the stakeholder register	Not regularly updated stakeholder files could indicate that stakeholder research and communication does not happen (anymore) or that the results not being communicated to the team
OM16	Amount of denied or delayed permits	Track the amount of denied or delayed permits	A high amount of denied or delayed permits may indicate confusion about responsibility, municipalities/governments are not cooperation or residents are obstructing (appeal)
OM17	Amount of preparatory research (timely) requested	Track the amount of preparatory research requested	A low amount of (timely) requested could indicate that environmental managers are incompetent, the responsibility is not delegated sufficiently or the research is being obstructed

Table 48: Control Indicators with how they should be measured and in what way they are leading

Appendix F: Quality Function Deployments

This appendix serves two purposes: display the four Quality Function Deployments that are used to support the selection of Control Indicators and illustrating the difference in output for two different project managers.

It has to be noted that the scores of Control Indicators on the attributes is not adjusted for organizational properties; this is possible, but not within the scope of this thesis. Therefore, it is possible that certain CIs score high on both project manager profiles.

Project manager 1

This project manager is mainly interested in quantitative data; therefore, measurability of qualitative data has high weight factors (Figure 48 and Figure 49). Since quantitative data is important for providing data to his superiors, the measurability of quantitative data is less important (Figure 50 and Figure 51). This is also the reason that the quantitative data should have higher communicability than the qualitative data. Quantitative/process&project data is expected to be completely subjective and therefore the reliability weight factor is '1'; quantitative/human and qualitative/process&project are both not completely objective and are assigned a '5'. The qualitative/human data category is too sensitive for manipulation in his opinion and therefore the data is assigned a '10' to reduce human bias within the data.

Qualitative/Human															
Clearly defined objectives formulated by the client	PM01														
Clients focus (within the iron triangle)	PM06	B													
Qualifications personnel	PM12														
Evaluation of social workings within the team	PM19														
Evaluation project manager/project leadership	PM21				A										
Trust among project participants	PM30														
Contractor profitability	CM03														
Technical knowledge contract managers	CM07			C											
Participants comply to contacts	CM09						A								
Attitude towards scope change	CM21														
Clear goals in stakeholder communication	OM02														
Perceived impact on the residents/surrounding community	OM04														
Goals formulated by stakeholders	OM07											A	A		
Presence of an up-to-date stakeholder register	OM15														

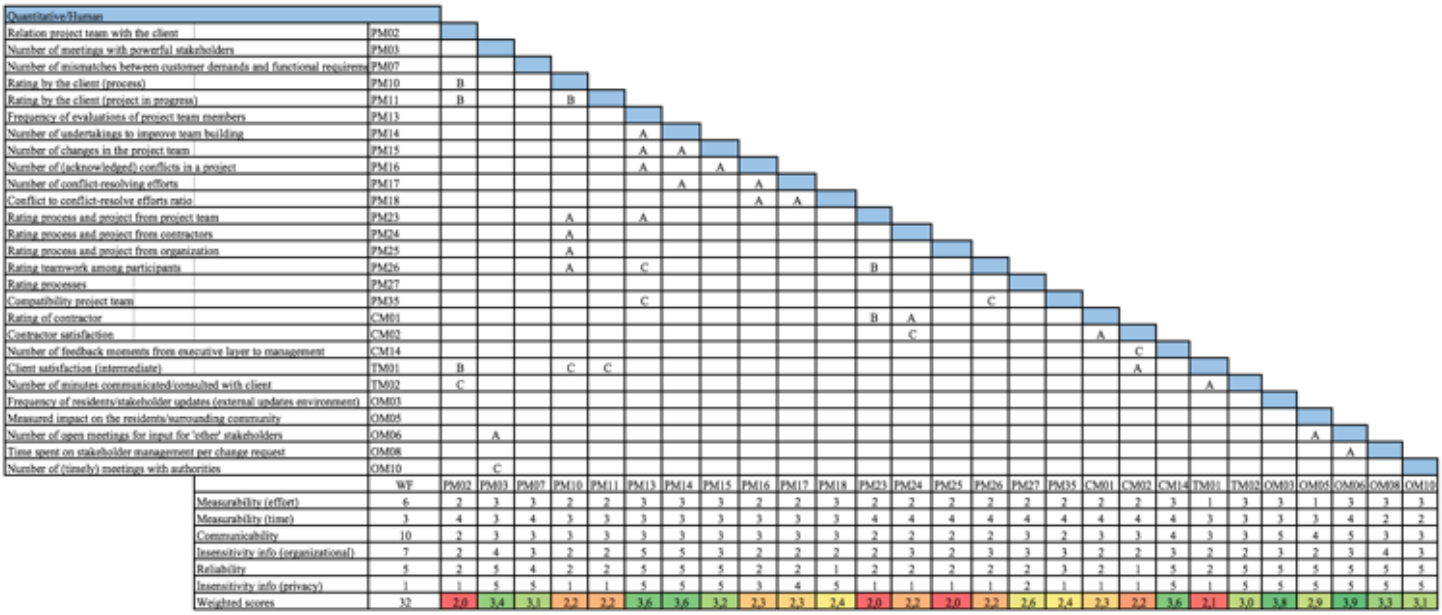
	WF	PM01	PM06	PM12	PM19	PM21	PM30	CM03	CM07	CM09	CM21	OM02	OM04	OM07	OM15
Measurability (effort)	10	1	1	3	2	1	2	1	1	1	2	3	2	1	3
Measurability (time)	3	5	5	5	3	4	4	5	5	4	5	5	3	5	3
Communicability	8	3	3	1	3	2	2	3	3	3	2	4	4	3	3
Insensitivity info (organizational)	10	2	2	2	2	3	2	4	3	3	2	2	2	3	3
Reliability	10	2	3	2	3	3	1	1	5	5	2	4	1	3	5
Insensitivity info (privacy)	1	1	3	1	1	1	1	2	5	3	5	2	1	1	5
Weighted scores	42	2,1	2,4	2,2	2,5	2,4	1,9	2,4	3,2	3,1	2,3	3,3	2,2	2,6	3,5

Figure 48: Project manager 1, Quality Function Deployment with the category qualitative/ human

Qualitative /Process&Project																										
Clear scope	PM08																									
Feasibility planning	PM09																									
Differences between goals organization to project team	PM20																									
Evaluation organizational support to project team	PM22			A																						
Process compliance	PM28																									
Visibility risk register	PB04																									
Last update (date) risk register	PB05					A																				
Standardized risk management	PB06				A																					
Risk included in budget	PB07																									
Independence risk analist	PB08																									
Existence of risk management database and plan	PB09					A		C																		
Mature scope change control process within organizations	PB10							A				A														
Assessment of scope control mechanism	PB13				C								C													
State of the market	CM04																									
Contract size/scope	CM05															B										
Incentives in contracts	CM06															B	B									
Contract type	CM08																									
Type of procurement	CM10																									
Independence quality control/audit	CM20				A						A															
Presence of a clear overview of functional and technical specifications	TM06																									
Environmental Impact Assessment	OM01																									
Presence of impact assessment	OM11																									
Completeness of regulations/legislation/procedures overview	OM13																									
Available information regarding the project environment	OM14																									

	WF	PM08	PM09	PM20	PM22	PM28	PB04	PB05	PB06	PB07	PB08	PB09	PB10	PB13	CM04	CM05	CM06	CM08	CM10	CM20	TM06	OM01	OM11	OM13	OM14
Measurability (effort)	10	1	1	1	1	1	2	3	3	3	2	3	3	3	2	1	1	1	3	1	3	1	3	3	3
Measurability (time)	3	4	5	4	4	4	3	2	4	5	5	5	5	3	5	5	5	5	5	5	3	5	5	4	3
Communicability	8	3	3	3	2	3	3	3	3	3	3	3	3	3	5	3	3	3	3	3	3	5	3	3	3
Insensitivity info (organizational)	7	5	4	3	3	3	3	3	3	3	3	3	3	4	5	2	3	3	3	3	3	2	2	3	3
Reliability	5	3	3	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5
Insensitivity info (privacy)	1	5	5	3	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Weighted scores	34	3,0	2,9	2,6	2,4	2,7	3,1	3,3	3,4	3,5	3,2	3,5	3,5	3,6	4,1	2,7	2,9	2,9	3,5	2,6	3,4	3,2	3,3	3,4	3,4

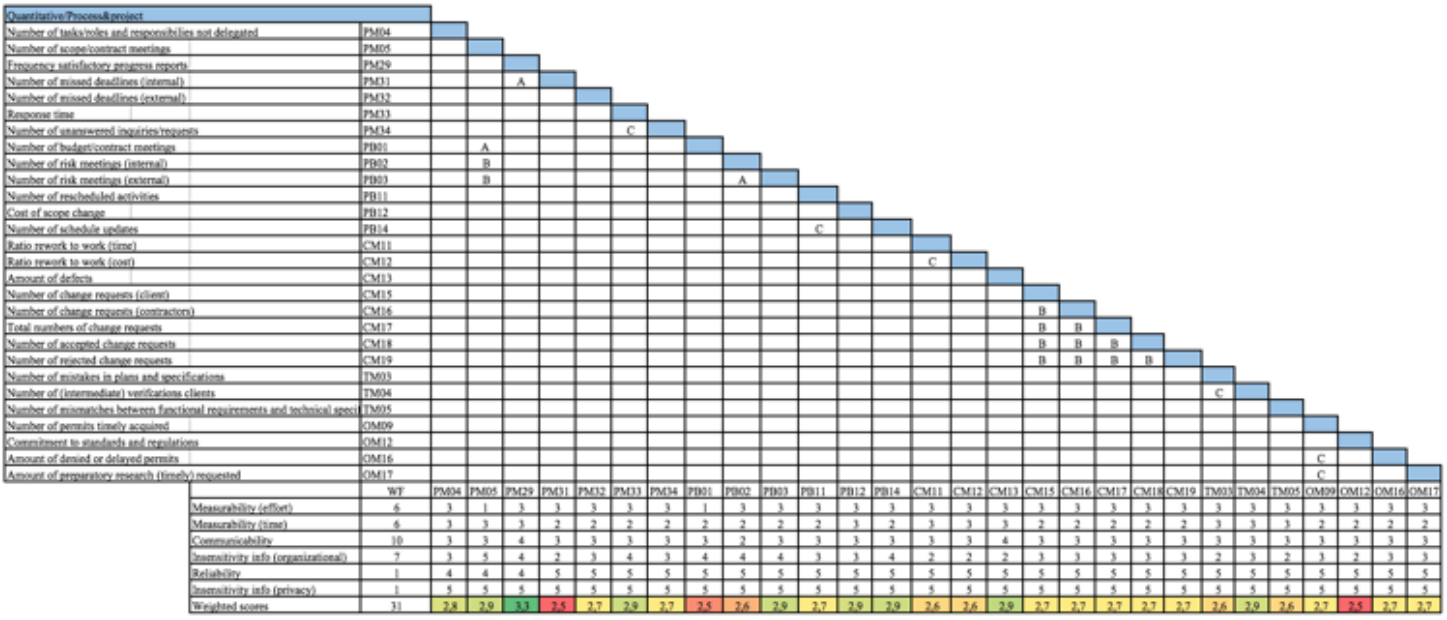
Figure 49: Project manager 1, Quality Function Deployment with the category qualitative/ process&project



Quantitative/Human																											
Relation project team with the client	PM02																										
Number of meetings with powerful stakeholders	PM03																										
Number of mismatches between customer demands and functional requirem	PM07																										
Rating by the client (process)	PM10	B																									
Rating by the client (project in progress)	PM11	B			B																						
Frequency of evaluations of project team members	PM13																										
Number of undertakings to improve team building	PM14						A																				
Number of changes in the project team	PM15						A	A																			
Number of (acknowledged) conflicts in a project	PM16						A		A																		
Number of conflict-resolving efforts	PM17							A		A																	
Conflict to conflict-resolve efforts ratio	PM18									A	A																
Rating process and project from project team	PM23				A		A																				
Rating process and project from contractors	PM24				A																						
Rating process and project from organization	PM25				A																						
Rating teamwork among participants	PM26				A		C						B														
Rating processes	PM27																										
Compatibility project team	PM35						C									C											
Rating of contractor	CM01												B	A													
Contractor satisfaction	CM02													C					A								
Number of feedback moments from executive layer to management	CM14																			C							
Client satisfaction (intermediate)	TM01	B			C	C															A						
Number of minutes communicated/consulted with client	TM02	C																				A					
Frequency of residents/stakeholder updates (external updates environment)	OM03																										
Measured impact on the residents/surrounding community	OM05																										
Number of open meetings for input for 'other' stakeholders	OM06		A																						A		
Time spent on stakeholder management per change request	OM08																									A	
Number of (timely) meetings with authorities	OM10		C																								

	WF	PM02	PM03	PM07	PM10	PM11	PM13	PM14	PM15	PM16	PM17	PM18	PM23	PM24	PM25	PM26	PM27	PM35	CM01	CM02	CM14	TM01	TM02	OM03	OM05	OM06	OM08	OM10
Measurability (effort)	6	2	3	3	2	2	3	3	3	2	2	3	2	2	2	2	2	2	2	2	3	1	3	3	1	3	3	3
Measurability (time)	3	4	3	4	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	3	3	3	3	4	2	2
Communicability	10	2	3	3	3	3	3	3	3	3	3	3	2	2	2	2	3	2	3	3	4	3	3	5	4	5	3	3
Insensitivity info (organizational)	7	2	4	3	2	2	5	5	3	2	2	2	2	3	2	3	3	3	2	2	3	2	2	3	2	3	4	3
Reliability	5	2	5	4	2	2	5	5	5	2	2	1	2	2	2	2	2	3	2	1	5	2	5	5	5	5	5	5
Insensitivity info (privacy)	1	1	5	5	1	1	5	5	5	3	4	5	1	1	1	1	2	1	1	1	5	1	5	5	5	5	5	5
Weighted scores	32	2,0	3,4	3,1	2,2	2,2	3,6	3,6	3,2	2,3	2,3	2,4	2,0	2,2	2,0	2,2	2,6	2,4	2,3	2,2	3,6	2,1	3,0	3,8	2,9	3,9	3,3	3,1

Figure 50: Project manager 1, Quality Function Deployment with the category quantitative/ human



Quantitative/Process&project																												
Number of tasks/roles and responsibilies not delegated	PM04																											
Number of scope/contract meetings	PM05																											
Frequency satisfactory progress reports	PM29																											
Number of missed deadlines (internal)	PM31			A																								
Number of missed deadlines (external)	PM32																											
Response time	PM33																											
Number of unanswered inquiries/requests	PM34						C																					
Number of budget/contract meetings	PB01		A																									
Number of risk meetings (internal)	PB02		B																									
Number of risk meetings (external)	PB03		B							A																		
Number of rescheduled activities	PB11																											
Cost of scope change	PB12																											
Number of schedule updates	PB14										C																	
Ratio rework to work (time)	CM11																											
Ratio rework to work (cost)	CM12														C													
Amount of defects	CM13																											
Number of change requests (client)	CM15																		B									
Number of change requests (contractors)	CM16																		B	B								
Total numbers of change requests	CM17																		B	B	B							
Number of accepted change requests	CM18																		B	B	B	B						
Number of rejected change requests	CM19																		B	B	B	B						
Number of mistakes in plans and specifications	TM03																						C					
Number of (intermediate) verifications clients	TM04																											
Number of mismatches between functional requirements and technical specif	TM05																											
Number of permits timely acquired	OM09																											
Commitment to standards and regulations	OM12																											
Amount of denied or delayed permits	OM16																											
Amount of preparatory research (timely) requested	OM17																											

	WF	PM04	PM05	PM29	PM31	PM32	PM33	PM34	PB01	PB02	PB03	PB11	PB12	PB14	CM11	CM12	CM13	CM15	CM16	CM17	CM18	CM19	TM03	TM04	TM05	OM09	OM12	OM16	OM17
Measurability (effort)	6	3	1	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Measurability (time)	6	3	3	3	2	2	2	2	2	2	2	2	3	2	3	3	3	2	2	2	2	2	3	3	3	2	2	2	2
Communicability	10	3	3	4	3	3	3	3	3	2	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3
Insensitivity info (organizational)	7	3	5	4	2	3	4	3	4	4	4	3	3	4	2	2	2	3	3	3	3	3	2	3	2	3	2	3	3
Reliability	1	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Insensitivity info (privacy)	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Weighted scores	31	2,8	2,9	3,3	2,5	2,7	2,9	2,7	2,5	2,6	2,9	2,7	2,9	2,9	2,6	2,6	2,9	2,7	2,7	2,7	2,7	2,7	2,6	2,9	2,6	2,7	2,5	2,7	2,7

Figure 51: Project manager 1, Quality Function Deployment with the category quantitative/ process&project

Project manager 2

This project manager is mainly interested in human information (Figure 52 and Figure 53). Since the project team should perform as good as possible and the information gained should not be communicated to other organizational levels, communicability is prioritized highly for human data not for process & project data. Reliability is rated '1' in every QFD since she trusts that people are honest.

Qualitative/Human															
Clearly defined objectives formulated by the client	PM01														
Clients focus (within the iron triangle)	PM06	B													
Qualifications personnel	PM12														
Evaluation of social workings within the team	PM19														
Evaluation project manager/project leadership	PM21				A										
Trust among project participants	PM30														
Contractor profitability	CM03														
Technical knowledge contract managers	CM07			C											
Participants comply to contacts	CM09						A								
Attitude towards scope change	CM21														
Clear goals in stakeholder communication	OM02														
Perceived impact on the residents/surrounding community	OM04														
Goals formulated by stakeholders	OM07											A	A		
Presence of an up-to-date stakeholder register	OM15														

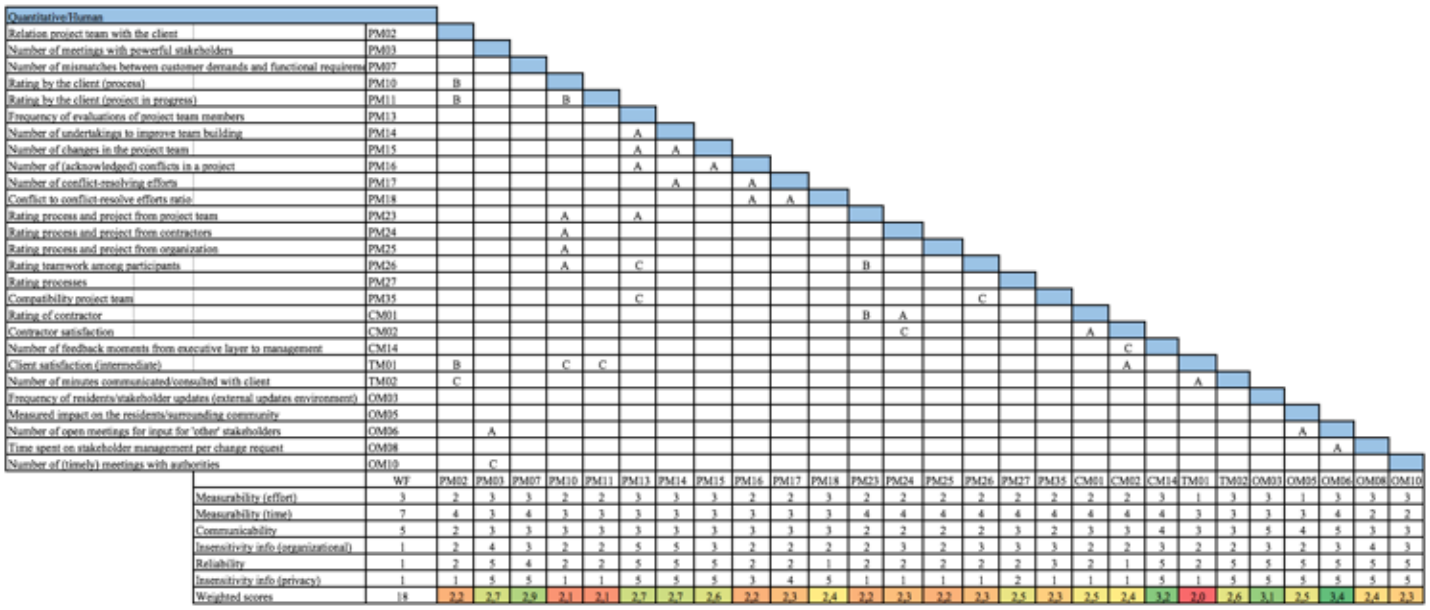
	WF	PM01	PM06	PM12	PM19	PM21	PM30	CM03	CM07	CM09	CM21	OM02	OM04	OM07	OM15
Measurability (effort)	7	1	1	3	2	1	2	1	1	1	2	3	2	1	3
Measurability (time)	3	5	5	5	3	4	4	5	5	4	5	5	3	5	3
Communicability	5	3	3	1	3	2	2	3	3	3	2	4	4	3	3
Insensitivity info (organizational)	1	2	2	2	2	3	2	4	3	3	2	2	2	3	3
Reliability	1	2	3	2	3	3	1	1	5	5	2	4	1	3	5
Insensitivity info (privacy)	1	1	3	1	1	1	1	2	5	3	5	2	1	1	5
Weighted scores	18	2,3	2,5	2,6	2,4	2,0	2,2	2,4	2,8	2,5	2,7	3,6	2,6	2,4	3,2

Figure 52: Project manager 2, Quality Function Deployment with the category qualitative/ human

Qualitative /Process&Project																										
Clear scope	PM08																									
Feasibility planning	PM09																									
Differences between goals organization to project team	PM20																									
Evaluation organizational support to project team	PM22			A																						
Process compliance	PM28																									
Visibility risk register	PB04																									
Last update (date) risk register	PB05					A																				
Standardized risk management	PB06					A																				
Risk included in budget	PB07																									
Independence risk analist	PB08																									
Existence of risk management database and plan	PB09						A		C																	
Mature scope change control process within organizations	PB10								A			A														
Assessment of scope control mechanism	PB13					C							C													
State of the market	CM04																									
Contract size/scope	CM05																		B							
Incentives in contracts	CM06																		B	B						
Contract type	CM08																									
Type of procurement	CM10																									
Independence quality control/audit	CM20					A					A															
Presence of a clear overview of functional and technical specifications	TM06																									
Environmental Impact Assessment	OM01																									
Presence of impact assessment	OM11																								C	
Completeness of regulations/legislation/procedures overview	OM13																									
Available information regarding the project environment	OM14																									

	WF	PM08	PM09	PM20	PM22	PM28	PB04	PB05	PB06	PB07	PB08	PB09	PB10	PB13	CM04	CM05	CM06	CM08	CM10	CM20	TM06	OM01	OM11	OM13	OM14
Measurability (effort)	7	1	1	1	1	1	2	3	3	3	2	3	3	3	2	1	1	1	3	1	3	1	3	3	3
Measurability (time)	3	4	5	4	4	4	3	2	4	5	5	5	5	3	5	5	5	5	5	5	3	5	5	4	3
Communicability	1	3	3	3	2	3	3	3	3	3	3	3	3	3	5	3	3	3	3	3	3	5	3	3	3
Insensitivity info (organizational)	7	5	4	3	3	3	3	3	3	3	3	3	3	4	5	2	3	3	3	3	3	2	2	3	3
Reliability	1	3	3	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5
Insensitivity info (privacy)	3	5	5	3	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Weighted scores	22	3,4	3,2	2,5	2,2	2,8	3,0	3,2	3,5	3,6	3,3	3,6	3,6	3,7	4,0	2,7	3,0	3,0	3,6	2,9	3,4	2,8	3,3	3,5	3,4

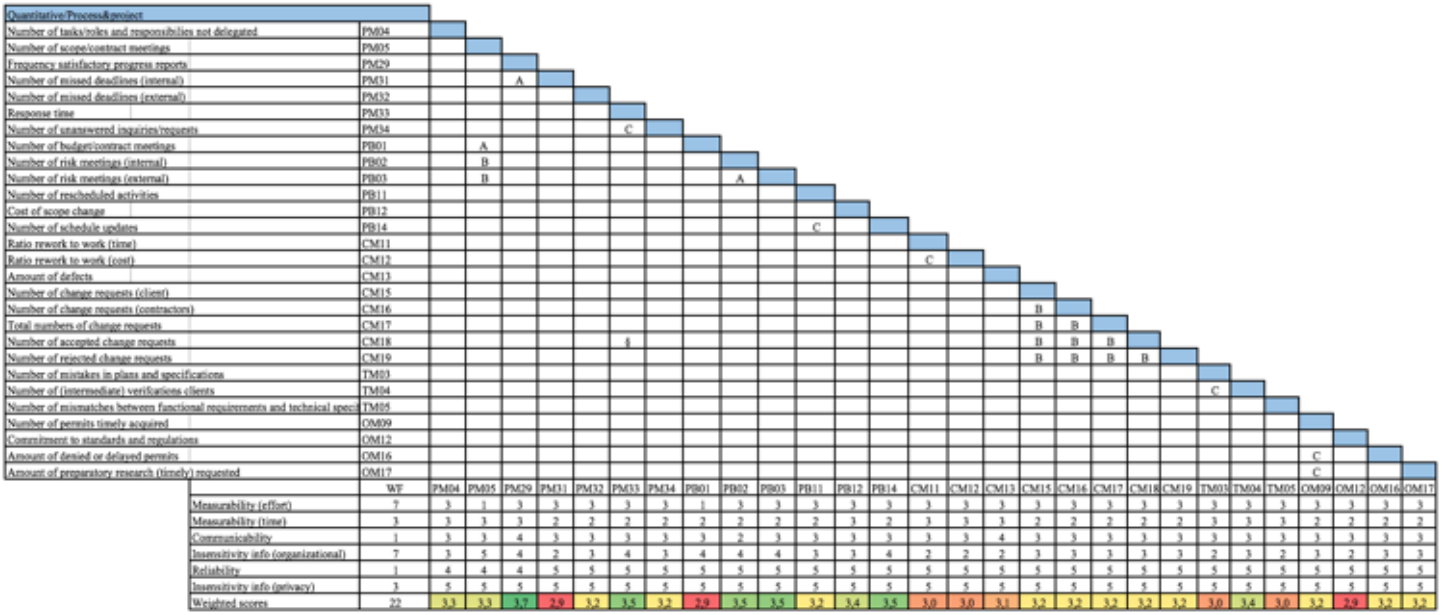
Figure 53: Project manager 2, Quality Function Deployment with the category qualitative/ process&project



Quantitative/Human																													
Relation project team with the client	PM02																												
Number of meetings with powerful stakeholders	PM03																												
Number of mismatches between customer demands and functional requirem	PM07																												
Rating by the client (process)	PM10	B																											
Rating by the client (project in progress)	PM11	B			B																								
Frequency of evaluations of project team members	PM13																												
Number of undertakings to improve team building	PM14						A																						
Number of changes in the project team	PM15						A	A																					
Number of (acknowledged) conflicts in a project	PM16						A		A																				
Number of conflict-resolving efforts	PM17							A		A																			
Conflict to conflict-resolve efforts ratio	PM18									A	A																		
Rating process and project from project team	PM23				A		A																						
Rating process and project from contractors	PM24				A																								
Rating process and project from organization	PM25				A																								
Rating teamwork among participants	PM26				A		C						B																
Rating processes	PM27																												
Compatibility project team	PM35						C									C													
Rating of contractor	CM01												B	A					A										
Contractor satisfaction	CM02													C						A									
Number of feedback moments from executive layer to management	CM14																				C								
Client satisfaction (intermediate)	TM01	B			C	C															A								
Number of minutes communicated/consulted with client	TM02	C																					A						
Frequency of residents/stakeholder updates (external updates environment)	OM03																												
Measured impact on the residents/surrounding community	OM05																												
Number of open meetings for input for 'other' stakeholders	OM06		A																								A		
Time spent on stakeholder management per change request	OM08																											A	
Number of (timely) meetings with authorities	OM10		C																										

	WF	PM02	PM03	PM07	PM10	PM11	PM13	PM14	PM15	PM16	PM17	PM18	PM23	PM24	PM25	PM26	PM27	PM35	CM01	CM02	CM14	TM01	TM02	OM03	OM05	OM06	OM08	OM10
Measurability (effort)	3	2	3	3	2	2	3	3	3	2	2	3	2	2	2	2	2	2	2	2	3	1	3	3	1	3	3	3
Measurability (time)	7	4	3	4	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	3	3	3	3	4	2	2
Communicability	5	2	3	3	3	3	3	3	3	3	3	3	2	2	2	2	3	2	3	3	4	3	3	5	4	5	3	3
Insensitivity info (organizational)	1	2	4	3	2	2	5	5	3	2	2	2	2	3	2	3	3	3	2	2	3	2	2	3	2	3	4	3
Reliability	1	2	5	4	2	2	5	5	5	2	2	1	2	2	2	2	2	3	2	1	5	2	5	5	5	5	5	5
Insensitivity info (privacy)	1	1	5	5	1	1	5	5	5	3	4	5	1	1	1	1	2	1	1	1	5	1	5	5	5	5	5	5
Weighted scores	18	2.2	2.7	2.9	2.1	2.1	2.7	2.7	2.6	2.2	2.3	2.4	2.2	2.3	2.2	2.3	2.5	2.3	2.5	2.4	3.2	2.0	2.6	3.1	2.5	3.4	2.4	2.3

Figure 54: Project manager 2, Quality Function Deployment with the category quantitative/ human



Quantitative/Process&project																													
Number of tasks/roles and responsibilies not delegated	PM04																												
Number of scope/contract meetings	PM05																												
Frequency satisfactory progress reports	PM29																												
Number of missed deadlines (internal)	PM31			A																									
Number of missed deadlines (external)	PM32																												
Response time	PM33																												
Number of unanswered inquiries/requests	PM34						C																						
Number of budget/contract meetings	PB01		A																										
Number of risk meetings (internal)	PB02		B																										
Number of risk meetings (external)	PB03		B							A																			
Number of rescheduled activities	PB11																												
Cost of scope change	PB12																												
Number of schedule updates	PB14											C																	
Ratio rework to work (time)	CM11																												
Ratio rework to work (cost)	CM12														C														
Amount of defects	CM13																												
Number of change requests (client)	CM15																												
Number of change requests (contractors)	CM16																		B										
Total numbers of change requests	CM17																		B	B									
Number of accepted change requests	CM18						§												B	B	B								
Number of rejected change requests	CM19																		B	R	B	B							
Number of mistakes in plans and specifications	TM03																												
Number of (intermediate) verifications clients	TM04																							C					
Number of mismatches between functional requirements and technical speci	TM05																												
Number of permits timely acquired	OM09																												
Commitment to standards and regulations	OM12																												
Amount of denied or delayed permits	OM16																											C	
Amount of preparatory research (timely) requested	OM17																											C	

	WF	PM04	PM05	PM29	PM31	PM32	PM33	PM34	PB01	PB02	PB03	PB11	PB12	PB14	CM11	CM12	CM13	CM15	CM16	CM17	CM18	CM19	TM03	TM04	TM05	OM09	OM12	OM16	OM17
Measurability (effort)	7	3	1	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Measurability (time)	3	3	3	3	2	2	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	3	3	3	2	2	2	2
Communicability	1	3	3	4	3	3	3	3	3	2	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3
Insensitivity info (organizational)	7	3	5	4	2	3	4	3	4	4	4	3	3	4	2	2	2	3	3	3	3	3	2	3	2	3	2	3	3
Reliability	1	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Insensitivity info (privacy)	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Weighted scores	22	3.3	3.3	3.7	2.9	3.2	3.5	3.2	2.9	3.5	3.5	3.2	3.4	3.5	3.0	3.0	3.1	3.2	3.2	3.2	3.2	3.2	3.0	3.4	3.0	3.2	2.9	3.2	3.2

Figure 55: Project manager 2, Quality Function Deployment with the category quantitative/ process&project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