EMBRACING CHANGE: THE ROAD TO IMPROVEMENT ?

A study into if and how a combination of Lean and Agile could help coping with complexity and uncertainty in the front-end development of an infrastructure project.

MSc thesis | RIANNE BLOM

The Hague, October 2014

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A study into if and how a combination of Lean and Agile could help coping with complexity and uncertainty in the front-end development of an infrastructure project.

Delft University of Technology
Civil Engineering and Geosciences
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PREFACE

Are we staying on the main road of Conventional Project Management or do we take the exit towards Lean and Agile?

Lying in front of you is the result of my thesis research performed in order to conclude my master Construction Management and Engineering at the Technical University of Delft. As can be obtained from the question just asked the subject of this thesis is Lean and Agile. During my master studies my interest in project management grew. We learned about several methods and techniques mostly part of, as I now know, conventional project management. It was during a presentation at the ICT firm I worked at as a part time job that I learned about Scrum. Scrum was used in that firm for software development purposes, yet I immediately started thinking about its possible application to infrastructure projects. At Antea Group they gave me the possibility to investigate this and I learned that Scrum was part of the Agile methods group, which showed much similarities with Lean. So I have ended up investigating the possible application of both Lean and Agile.

I have spent the last seven months working on this research and without some people this would never have been possible. First of all I would like to thank my graduation committee. Hans, for always providing me with critical notes and questions, Ype for introducing me to Lean and for all the interesting conversations, Afshin for answering all of my questions and helping me whenever I needed guidance and lastly Sander for giving me the opportunity to perform my research and for giving me the freedom to form and define my research as I wanted it.

I would also like to thank all the people who furthermore contributed to this research in one way or the other. Special thanks to Rene de Boer, Reinier Koenraadt and Geert Roovers for providing me with insight in the current situation at Antea Group. Also thanks to the project leaders who contributed to the Q sorting questionnaire and thanks to all the participants of the correlation questionnaire.

There are many others who contributed by either informally discussing my research or just by keeping me company while working on my thesis. Thanks to you all! In specific I would like to thank my family: pap, mam and Alieke, for always supporting me during the last couple of months as well as during my entire studies. Thanks to Elco for being there to listen, support and help me during the past seven months.

Coming back to the question asked at the beginning, I can now say that it is not an exit we will take, but more an improvement of the current road.

Enjoy reading!

Rianne Blom
The Hague, October 2014

SUMMARY

Introduction

Cost overruns and delays form a big problem in the infrastructure sector. Pinpointing a main cause for cost overruns and delays is not easy. Several reasons can be found in literature, with one being that most projects are not managed in a proper manner. Project management methods and tools are described in many well-established guidelines and several have become the standard in the field of project management. Yet, despite those guidelines, handbooks and bodies of knowledge, projects still fail (Priemus, Bosch-Rekveldt, & Giezen, 2013; Williams, 2005). One could thus say that current project management methods and tools are not adequate anymore. This inadequacy of conventional project management is due to the fact that projects are becoming more complex and uncertain for which conventional project management does not provide sufficient tools to cope with (Williams, 1999; Baccarini, 1996; Hobday, 1998). Conventional project management is aimed at reaching predefined goals (Aritua et al., 2009), mostly constituted of criteria for time, budget and performance goals (Koppenjan, Veeneman, Van Der Voort, Ten Heuvelhof, & Leijten, 2010). Here the assumption is made that it is possible to well-define these goals at the start of the project (Atkinson et al., 2006). Yet, the complexity and uncertainty of many projects makes that this preplanning becomes less appropriate (Williams, 2005). Projects should thus not be aimed at following a planning focussed on achieving predetermined time, budget and performance goals but should be aimed at real performance (Perminova, Gustafsson, & Wikström, 2008). For this a new approach is needed which recognizes and provides tools to cope with the complexity and uncertainty of a project, an approach that is aimed at increasing flexibility (Koppenjan et al., 2010; Atkinson et al., 2006).

This inadequacy of conventional project management was chosen as subject for the problem definition of this thesis: c*onventional project management shows to be inadequate for coping with complexity and uncertainty.*

Two approaches receiving increasing attention due to the rethink of project management are Lean and Agile (Maylor, 2010). Due to scope decisions it was chosen to investigate the applicability of Lean and Agile to the front-end development of infrastructure projects. This results in the following research question: c*ould, and how could, a combination of Lean and Agile help coping with complexity and uncertainty in the front-end development of an infrastructure project?*

To come to a clear answer to this research question three sub-questions were composed:

1. *In what direction does project management need to evolve in order to cope with complexity and uncertainty?*
2. *Can Lean and Agile be applied to the front-end development to cope with complexity and uncertainty?*
3. *Does the combined approach of Lean and Agile work in practice?*

By answering these questions and composing an answer to the main research question the objective of this research will be met. The objective is formulated as follows: *composing a grounded advice for civil engineering firms on whether Lean and Agile could help them to cope with complexity and uncertainty in a project's front-end development.*

For answering the sub-questions and in the end the main research question several studies and researches will be performed. In order to come to an answer to sub-questions one and two literature studies in the field of project management, complexity, uncertainty, Lean and Agile will be performed. Also some interviews to assess the current situation will be carried out. Together this will form the theoretical framework. In order to come to an answer to sub-question three two researches will be performed. A Q sorting research will be carried out, as well as a correlation analysis. Together with the results of the theoretical framework, the results of the research will provide the basis for answering the main research question.

Theoretical background

In the theoretical framework an answer to sub-questions one and two was sought after. Below the answers are provided.

For answering the first sub-question literature studies in the field of project management, complexity and uncertainty were performed. Combining the results of these studies results in a list of criteria for project management in order to manage complexity and uncertainty in an appropriate manner:

- Considering all possible alternatives and making a decision at the last responsible moment (redundancy) (Priemus et al., 2013).
- Using standardization to an extent that fits with the project's context in order to achieve reflective learning (Giezen, 2012; Perminova et al., 2008).
- Recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats (resilience) (Priemus et al., 2013).
- A functional scope description (Koppenjan et al., 2010).
- Close cooperation between the stakeholders (Koppenjan et al., 2010).
- Self-steering of the complete project team (Koppenjan et al., 2010).
- Open information exchange (Koppenjan et al., 2010).
- Trust (Atkinson et al., 2006).

For answering the second sub-question the list of criteria was combined with results of the literature study on Lean and Agile. In the table below the Lean and Agile approach related to the criteria is presented.

criteria	Lean and Agile element
considering all possible alternatives and making a decision at the last responsible moment (redundancy)	Lean: set based strategy through many alternatives and late decision
using standardization to an extent that fits with the project's context in order to achieve reflective learning	Lean: continuous learning through standardization of the product and process
recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats (resilience)	Agile: see change as added value and managing change by applying Scrum process Lean: small batches
functional scope description	Agile: no complete and definite definition of scope is needed
close cooperation between the stakeholders	Lean: involve all stakeholders in decision making, share incomplete information, considering subsequent phases, cross functional teams Agile: cross functional teams
self-steering of the complete project team	Agile: self-organizing teams
open information exchange	Lean: share incomplete information, information visible to all stakeholders Agile: daily meetings
trust	Lean: involve all stakeholders in decision making, share incomplete information, information visible to all stakeholders Agile: cross functional teams, daily meetings

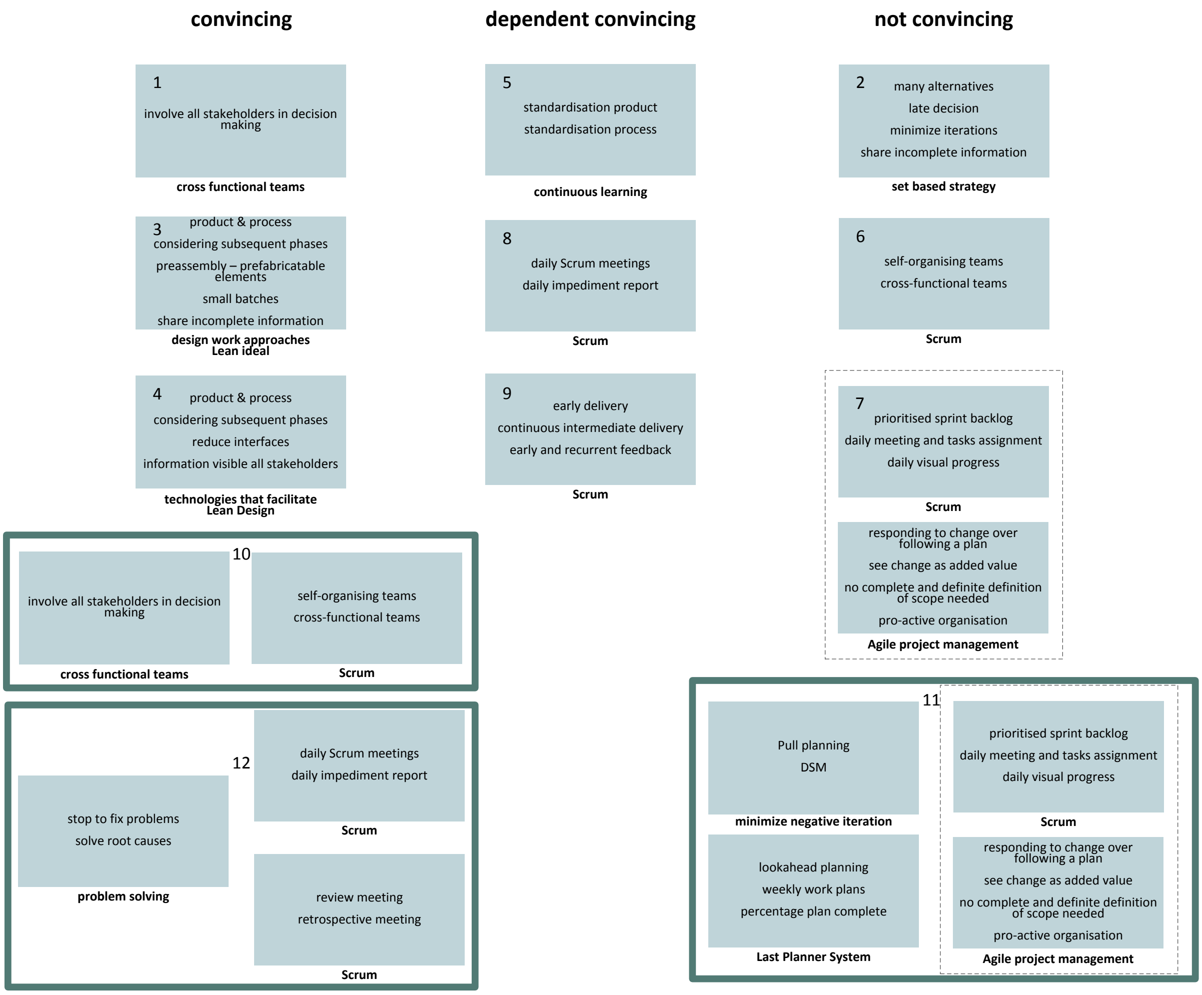
Research

For answering sub-question three both a Q sorting research and a correlation analysis were performed. For the Q sorting research a questionnaire was made which asked the respondents to rank 21 statements, based on elements of Lean and Agile, on their capability to handle the complexity of a project. In total 25 respondents contributed to this research. Resulting from the Q sorting research was the definition of three perspectives on the applicability of Lean and Agile:

1. Commitment and alignment
2. Simplification and no hassle
3. Collaboration restricted by role division

For the correlation analysis also a questionnaire was made. In this questionnaire respondents were asked to assess seventeen statements about the complexity of the project they were currently working on and fifteen statements on the implicit usage of Lean and Agile in those projects. In total 67 respondents contributed to this research. Resulting from the correlation analysis was an assessment of the elements on whether they helped with reducing the complexity of the projects, whether they helped managing the complexity or whether it was unsure they reduced or helped managing the complexity.

Combining those results provides the answer to sub-question three translated in the figure below.



Conclusion

In this research several elements of Lean and Agile were identified as helpful for coping with complexity and uncertainty. First a selection was made based on available theory and next the elements were examined on their true applicability. Resulting in the conclusion as presented in the preceding section. Based on this conclusion, keeping the scope and limitations of this research in mind, it can be concluded that the answer to the research question is yes: a combination of Lean and Agile could help coping with complexity and uncertainty in the front-end development of an infrastructure project. How the combination helps managing complexity is related to their shared underlying ideal. The ideal behind both Lean and Agile is value maximization for the client. Conventional project management is also aimed at value maximization, but does this for the value as defined by the client at the beginning of the process. For projects not subjected to complexity and uncertainty, this may be sufficient. Yet, for complex and uncertain projects conventional project management is not adequate. For these projects the client's definition of value at the beginning of the process differentiates for the client's definition of value at the end of the process. For these projects value maximization means maximization of the client's definition of value at the end of the project. This requires a project that is more flexible and adaptive to changes instead of a project that rebels against changes, complexity and uncertainty require a project that *embraces change*. Both Lean and Agile *embrace change* instead of rebel against it. Thus implementing the Lean and Agile ideal in project management would help coping with complexity and uncertainty in the front-end development of an infrastructure project as they *embrace change*.

SAMENVATTING

Introductie

Kostenoverschrijdingen en vertragingen vormen een groot probleem in the infrastructuur sector. Het aanwijzen van een hoofdoorzaak hiervoor is lastig. In de huidige literatuur kunnen er verscheidende redenen gevonden worden. Eén hiervan is dat de meeste projecten niet op de juiste wijze gemanaged worden. Projectmanagement methoden en technieken staan beschreven in gevestigde richtlijnen en sommige zijn de standaard geworden voor project management. Maar ondanks deze richtlijnen en handboeken zijn er nog steeds projecten die falen (Priemus, Bosch-Rekveldt, & Giezen, 2013; Williams, 2005). Men zou dus kunnen zeggen dat de huidige methoden en technieken niet meer voldoende zijn. Dit tekortschieten van de huidige methoden en technieken is te wijten aan de toenemende complexiteit en onzekerheid binnen projecten en het feit dat de huidige methoden en technieken te kortschieten in het omgaan met deze complexiteit en onzekerheid (Williams, 1999, Baccarini, 1996 Hobday, 1998). Conventioneel projectmanagement is gericht op het bereiken van vooraf vastgestelde doelen (Aritua et al., 2009), meestal gebaseerd op tijd, budget en kwaliteit criteria (Koppenjan, Veeneman, Van Der Voort, Ten Heuvelhof, & Leijten, 2010). Hierbij wordt aangenomen dat deze criteria al aan het begin van het project vastgesteld kunnen worden (Atkinson et al., 2006). Maar de complexiteit en onzekerheid van vele project maakt dit vooraf plannen minder geschikt (Williams, 2005). Projecten moeten dus minder gefocust zijn op het bereiken van vooraf gestelde doelen en meer op de werkelijke prestaties van het project (Perminova, Gustafsson, & Wikström, 2008). Hiervoor is er een nieuwe aanpak nodig die deze complexiteit en onzekerheid erkent en die middelen biedt om hiermee om te gaan, dus een aanpak die gericht is op het vergroten van de flexibiliteit (Koppenjan ea, 2010;. Atkinson et al, 2006.).

Deze ontoereikendheid van conventioneel projectmanagement werd gekozen als onderwerp voor de probleemstelling van dit thesis: *conventioneel projectmanagement blijkt ontoereikend voor het omgaan met complexiteit en onzekerheid.*

Twee aanpakken die meer en meer aandacht krijgen door deze heroverweging van projectmanagement zijn Lean en Agile (Maylor, 2010). Door scope keuzes is ervoor gekozen om de toepasbaarheid van Lean en Agile ten aanzien van de front-end ontwikkeling van infrastructuur projecten te onderzoeken. Dit heeft geresulteerd in de volgende onderzoeksvraag: *kan, en op welke manier, een combinatie van Lean en Agile helpen met het omgaan met complexiteit en onzekerheid in de front-end ontwikkeling van een infrastructuur project?*

Om tot een antwoord op deze onderzoeksvraag te komen zijn er drie deelvragen opgesteld:

1. *In welke richting zal projectmanagement zich moeten ontwikkelen om om te kunnen gaan met complexiteit en onzekerheid?*
2. *Kunnen Lean en Agile worden toegepast op de front-end ontwikkeling om om te kunnen gaan met complexiteit en onzekerheid?*
3. *Werkt de gecombineerde aanpak van Lean en Agile in de praktijk?*

Door het beantwoorden van deze vragen en het beantwoorden van de onderzoeksvraag zal de doelstelling van dit onderzoek worden voldaan. De doelstelling van dit onderzoek is als volgt: *het samenstellen van een advies voor civiel technische ingenieursbureaus op het gebied van de toepasbaarheid van Lean en Agile om om te kunnen gaan met complexiteit en onzekerheid in de front-end ontwikkeling van hun projecten.*

Om de deelvragen en onderzoeksvraag te kunnen beantwoorden zullen er een aantal studies en onderzoeken worden uitgevoerd. Om tot een antwoord te komen op de eerste twee deelvragen zullen er literatuurstudies op het gebied van projectmanagement, complexiteit, onzekerheid, Lean en Agile uitgevoerd worden. Ook zullen er een aantal interviews plaatsvinden om de huidige situatie in kaart te brengen. Samen zullen zij het theoretisch kader vormen. Om tot een antwoord op de derde deelvraag te komen zullen er twee onderzoeken worden uitgevoerd. Zowel een Q sorting onderzoek als een correlatie analyse zullen worden uitgevoerd. Samen met de resultaten van het theoretisch kader zullen de resultaten van deze onderzoeken de basis vormen voor het beantwoorden van het onderzoeksvraag.

Theoretisch kader

In het theoretische kader werd er gezocht naar antwoorden op deelvragen één en twee. Hieronder kunnen deze antwoorden worden gevonden.

Voor het beantwoorden van de eerste deelvraag zijn er literatuur studies op het gebied van projectmanagement, complexiteit en onzekerheid uitgevoerd. Samen vormen de resultaten van deze studies een lijst met criteria waar projectmanagement aan zou moeten voldoen om op de juiste manier om te kunnen gaan met complexiteit en onzekerheid:

- In beschouwing nemen van alle mogelijke en relevante alternatieven en de beslissing hierover tot het laatst mogelijke moment uitstellen (redundantie) (Priemus et al., 2013).
- Gebruik maken van standaardisatie in een mate die past bij het desbetreffende project om zo reflectief leren te realiseren (Giezen, 2012; Perminova et al., 2008).
- Erkennen dat verandering onvermijdelijk is en omgaan met deze verandering, door kansen te benutten en om te gaan met bedreigingen (weerbaarheid) (Priemus et al., 2013).
- Een functionele scope beschrijving (Koppenjan et al., 2010).
- Nauwe samenwerking tussen de belanghebbenden (Koppenjan et al., 2010).
- Zelfsturend project team (Koppenjan et al., 2010).
- Open uitwisseling van informatie (Koppenjan et al., 2010).
- Vertrouwen (Atkinson et al., 2006).

Deze lijst werd gecombineerd met de resultaten van de literatuur studies op het gebied van Lean en Agile om deelvraag twee te kunnen beantwoorden. In de onderstaande tabel is de Lean en Agile aanpak ten aanzien van de criteria te uitgezet.

criteria	Lean and Agile element
in beschouwing nemen van alle mogelijke en relevante alternatieven en de beslissing hierover tot het laatst mogelijke moment uitstellen (redundantie)	Lean: set based strategie door het in beschouwing nemen van veel alternatieven en het maken van een verlate beslissing
gebruik maken van standaardisatie in een mate die past bij het desbetreffende project om zo reflectief leren te realiseren	Lean: continue leren door standaardisatie van het product en proces
erkennen dat verandering onvermijdelijk is en omgaan met deze verandering, door kansen te benutten en om te gaan met bedreigingen	Agile: verandering zien als toegevoegde waarde en verandering managen door het Scrum proces toe te passen Lean: kleine batches
functionele scope beschrijving	Agile: geen complete of definitieve definitie van de scope nodig
nauwe samenwerking tussen de belanghebbenden	Lean: alle belanghebbende betrekken in de besluitvorming, incomplete informatie uitwisselen, vervolg fases in beschouwing nemen, cross functionele teams Agile: cross functionele teams
zelfsturend project team	Agile: zelfsturende teams
open uitwisseling van informatie	Lean: incomplete informatie uitwisselen, informatie zichtbaar maken voor alle belanghebbenden Agile: dagelijkse bijeenkomsten
vertrouwen	Lean: alle belanghebbende betrekken in de besluitvorming, incomplete informatie uitwisselen, informatie zichtbaar maken voor alle belanghebbenden Agile: cross functionele teams, dagelijkse bijeenkomsten

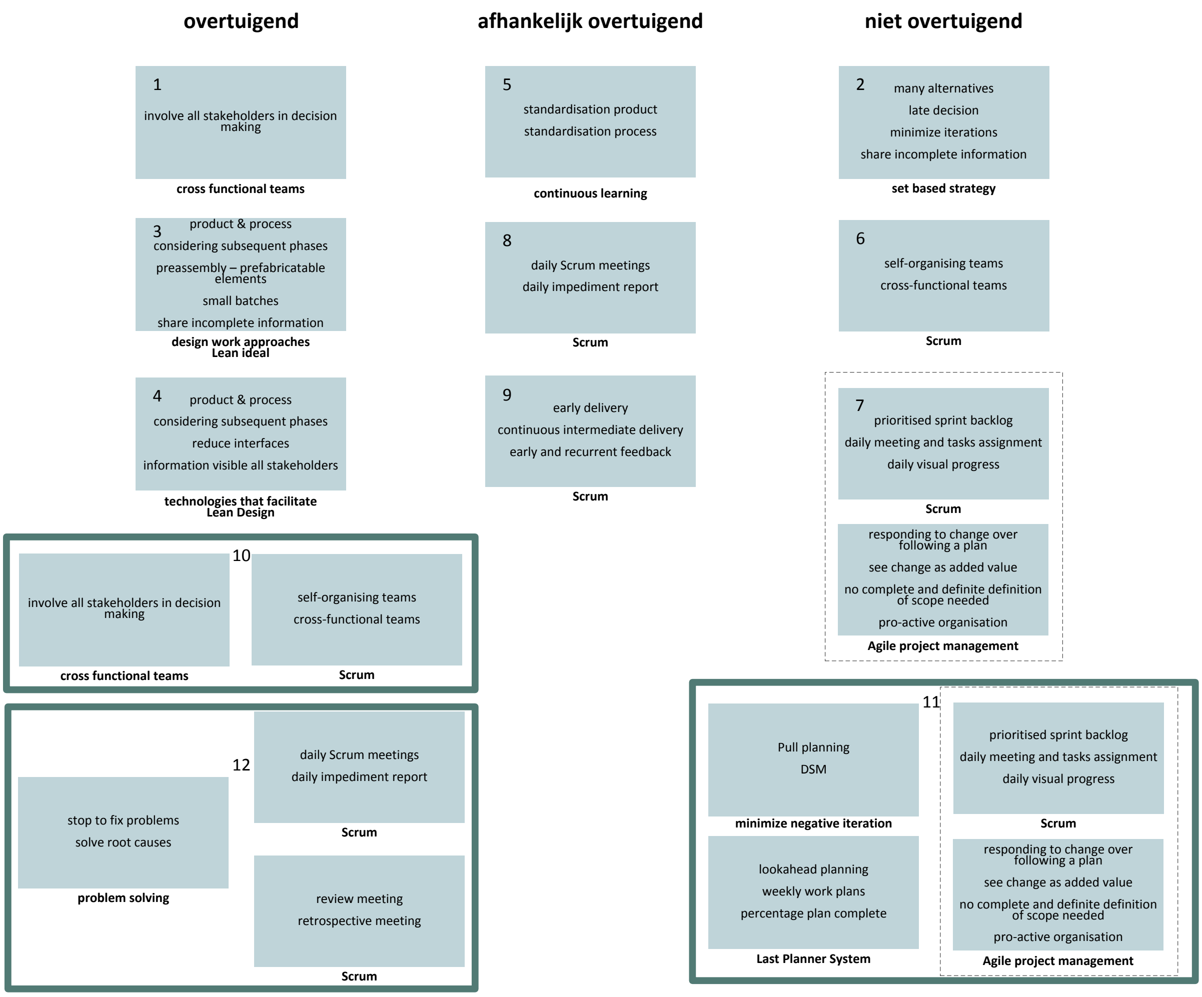
Onderzoek

Voor het beantwoorden van de derde deelvraag is er zowel een Q sorting onderzoek als een correlatie analyse uitgevoerd. Voor het Q sorting onderzoek is er een enquête opgesteld welke de respondenten vroeg om 21 stellingen, gebaseerd op elementen van Lean en Agile, te rangschikkende op hun vermogen om om te kunnen gaan met de complexiteit van een project. In totaal hebben 25 respondenten een bijdrage geleverd aan dit onderzoek. Het Q sorting onderzoek heeft geresulteerd in de onderscheiding van drie verschillende perspectieven ten aanzien van de toepasbaarheid van Lean en Agile:

1. Betrokkenheid en afstemming
2. Vereenvoudiging en geen gedoe
3. Samenwerking beperkt door rolverdeling

Voor de correlatie analyse is er ook een enquête opgesteld. In deze enquête werd de respondenten gevraagd zeventien stellingen met betrekking tot de complexiteit van het project waar ze momenteel aan werkten en vijftien stellingen met betrekking tot het impliciete gebruik van Lean en Agile te beoordelen. In totaal hebben 67 respondenten een bijdrage geleverd aan dit onderzoek. Dit heeft geresulteerd in een categorisatie van de elementen in of ze helpen bij het verminderen van de complexiteit, helpen bij het managen van de complexiteit of elementen voor welke het onzeker was of ze complexiteit verminderde of konden managen.

Het combineren van deze resultaten biedt het antwoord op deelvraag drie en is vertaald in de figuur hieronder.



Conclusie

Tijdens dit onderzoek zijn verschillende elementen van Lean en Agile geïdentificeerd als zijnde behulpzaam bij het om gaan met complexiteit en onzekerheid. Ten eerste is er een selectie gemaakt gebaseerd op reeds beschikbare theorieën en daarna zijn de elementen getest op hun praktisch toepassingsvermogen. Dit heeft geresulteerd in de conclusie zoals die zojuist is gepresenteerd. Gebaseerd op deze conclusie, met de scope en limitaties van dit onderzoek in het achterhoofd houdend, kan er geconcludeerd worden dat het antwoord op de onderzoeksvraag ja is: een combinatie van Lean en Agile kan helpen bij het om gaan met complexiteit en onzekerheid in de front-end ontwikkeling van een infrastructuur project. Hoe deze combinatie helpt met het managen van complexiteit is gerelateerd aan hun gedeelde onderliggende ideaal. Het ideaal achter zowel Lean en Agile is waarde maximalisatie voor de klant. Conventioneel projectmanagement is ook gericht op waarde maximalisatie voor de klant, maar doet dit voor de waarde gedefinieerd door de klant aan het begin van het proces. Voor projecten niet onderworpen aan complexiteit en onzekerheid zou dit voldoende kunnen zijn. Maar voor complexe en onzekere projecten is conventioneel projectmanagement niet geschikt. Voor deze projecten is er een verschil in de door de klant gedefinieerde waarde aan het begin van het proces en de door de klant gedefinieerde waarde aan het einde van het proces. Voor deze projecten geldt dat waarde maximalisatie betekend maximalisatie van de waarde zoals gedefinieerd door de klant aan het einde van het project. Hiervoor is een project nodig dat flexibeler en meer adaptief vermogen heeft ten aanzien van veranderingen in plaats van een project dat zich afzet tegen veranderingen, complexiteit en onzekerheid vereisen een project dat verandering omarmt. Zowel Lean als Agile *omarmen verandering* in plaats van dat ze zich hier tegen afzetten. Door dus het Lean en Agile ideaal te implementeren in project management kan er beter worden omgegaan met complexiteit en onzekerheid in de front-end ontwikkeling van een infrastructuur project omdat beide *verandering omarmen*.

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INTRODUCTION

1 INTRODUCTION TO THE PROBLEM

This chapter can be seen as starting point for defining and framing the research. In the first paragraph of this chapter the subject will be introduced. Next the problem will be defined, resulting in a problem statement and finally in paragraph three the context will be discussed.

1.1 INTRODUCTION TO THE SUBJECT

The Central Artery/Tunnel Project in Boston, the Sydney Opera House, and in the Netherlands the North/Southline, the HSL-line and the Betuweline are just a few examples of construction projects that suffer or have suffered major cost overruns and delays (Chartered Institute of Management Accountants [CIMA], 2013; Vrijdenker, 2009). Even though cost overruns and delays in the construction sector are not new (Vrijling & Van Gelder, 2013) it seems like recently more and more projects are experiencing high cost overruns and delays. As can be obtained from figure 1 cost overruns in infrastructure projects are these days more rule then exception (Flyvbjerg, Skamris Holm, & Buhl, 2002). In the Netherlands the average cost overrun for infrastructural projects is 16.5 per cent (Cantarelli, 2011) and also delays are occurring more and more often (Davies, Gann, & Douglas, 2009). A recent study of the Economical Institute for Construction showed that 21 per cent of the studied Dutch infrastructure projects suffered from delays. With the most delays occurring in the plan study phase (Groot & Suiskind, 2012).

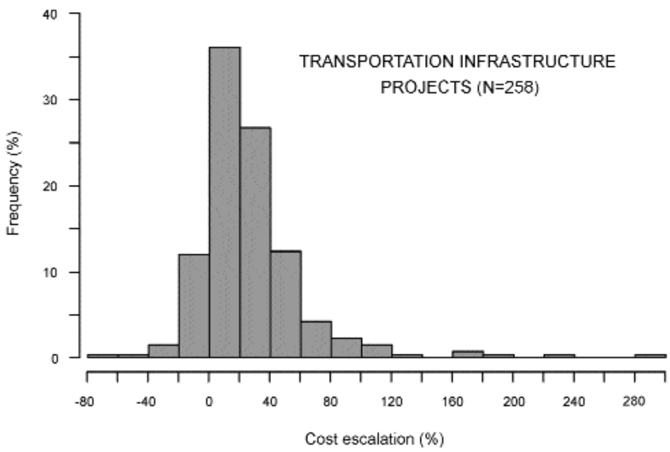


figure 1: cost escalations (Flyvbjerg et al., 2002)

It can be said that there is simultaneity between delays and cost overruns (Singh, 2010; Giezen, 2012). Delays cause cost overruns, e.g. in forms of losses in income. This means that not only cost overruns lead to financial problems, but also delays. Not only the financial position, but also the image or reputation of a company can be damaged by suffering from cost overruns and delays (Wijnen & Storm, 2007). Therefore cost overruns and delays could cause considerable damage. Cost overruns and delays do not only cause damage on a micro-economic scale, by causing financial or reputational damage to the client and the company performing the project, but also on a macro-economic scale. This because projects that suffer from cost overruns and delays affect the total amount of projects available on the market. This is especially the case for public projects. The funds for these projects are limited. This means that in case of cost overruns on one project, the money available for other public projects will decrease (Shane, Molenaar, Anderson, & Schexnayder, 2009).

But what is the reason for these cost overruns and delays? Three points of view to this question are distinguished. The first one being advocated by Flyvbjerg et al. (2002). They focus on cost underestimations being the reason behind cost overruns. Mostly cost estimates are based on the scenario that everything will go to plan. Thus the most optimistic scenario. This explanation in combination with an economic explanation of intentional lying in order to increase the benefits provides the best explanation for cost underestimations (Flyvbjerg et al., 2002). This point of view on cost overruns thus focuses on strategic lying leading to underestimating costs.

The second reason found in literature for poor project performance does not provide an explanation of what goes wrong in these projects, but states that projects are assessed wrongly, leading to many projects being improperly characterized as unsuccessful. In the former mentioned examples the performance of the project was assessed by comparing the estimated time and costs at the start of the project with the actual time and costs at the delivery of the project. But is this the right estimate of project performance? In literature many definitions of project success are provided. The most conventional definition of project success is that a project can be seen as successful when it met the schedule, budget and performance goals, also called the iron triangle (Pinto & Slevin, 1988). But what about for example the Sydney Opera House, which suffered from a cost overrun of 1,400 per cent and was delivered six years after the original deadline (Flyvbjerg, 2005a). It is now seen as an iconic building and a masterpiece of the twentieth century. Not to forget that it also quickly repaid its own cost overruns (Murray, 2004). According to project success measures: schedule, budget and performance goals, the Sydney Opera House would have been a failure, yet it is now seen as a success. This is one of the reasons why many researchers (Baker, Fisher, & Murphy, 1974; De Wit, 1988; Shenhar & Dvir, 2007) looked for different measures of project success.

The third point of view, which provides the starting point for the problem definition of this research, is related to the former point of view. It is also based on the fact that not all projects exceeding time, budget and performance goals are inherent unsuccessful and that not all projects meeting time, budget and performance goals are inherent successful. Yet, instead of focussing on success assessment, this point of view focuses on how projects are managed. Project management methods and tools are described in many well-established guidelines and several have become the standard in the field of project management. Yet, despite those guidelines, handbooks and bodies of knowledge, projects still fail (Priemus, Bosch-Rekveldt, & Giezen, 2013; Williams, 2005). One might conclude that this is the result of inadequately applying these guidelines. Yet, "often even if you do everything by the book of conventional project management you may still fail" (Shenhar & Dvir, 2007). Thus also well managed projects could still fail (Shenhar & Dvir, 2007). Advocated by Shenhar and Dvir (2007) this can be ascribed to the fact that a project's success it assessed wrongly. Yet, as is advocated by this third point of view, it could also be due to the fact that the current project management techniques are not sufficient. This inadequacy of conventional project management is due to the fact that projects are becoming more complex and uncertain for which conventional project management does not provide sufficient tools to cope with (Williams, 1999; Baccarini, 1996; Hobday, 1998). This makes the conventional project management approach insufficient for most projects, since most projects are considered to be complex (Turner & Cochrane, 1993; Maylor, 2010; Williams, 2005; Whitty & Maylor, 2009) and thus there is a high need for a new approach (Aritua, Smith, & Bower, 2009). Koskela and Howell (2002) even go a step further and claim that "traditional project management is simply counterproductive; it creates self-inflicted problems that seriously undermine performance" (Koskela & Howell, 2002). Geraldi (2008) states that the tools conventional project management provides are simple and practical which does not fit with the complex and changing character of projects. The linear and rational character of conventional project management shows to be insufficient for dealing with complexity (Geraldi et al., 2008). Also Artto and Wikström (2005) acknowledge this inadequacy. They state that current research in the field of project management is "a too rigid and narrow closed system view" (Artto & Wikström, 2005). This systems approach of conventional project management is reflected in the focus on planning and control (Bosch-Rekveldt, 2011). It is this focus on planning and control that might explain the inadequacy of conventional project management (Atkinson, Crawford, & Ward, 2006). Conventional project management is aimed at reaching predefined goals (Aritua et al., 2009), mostly constituted of criteria for time, budget and performance goals (Koppenjan, Veeneman, Van Der Voort, Ten Heuvelhof, & Leijten, 2010). Here the assumption is made that it is possible to well-define these goals at the start of the project (Atkinson et al., 2006). Yet, the complexity and uncertainty of many projects makes that this preplanning becomes less appropriate (Williams, 2005). Projects should thus not be aimed at following a planning focussed on achieving predetermined time, budget and performance goals but should be aimed at real performance (Perminova, Gustafsson, &

Wikström, 2008), as was also stressed by the project success field of research. For this a new approach is needed which recognizes and provides tools to cope with the complexity and uncertainty of a project, an approach that is aimed at increasing flexibility (Koppenjan et al., 2010; Atkinson et al., 2006).

1.2 PROBLEM DEFINITION

Even though the three points of view are here represented as three distinguishing points of view, they have something in common. All three point of view consider that for most projects the possibility of changes happening during the projects is not taken into account. The first point of view advocated that cost estimations are based on the scenario that everything will go to plan, no changes will happen. The second point of view advocated that projects are assessed wrongly, since they are assessed by means of the predetermined schedule, budget and performance goals. With predetermined indicating that the possibility of changes happening during the project are not taken into account, and will lead to a deviation from the predetermined schedule, budget and performance goals leading to, in most cases, a negative assessment of the project. The third point of view focuses on project management, and the inadequacy of conventional project management to cope with complexity and uncertainty. This point of view thus also focuses on the fact that changes happening during the project are not taken into account, or more applicable to this point of view, are not managed in a proper way.

Trying to improve the performance of projects according to the first point of view would imply that estimates should be made more accurate. But in how far is it possible to make estimates more accurate, is it possible to know exactly on beforehand which changes will happen, what their probability is and how big their impact is? As advocated by the third point of view this is not possible due to a project's complexity and uncertainty. Trying to improve the performance of projects according to the second point of view would mean that a project's success should be assessed differently, not via comparing the outcome to the predetermined schedule, budget and performance goals, but by considering that project success is dynamic. Thus by accepting changes and not inherently seeing changes as threats to project success. Yet, by doing so one can question whether or not the project performance actually increases. Is it not better to not only accept changes, but also try to manage changes? It can be concluded that it is not possible to take all changes into account on beforehand and that project management thus needs to be able to cope with these changes, caused by the project's complexity and uncertainty. As was advocated by the third point of view conventional project management does not provide sufficient tools to cope with complexity and uncertainty in projects. This inadequacy of conventional project management was chosen as subject for the problem definition of this thesis.

Conventional project management shows to be inadequate for coping with complexity and uncertainty.

1.3 CONTEXT

One of the reasons behind the increasing complexity and uncertainty in construction projects is the increasing popularity of mega-projects (Van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008). The increasing popularity of mega-projects leads to the conclusion that most infrastructure projects nowadays are in fact mega-projects. Priemus and Van Wee (2013) define mega-projects as: "large infrastructure projects for the transportation of people and/or other goods" which are considered "to be complex products that are the result of complex decision-making processes and the resulting infrastructure product". Complexity can be seen as a main characteristic of mega-projects (Priemus et al., 2013). Most literature on complexity in projects also focuses on these mega-projects (Priemus et al., 2013; Koppenjan et al., 2010; Giezen, 2012; Hertogh & Westerveld, 2009). This is why infrastructural mega-projects frame the context of this research. Most mega-projects can be seen as public investments in order to increase the overall quality of a nation's infrastructure. Mega-projects also mostly entail utilising new and innovative techniques for which major investments are needed. In most cases a choice needs to be made between either keeping the project simple by using standardised solutions and thus reducing the risks, or pushing innovation and striving for a more applicable and complete solution while taking on more risks and accepting complexity (Lessard & Miller, 2013). Lessard and Miller (2013) state that mega-projects are subjected to complex political and technical difficulties, which makes them complicated and complex and thus hard to manage properly. This in contrast with the more simple projects, which take place in a more predictable environment (Lessard & Miller, 2013). This also influenced the evolution of the decision-making processes related to mega-projects. Which is more and more directed towards considering "flexibility, adaptability, uncertainties, resilience and option values" (Priemus & Van Wee, 2013).

Mega-projects are increasingly procured through a public-private partnership (PPP). PPPs are based on a collaboration between the public and the private stakeholder working on the mega-project. By doing so it is believed that the outcomes are of higher quality than one party on its own could achieve. PPPs drive innovative projects and make the project's risks better to control. For PPPs long-term contractual relationships between the public and private stakeholders are created in order to achieve bilateral benefits. In most cases the designing and building of the mega-project is in hands of the private stakeholder, whilst the risks are allocated to the stakeholder who it best able to bear them. By contracting both the designing and building, and in some cases even the financing, maintaining and/or operating, out to one private party incentives for the private party to execute the mega-project to the best of its ability are high (Siemiatycki, 2013).

2 RESEARCH APPROACH

In this chapter the research design will be set up. This research design is aimed at answering the main research question. This main research question will be defined in the first paragraph of this chapter, alongside with the sub research questions, the objective and the relevance of the research. The second paragraph will elaborate on the chosen research methodology. The third and last paragraph of this chapter will discuss the research approach.

2.1 RESEARCH QUESTIONS, OBJECTIVE AND RELEVANCE

Based on the problem statement: *conventional project management shows to be inadequate for coping with complexity and uncertainty*, the research question was formed. This research question can be found in the first sub-paragraph. In this sub-paragraph also the sub-questions will be explained. In the second sub-paragraph the objective and the related deliverables of the research will be formulated. In the last sub-paragraph the relevance of the study will be discussed.

2.1.1 RESEARCH QUESTIONS

Conventional project management is not sufficiently adequate for coping with complexity and uncertainty, as occurring in many projects. It can thus be concluded that there is need for a new or a complementary approach. Two approaches receiving increasing attention due to the rethink of project management are Lean and Agile (Maylor, 2010). Due to scope decisions (see chapter three) it was chosen to investigate the applicability of Lean and Agile to the front-end development of infrastructure projects. This results in the following research question:

Could, and how could, a combination of Lean and Agile help coping with complexity and uncertainty in the front-end development of an infrastructure project?

To come to a clear answer to this research question three sub-questions were composed. Each of these three questions will be investigated in different parts of the research. In the end, answering these three sub-questions will lead to one clear answer to the main research question.

First of all it is important to know what the new approach should look like or how conventional project management should evolve. Since the need for a new approach is due to the increasing complexity and uncertainty of many infrastructure projects, it would be useful to know what it is that makes a project complex or uncertain.

1. *In what direction does project management need to evolve in order to cope with complexity and uncertainty?*
    - *1.1 What makes a project uncertain?*
    - *1.2 What makes a project complex?*
    - *1.3 What, in the field of project management, is needed to cope with complexity and uncertainty?*

Next it is useful to gain insight in both Lean and Agile. This to assess which strategies they provide to cope with complexity and uncertainty. By comparing this to the strategies of conventional project management to cope with complexity and uncertainty a profound basis for answering the main research question will be created.

2. *Can Lean and Agile be applied to the front-end development to cope with complexity and uncertainty?*
    - *2.1 What are the characteristics of the Lean approach?*
    - *2.2 What are the characteristics of the Agile approach?*
    - *2.3 How do Lean and Agile differ from conventional project management?*

Last, it is interesting to investigate whether the theory created, based on the answers to sub-questions one and two, is also practically applicable. For which elements of Lean and Agile can difficulties be expected when implementing them and does the application of these elements in practice really help with coping with complexity and uncertainty.

3. *Does the combined approach of Lean and Agile work in practice?*
    3.1 Which elements of Lean and Agile can, and which elements cannot, be used in practice?
    3.2 Does applying elements of Lean and Agile in practice lead to a better way of coping with complexity and uncertainty?

2.1.2 RESEARCH OBJECTIVE

By answering these questions and composing an answer to the main research question the objective of this research will be met. The objective is formulated as follows: *composing a grounded advice for civil engineering firms on whether Lean and Agile could help them to cope with complexity and uncertainty in a project's front-end development.* This objective, and thus the advice, is translated into three deliverables. These deliverables are listed below:

1. A framework of useful elements of Lean and Agile.
2. An advice on how to use the proposed elements of Lean and Agile.
3. An advice on how to implement the Lean and Agile ideal.

2.1.3 RELEVANCE

Scientific relevance

In the field of complexity and uncertainty much research is done. Many studies can be found aimed at defining complexity (Baccarini, 1996; Geraldi ,2008; Priemus et al., 2013; Whitty & Maylor, 2009) and uncertainty (Atkinson et al., 2006; Giezen, 2012; Kerzner, 2009; Perminova et al., 2008; Van der Heijden, 1996; Ward & Chapman, 2003). There are even several studies into defining frameworks in order to capture complexity. Frameworks with which complexity can be estimated (Ahmadi & Golabchi, 2013; Bosch-Rekveldt, 2011; Gidado, Wood & Ashton, 1996; 2004; Hertogh & Westerveld, 2009; Vidal, 2008). Also evident in literature are studies into what is needed to cope with complexity and uncertainty or, in other words, in which direction current project management practices need to evolve. These studies all emphasis the need for more flexibility and adaptability (Atkinson et al., 2006; Geraldi et al., 2008; Giezen, 2012; Koppenjan et al., 2010; Perminova et al., 2008; Priemus et al., 2013; Vidal, 2008). Yet practical tools for how to achieve flexibility and adaptability are scares or even not existing. Here a knowledge gap was found. This knowledge gap is also recognised by several researchers. Koppenjan et al. (2010) emphasise the need for studies that will bridge the gap "between existing project management theories, with their strong prescriptive slant, and the paradoxical reality of large engineering projects project managers have to cope with" (Koppenjan et al., 2010). Also Whitty and Maylor (2009) acknowledge this knowledge gap as they state that even though much research is done in the field of projects' complexity, which may provide us with much insight in the real situation, little research is done into developing practical tools in order to control or manage these complex projects. This research can be seen as a first step into bridging this knowledge gap. For this research practical tools of Lean and Agile will be tested to see whether they would be able to help coping with the complexity and uncertainty in many infrastructure projects. Maylor (2010) underpins the relevance of doing so. He states that, until 2010, little research is done in the field of applying Lean to project management. "The Toyota's of the project management world" (Maylor, 2010) are not discovered yet. He recognises that due to the successfulness of Lean in other sectors it would also be worthwhile to investigate the applicability of Lean to the field of project management. The same goes for Agile practices. Studies into Agile outside the IT world, until 2010, are scares. This could either be due to the fact that it is not applicable outside the IT world or due to the fact that this simply was never investigated (Maylor, 2010).

By conducting this research a step towards bridging the gap between the existing knowledge on project complexity and uncertainty and flexibility and adaptability which are needed to help managing this complexity and uncertainty, and practical tools to achieve flexibility and adaptability will be taken. In this research aspects of

Lean and Agile will be tested. This research thus links the knowledge gap with existing information on Lean and Agile in order to provide a first step towards the development of practical tools needed for the evolution of project management in order to cope with complexity and uncertainty.

Societal relevance

Bridging this knowledge gap is also relevant to the society. This because cost overruns on infrastructure projects can impact the wellbeing of a nation. Resulting from one infrastructure project suffering from cost overruns other infrastructure projects might get cancelled or even not considered anymore. Thus cost overruns on infrastructure projects affect the overall quality of a nation's infrastructure (Shane et al., 2009). Considering that infrastructure is one of the biggest contributors to a nation's economy one could conclude that cost overruns on infrastructure projects, leading to deterioration of a nation's overall infrastructure, do affect the wealth of a nation (Sachs, 2005; Collier, 2007). Also the fact that most mega-projects, which framed the context of this research, are funded with the public's money makes that this research is of societal relevance. Cost overruns on public infrastructure projects self-evidently lead to a waste of the public's money.

2.2 RESEARCH DESIGN

In this paragraph the research design will be discussed. First the different research methods which will be used to answer the three sub-questions will be discussed. This will be done in sub-paragraph 2.2.1. In the second sub-paragraph, 2.2.2, the final research design will be set up and elaborated.

2.2.1 RESEARCH METHODOLOGY

In order to create a starting point for the study a literature study on project management will be conducted. This literature study will be complemented with statements from three interviews with experts in the field of project management. This in order to create a clear view on conventional project management and the way project management is applied nowadays. In order to come to an answer to the first two research questions literature studies on complexity, uncertainty, Lean and Agile will be conducted. The choice for conducting literature studies was made based on the fact that for all aspects: project management, complexity, uncertainty, Lean and Agile, plenty of literature is available in order to provide sufficient answers to the first two research questions.

For answering the third research question a study will be performed. For this study a mixed methods research design will be used. The mixed methods research design "is an approach to inquiry that combines or associates both qualitative and quantitative forms". Where qualitative research "is a means for exploring and understanding the meaning individuals or group ascribe to a social or human problem" and quantitative research "is a means for testing objective theories by examining the relationship among variables" (Creswell, 2009). The choice for a mixed methods research was made because it was chosen to study the effect of using elements of Lean and Agile in the way the project's complexity and uncertainty is coped with, but also to study which elements of Lean and Scrum can, according to experts, really be used in practice and which cannot be used in practice or will lead to difficulties when used in practice. Which means that qualitative and quantitative data will be merged. Due to the fact that both studies will have their own limitations, combining both results will give a more complete overview which will lead to a better understanding in answering the main research question. Due to time limitations and the fact that the results will be merged and complement each other it was chosen to conduct a concurrent mixed methods research. There will be no predefined sequence of conducting the research.

For both studies a statistical test will be performed. For these tests mostly qualitative data will be collected, yet the data will be analysed in a more quantitative way. For the study into the practical use of the elements or characteristics of Lean and Agile it was chosen to conduct a factor analysis. This because the aim is to assess what experts think about the elements or characteristics and to see whether underlying dimensions or factors can be identified. By doing so groups can be distinguished. Normal factor analysis, conducted by means of the R method, tries to define groups of variables amongst the subjects, which are the set of respondents. For this research this would not add much value. For this research it would be interesting to define groups of subjects amongst the variables, thus define groups of respondents who share the same point of view. This can be examined by means of the Q method (Webler, Danielson, & Tuler, 2009). An elaborate explanation of the Q method is provided in appendix C. For the study into the relationship between the implicit use of Lean and Agile and the ability to cope with complexity and uncertainty it was chosen to conduct a correlation analysis. This because here the existence, strength and direction of the relationship between complexity elements and Lean and Agile elements is to be studied. An elaborate explanation of correlation analysis is provided in appendix C.

2.2.2 FINAL RESEARCH DESIGN

Concluding, the research design, as can be seen in figure 2 was set up. In the second part of this thesis the theoretical framework will be set up. This theoretical framework will include a literature study on project management which will be combined with information obtained from the interviews, a literature study on complexity, a literature study on uncertainty and a literature study on both Lean and Agile. This theoretical framework will provide answers to the first two research questions. After composing the theoretical framework, the research will be conducted. The correlation analysis and the Q sorting research will take place concurrently. For both first a survey will be constructed and conducted, thereafter the results will be analysed. For the correlation analysis results of the entire theoretical framework are relevant, whilst for the Q sorting research only the results of the literature studies on Lean and Agile will be relevant. After the results are analysed conclusions for both studies will be formed, which will provide an answer to the third research question. Combining the results will lead to the formation of the final conclusions and recommendations. These conclusions will correspond with answering the main research question and the recommendations will correspond with the objective of this study.

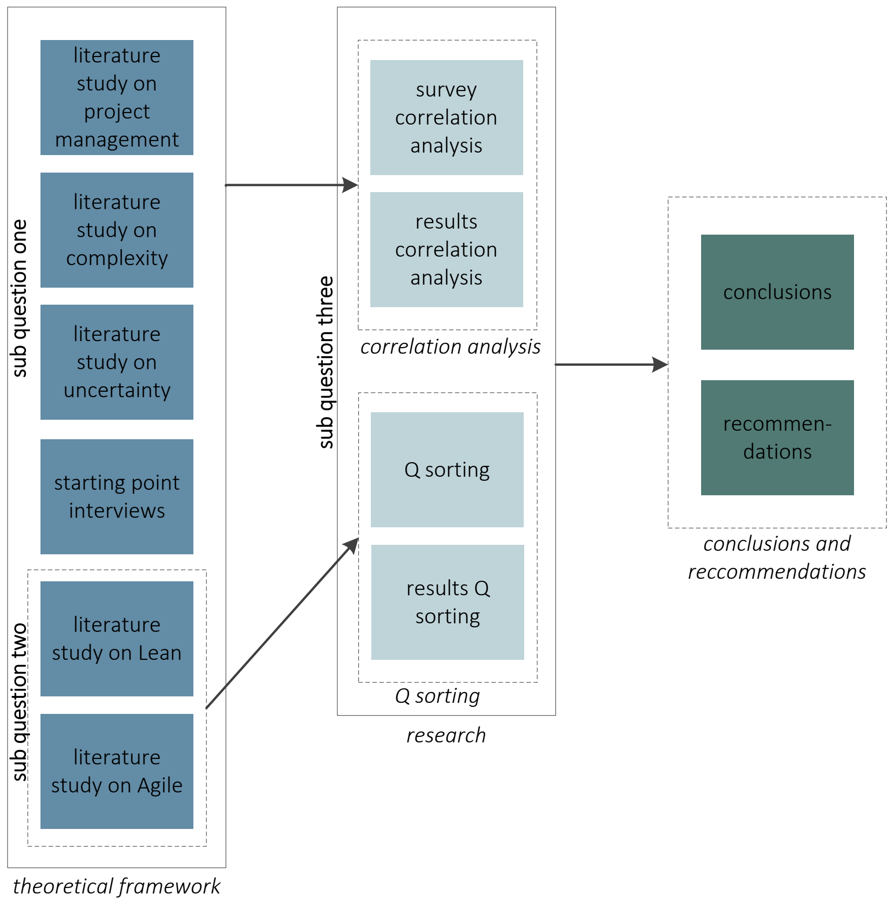


figure 2: final research design

3 SCOPE OF THE RESEARCH

In this paragraph the scope of the research will be defined. According to the Oxford Dictionaries the definition of the word scope is: "the extent of the area or subject matter that something deals with or to which it is relevant". Therefore, in this paragraph, the area in which the research will be conducted will be specified. As can be seen in figure 3, the scope is defined by three different aspects. Each of these aspects will be discussed in the sub-paragraphs of this paragraph.

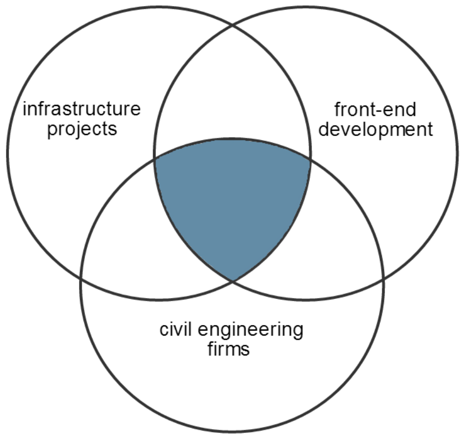


figure 3: research scope

3.1 INFRASTRUCTURE PROJECTS

The research will be conducted for infrastructure projects. This because of personal interest, but also because of the focus of the company for whom this research will be conducted (see 3.3). The Oxford Dictionaries gives the following definition of a project: "An individual or collaborative enterprise that is carefully planned to achieve a particular aim." Also the Project Management Book of Knowledge, or PMBoK guide, provides a definition of a project: "A project is a temporary endeavour undertaken to create a unique product, service, or result. The temporary nature of projects indicates that a project has a definite beginning and end." (Project Management Institute [PMI], 2013). In general it can thus be said that a project has two main characteristics:

1. unique aim or end product
2. defined begin and end, thus temporary

These two characteristics can also be found in construction projects. As Koskela (1993) described, a construction project has different peculiarities. The first being that a construction project is one-of-a-kind and can be seen as unique (Koskela, 1993). This peculiarity corresponds with the first characteristic, as defined above. The second peculiarity, which partially corresponds with the second characteristic as defined above, is that a project is undertaken by a temporary project team. In construction projects, not only the project itself, the achievement of a unique aim or creation of a unique end product, is temporary, but also the project team responsible for achieving the aim is temporary. There are temporary linkages between the team members in the project team. The third peculiarity describes the fact that in construction projects there is on site production. This means that the complete end product is produced in or on the end location of the product (Koskela, 1993).

Since infrastructure projects can both be scaled under projects and construction projects, they will show the characteristics as described above. Yet, there are more things that set infrastructure projects apart from other kind of projects. Both, Paul Collier (2007) and Jeffrey Sachs (2005) described that infrastructure is one of the biggest contributors to the economy of a nation. The wealth of a nation is partially affected by the state of its infrastructure (Collier, 2007; Sachs, 2005). This means that infrastructure projects are of great importance for nations. On the long-term a sufficient state of a nation's infrastructure could lead to a growing economy, yet as already mentioned in chapter one the failure, in terms of cost overruns and delays, of infrastructure projects could also damage the nation's economy, since there will be less money available for other infrastructure projects. This shows that infrastructure projects have significant influence on the economy, and thus wealth, of a nation and therefore the performance of an infrastructure project is of great importance. The performance of infrastructure projects is lately complicated by the fact that infrastructure projects are becoming more and more complex (Omar, Trigunarsyah, Wong, 2009). This increased complexity makes that an infrastructure project has even more specific characteristics. The long time-span of many complex infrastructure projects leads to higher risks, also affected by the fact that in most complex projects new and not standard technologies are used. Many actors are involved, with each their own interest in the project, this could lead to difficulties with the decision making and could also lead to scope changes and unplanned events. All together this in most cases leads to inefficiency and suboptimal value generation (Flyvbjerg, 2005b). For most infrastructure projects these are the characteristics.

3.2 FRONT-END DEVELOPMENT

For this thesis a decision was made to focus on the front-end development (FED) phases of an infrastructure project. During the FED of a project the information needed to make the final investment decision, the decision on whether or not the project will be executed, will be compiled. In general in the FED phases the project is initiated, the requirements are set up and the way these requirements can be met is set out. All the steps from initiation to execution are part of the FED of a project. Or in other words, the scope of the project is established. It is important that this scope description meets the requirements set for the project, since this scope description is frozen early on in the project. In general the front-end development of a project can be divided into three stages: FED1, FED2, and FED3 (Bosch-Rekveldt, 2011).

- FED1: In this first phase of the front-end development the objectives and constraints for project performance, which mostly define the budget and time available for the project and the aimed quality of the end product, are set. The desired outcome of the project is described functionally, a risk analysis is performed and a planning for the following two phases of the FED is created.
- FED2: In this second phase of the front-end development alternatives are created, assessed and compared. FED2 results in the decision on one preferential alternative.
- FED3: In this last phase of the front-end development the preferred alternative is worked out in more detail. The level of detail needs to be sufficient in order to make the final investment decision, yet creating a detailed design mostly is not part of the FED phases but is part of the execution phase. The preferred alternative sets the scope for the execution phase. The scope will be frozen as much as possible.

  (Bosch-Rekveldt, 2011)

It is pointed out by quite some researchers that the front-end development of a project is vital for ensuring the project will perform up to standard (Paulson, 1976; Josephson, 2009; Bosch-Rekveldt, 2011; Lessard & Miller, 2013). The influence of the decisions made in these phases of a project on the actual final costs is the greatest, compared to the other phases of a project (Paulson, 1976). Defects in the FED phases are the biggest contributors to cost overruns (Josephson, 2009). In order to enable a smooth execution phase accurate and complete FED phases are needed. Yet, for most projects the complexity and uncertainty is these phases is underestimated (Bosch-Rekveldt, 2011). Thus, by recognising and managing the complexity and uncertainty in the FED phases of a project the overall project performance would theoretically increase.

3.3 CIVIL ENGINEERING FIRMS

As already mentioned in the preceding this research will focus on the FED phases of a project. This also because of the fact that the objective of this research is to create a substantive advise for civil engineering firms on how they can cope with complexity and uncertainty in their projects. A generalisable advise will be created, which will be done by using Antea Group as an example civil engineering firm. In order to give some context, a short description of the company will be provided below.

Antea Group is an international civil engineering and environmental consulting firm, which operates in several fields. It has locations in several continents and countries, including: Africa, Belgium, Colombia, France, the USA and the Netherlands. In total the group has over 3,000 employees located in around a 100 offices. The name Antea Group originates from the ancient Greek mythological figure Antaeus, who gained strength by keeping close contact with the earth. Which is reflected in the nature of the company. Antea Group is part of Oranjewoud N.V., in which also Dutch contracting company Strukton takes part. Oranjewoud N.V. is a listed company and is currently for 95.56 per cent owned by Gerard Sanderink. In 2012 Oranjewoud N.V. had a turnover of 1.8 billion euros (Antea Group, 2014a; Antea Group, 2014b).

Antea Group the Netherlands, formerly known as Oranjewoud Consulting and Engineering Firm, was founded by two Frisian brothers right after World War II. Nowadays Antea Group the Netherlands has eight offices spreading across the country. Antea Group the Netherlands is active in several work fields: *infrastructure, sports, water, space, environment* and *realization*. These are called the business lines. Each of these business lines consist of different departments. This research will be conducted for the department *Roads*, as part of the business line *infrastructure* (Antea Group, 2014c).

4 THESIS OUTLINE

Regarding the problem statement, a solution will be put forward and there will be investigated whether this solution could lead to the ability to cope with complexity and uncertainty. In order to come to a substantive advice regarding the proposed solution, the thesis outline as shown in figure 4 will be followed. As can be seen, this thesis is divided into four parts. These first four chapters are part of part one, the introduction. In part two a theoretical framework will be provided. In the first chapter of part two, chapter five, a literature study on conventional project management, complexity and uncertainty will be presented. Chapter six presents a literature study on Lean and Agile. In part three the research will be conducted. First, in chapter seven, the data gathering will be discussed. Chapter eight will elaborate on both analyses and the results from the analyses. In the fourth and final part of this thesis the conclusions and recommendations will be formulated. First in chapter nine a discussions will be formed, next the conclusions will be discussed. This will be done in chapter ten. In the final chapter, chapter eleven, recommendations regarding the objective of the research and recommendations for further research will be provided.

figure 4: thesis outline

TWO//

THEORETICAL FRAMEWORK

5 PROJECT MANAGEMENT, COMPLEXITY AND UNCERTAINTY

In this chapter the first part of the theoretical framework will be set up. First of all an introduction to project management and a brief history description of project management will be provided (5.1). Next, in the second paragraph (5.2), the phenomena complexity and uncertainty will be discussed and explained. In paragraph 5.3 a literature review on what is needed to cope with this complexity and uncertainty in projects is conducted. This last paragraph will provide an answer to sub research question one.

5.1 HISTORY OF PROJECT MANAGEMENT

In this paragraph the history and the maturity of project management will briefly be discussed. The history of project management can roughly be divided into three stages. The first stage being the period before the 1950s. This period is characterised by the lack of standard, generally accepted, project management methods and tools. Project management in this period was a tailor made practice. From the 1950s, after World War II, a standard approach emerged (Maylor, 2010), which was based on best practices (Wysocki & McGary, 2003). This standard approach is described in several bodies of knowledge and handbooks like the PMBoK guide as set up by the Project Management Institute (PMI, 2013) or the IPMA Competence Baseline as set up by the International Project Management Association (Caupin et al., 2006). Sub-paragraph 4.1.1 will further elaborate on this view on project management. Ideas beyond this conventional view on project management characterise the last stage, the 1990s and onwards (Maylor, 2010). These new ideas emerged as a result of increased awareness of the changing and dynamic environment of a project (Bosch-Rekveldt, 2011). Sub-paragraph 4.1.2 will further elaborate on this 'trend' in project management.

5.1.1 1950S – CONVENTIONAL PROJECT MANAGEMENT

Project management as we know it today, or conventional project management, emerged in the 1950s in the Defence and Aerospace sectors. These sectors in this timeframe can be characterised as little flexible and complex (Morris, 1994). This little flexible and complex context in which project management emerged defined project management as we know it today, as can be noted from the underlying assumptions about project management. It assumes that project management is rational and normative, that there is only one reality based on causal relationships, and that scope management by deconstruction, in forms of for example a Work Breakdown Structure, should be the main concern (Williams, 2005). Conventional project management is aimed at predetermining time, budget and performance goals by extensive front-end analysis, which results in a "blueprint-type scope description" specifying the tasks which need to be performed and a planning based on this scope description, which both will be "frozen and strictly controlled during execution" (Koppenjan et al., 2010).

A more elaborated description of conventional project management will be provided by means of the most commonly used guidelines as described in the PMBoK guide (Koskela & Howell, 2002). The PMBoK guide states that a project in general consist of two processes, which are to be performed by the project team. The project management processes, which focus on creating sufficient flow and the product-oriented processes, which focus on the specification and creation of the end product. The PMBoK guide mainly focuses on the former (PMI, 2013). In the guide project management is defined as follows:

> Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is accomplished through the appropriate application and integration of the 47 logically grouped project management processes, which are categorized into five Process Groups. These five Process Groups are: initiating, planning, executing, monitoring and controlling, and closing (PMI, 2013).

These Process Groups are thus part of the project management processes. Below only the two most distinct Process Groups, planning and monitoring and control, of conventional project management will be discussed, alongside with some product-oriented process features of conventional project management.

Planning processes: "Those processes required to establish the scope of the project, refine the objectives, and define the course of action required to attain the objectives that the project was undertaken to achieve" (PMI, 2013).

The planning process is a preliminary phase of the project in which all aspects of, amongst others, the time, budget and performance goals of the project are explored and defined (PMI, 2013). The planning and scope description will be "frozen and strictly controlled during execution" (Koppenjan et al., 2010). Changes, as a result of the monitoring and controlling processes, have significant impact on the planning and budgeting of the project, since those should be adjusted accordingly in order to meet the predefined scope of the project (PMI, 2013). The planning can be seen as a very important tool, as the execution of a tasks begins according to when the tasks were planned to begin (Koskela & Howell, 2002). According to the PMBoK guide the project manager performs "activities such as scheduling, budgeting, reporting and control, communications, risk management and administrative support" (PMI, 2013). The project manager is the one who sets up the planning and who authorises a task to start and thus "coordinative steer is highly hierarchical" (Koppenjan et al., 2010).

"The project leader sets up the framework for a task, based on the available budget, the deadline for the task and the required quality of the task" (G. Roovers, personal communication, April 4, 2014).

Monitoring and controlling processes: "Those processes required to track, review, and regulate the progress and performance of the project; identify any areas in which changes to the plan are required; and initiate the corresponding changes" (PMI, 2013).

Conventional project management is based on the transformation principle (Koskela, 2000). Slack, Chambers and Johnston (2007) defined the transformation principle as the process of transforming input resources into output. The input and the output are the main focus points of the transformation principle. The process converting the input into the output itself is not taken into consideration (Koskela, 2000). Conventional project management can thus be seen as activity centred and is based on a systems approach. Control is exercised by dividing the project into smaller pieces, creating narrow task descriptions for these pieces and contracting based on these sub tasks (Koppenjan et al., 2010). By cutting the project into pieces, in for example a Work Breakdown Structure, and by executing the different pieces/tasks in a linear and sequential order the project is kept manageable (Giezen, 2012).

"In this WBS the project is divided in several sub-projects and for each sub-project a sub-project leader is assigned" (R. Koenraadt, personal communication, April 4, 2014).

Performance is measured and analysed by comparing the output to quality standards, this in order to identify variances from the predetermined scope description (PMI, 2013). Variances from the predetermined scope, or thus changes of the scope are considered highly undesirable (Koppenjan et al., 2010) and should thus be removed or substantially reduced (Atkinson et al., 2006). Progress related to the time goals is measured by means of the planning. Monitoring and controlling is thus achieved by comparing the outcome with the predefined time, budget and performance goals.

"We actually use the planning as a control instrument" (R. Koenraadt, personal communication, April 4, 2014).

Product-oriented processes: "These processes specify and create the project's product" (PMI, 2013).

First of all the product-oriented processes are characterized by the fact that conventional project management sees a construction project as a unique and one-of-a-kind project (Koskela, 1993). The PMBoK guide endorses this feature: "a project is a temporary endeavor undertaken to create a unique product, service, or result" (PMI, 2013).

"...most advisors believe that each project is unique and one-of-a-kind...standardizing is not in our culture. We don't like to do the same thing twice, but we like to invent new possibilities" (R. De Boer, personal communication, March 26, 2014)

Another distinct feature of conventional project management regarding product-oriented processes relates to design alternatives. The conventional project management approach to design alternatives is that funnelling should take place as soon as possible and an irreversible action plan based on this funnelling is to be created. In most cases one preferential alternative is chosen early on in the project, dropping numerous other worthwhile alternatives (Priemus et al., 2013; Priemus, 2007). It is common, also because of the recently rising time pressure on projects, to just start the process as soon as possible and deal with problems later (Ballard & Zabelle, 2000).

"In our projects we always begin with several alternatives, which are elaborated. In the most ideal case, one preferential alternative is chosen" (G. Roovers, personal communication, April 4, 2014).

5.1.2 1990S – PREPARE-AND-COMMIT APPROACH

Starting in the 1990s and still growing is the awareness of the changing and dynamic project environment (Bosch-Rekveldt, 2011). It is recognized that the complex and changing context of a project makes it impossible to make reliable predictions, and instead of predicting and correspondingly avoiding changes, changes need to be incorporated in the project (Priemus et al., 2013). This asks for a broader approach, which Koppenjan et al. (2010) named the "prepare-and-commit" approach. This approach recognises that scope changes are inevitable, due to the many unknowns and the client's learning curve, and thus acknowledges the uncertainty and complexity of many infrastructure projects (Koppenjan et al., 2010). So both uncertainty and complexity should be managed by this prepare-and-commit approach in order to be effective (Atkinson et al., 2006). Several researchers (Geraldi, 2008; Geraldi et al., 2008; Perminova et al., 2008; Koppenjan et al., 2010) argue that project management should evolve or mature in this direction, and thus conventional project management should be combined with the prepare-and-commit approach. Geraldi (2008) states: "projects demand both mechanic and organic paradigms, both order and chaos". With order being reflected by conventional project management and chaos by the awareness of complexity and uncertainty. Combining both approaches means that a certain degree of flexibility is needed or in other words a balance between controlling complexity and uncertainty and maintaining flexible in order to cope with complexity and uncertainty (Geraldi, 2008; Koppenjan et al., 2010).

5.2 COMPLEXITY AND UNCERTAINTY

From the preceding it became clear that awareness of the complexity and uncertainty of many infrastructure projects is increasing and that project management should evolve in this direction. Yet, what exactly is complexity and uncertainty and how do they relate to one another? This paragraph is aimed at defining both phenomena. Sub-paragraph 5.2.1 aims to define uncertainty and sub-paragraph 5.2.2 aims to define complexity and will also elaborate on the relation between both phenomena. Sub-paragraph 5.2.3 summarizes the theories on complexity and uncertainty.

5.2.1 UNCERTAINTY

Q1.1 What makes a project uncertain?

Uncertainty in projects is a given fact, all projects have to deal with some extend of uncertainty. In the early stages of the project uncertainty will be extensive but will decrease as the project evolves, due to the learning curve of the project's stakeholders (Kerzner, 2009). Giezen (2012) described uncertainty as the antonym of planning, as the "possible failure to control consequences of our actions" (Giezen, 2012). Uncertainty can be seen as an event, which might have been considered in advance, yet was unexpected (Perminova et al., 2008). Van der Heijden (1996) distinguishes three types of uncertainties. The first one being risks, which are the uncertainties for which probabilities and impacts can be estimated in advance, due to lessons learned from similar contexts. Second type of uncertainties are the structural uncertainties, for these uncertainties one is unable to predict the likelihood or probability due to the uniqueness of the event, yet one does know in advance that the future event will happen. The last type of uncertainty, the unknowables, are future events for which it is impossible to know in advance that they will happen. One is aware that unknowable uncertainties will be present, due to lessons learned from past experiences, yet it is impossible to estimate what these events will entail (Van der Heijden, 1996). These three types of uncertainty are summarized in table 1.

table 1: types of uncertainty

type of uncertainty	characteristics		
1) risks	awareness	event	probability
2) know uncertainties	awareness	event	
3) unknown uncertainties	awareness		

It can thus be concluded that risks and uncertainties are not the same. Each risk is an uncertainty, but not each uncertainty is a risk. Several researchers (Ward & Chapman, 2003; Atkinson et al., 2006; Perminova et al., 2008) emphasize the negative connotation of the word 'risk'. Risks are mostly considered to be undesired events, which negatively influence the performance of the project. Or in other words, risks are considered to be threats to the project. Normally most attention is paid to these undesired events, or risks (Atkinson et al., 2006), whilst in every situation also desired events, or opportunities are involved. It is important that the management also pays attention to this last form of uncertainty (Ward and Chapman, 2003).

Different causes for uncertainty are described in literature. Atkinson et al. (2006) define completeness, or incompleteness, of information, the amount of differentiating interests and the project's sensitivity to external influences as three main causes for uncertainty. Ward and Chapman (2003) assign the occurrence of uncertainty to ambiguity amongst the stakeholders. Perminova et al. (2008) argue that uncertainty could also be the cause of a project's complexity.

5.2.2 COMPLEXITY

Q1.2 What makes a project complex?

But what is complexity and what makes that a project is considered to be complex? The dictionary (as cited in Baccarini, 1996) gives two definitions of complexity. The first one is concerned with the amount of differing but interrelated parts. Following this definition a project can thus be characterized as complex when it exists of many different and interrelated parts. Thus a project's complexity is defined by differentiation and interdependencies. This definition reflects a systems approach. The second definition defines complexity as complicated, intricate or involved. Where the state of complication, intricateness and involvement can and will be interpreted in many different ways. This meaning of complexity is thus subjected to subjectivity, it’s in the eyes of the beholder (Baccarini, 1996). Also Whitty and Maylor (2009) make this distinction. They first state that complexity can be defined as having many components with an emergent behaviour. But they also recognize the fact that complexity is in the eyes of the beholder, as they state that complexity can be seen as a "measure of inherent difficulty to achieve the desired understanding of a complex system" (Whitty & Maylor, 2009). Vidal (2008) provides an explanation of perceived, in the eyes of the beholder, complexity. Due to the fact that each person has his or her own references and culture, his or her perspective on the project’s complexity will thus differ from another person’s perception of the complexity and will also differ from reality (Vidal, 2008). Priemus et al. (2013) state that perceived complexity depends "on previous experiences and different roles in the project". But also the complexity characteristic of a project itself makes that the reality and complexity of the project in essence cannot be understood completely. There will always be some residual uncertainty as a result of the project's complexity. This makes that decisions in complex projects are always made on the basis of perceived complexity, which hampers accurately forecasting the project's evolution (Vidal, 2008).

Also where this complexity originates from is described in literature. Maylor and Vidgen (as cited in Whitty & Maylor, 2009) distinguish individual and interacting structural elements as the first type of complexity and the dynamic effects as result of these elements changing, and then interacting causing also change in other elements. They also state that structural complexity, unlike dynamic complexity, can be quantified, measured and thus predicted and prepared for (Maylor and Vidgen, as cited in Whitty & Maylor, 2009). Also Hertogh and Westerveld (2009) recognize these dynamic effects. They distinguish detailed and dynamic complexity. Where detailed complexity deals with the components and the interrelations in the stakeholder-, product-, and activity sub-system and dynamic complexity deals with uncertainties in the decision-making and unpredictable cause-and-effect relations (Hertogh & Westerveld, 2009). Geraldi (2008) distinguishes complexity in three types, namely complexity of faith, complexity of fact and complexity of interaction. Complexity of faith is the complexity that emerges from uniqueness or newness of the project, and thus relates to uncertainty. One needs to have faith that the project will turn out well, since this cannot be accurately estimated. Complexity of fact is defined as being structural complexity. Structural complexity relates to a high amount of interrelated information (Geraldi, 2008). This type of complexity corresponds with the first type of complexity as mentioned by Baccarini (1996). Thirdly she distinguishes complexity of interaction. This type of complexity relates to the interfaces between persons (Geraldi, 2008).

Next several researchers defined different types or categorizations of complexity (Baccarini, 1996; Hertogh & Westerveld, 2009; Bosch-Rekveldt, 2011). Based on an extensive literature study Baccarini (1996) defines two categories of complexity, being organizational complexity and technological complexity. With organizational complexity explained as differing and interrelated levels in the organization, organizational units and tasks and division of tasks. Technological complexity is explained as differing and interrelated inputs and outputs, actions or tasks to produce the end product and specialities involved in the project (Baccarini, 1996). Hertogh and Westerveld (2009) on the other hand concluded that there are six types of complexity: technical, social, financial, legal, organisational and time. Technical, financial, legal and organisational complexity all could lead to social complexity. Changes in these types of complexities could influence interests and perceptions and thus lead to social complexity. Social complexity is therefore the core of the project's complexity (Hertogh & Westerveld, 2009). Bosch-Rekveldt (2011) distinguishes three main types of complexity, being technical complexity, organizational complexity and complexity of environment.

Several researchers (Gidado, Wood & Ashton, 1996; 2004; Vidal, 2008; Hertogh & Westerveld, 2009; Ahmadi & Golabchi, 2013; Bosch-Rekveldt, 2011) have formed frameworks to help quantifying complexity. By using such a framework a 'footprint' of where complexity is present in the project can be created. When there is insight in where complexity is to be expected in the project, several front-end measures can be taken, like a risk analysis (Bosch-Rekveldt, 2011). It can also be used to decrease the gap between real project complexity and perceived project complexity, as filling out the framework will create more insight in the real complexity of the project. In this thesis it was chosen to also define such a complexity framework. For this framework, the TOE (Technical, Organizational, External) framework as set up by Bosch-Rekveldt (2011) was used as a basis. This because of the elaborate literature and case study that preceded the creation of this framework. Yet, due to the considerable size of this framework, existing of 50 elements, it was chosen to compare the framework of Bosch-Rekveldt (2011) to three other frameworks found in literature (Gidado, Wood & Ashton, 1996; 2004; Hertogh & Westerveld, 2009; Ahmadi & Golabchi, 2013). The framework of Vidal (2008) was not taken into account due to the fact that this framework was part of the literature study that preceded the setup of the TOE framework. An more elaborate literature study on the selection of the final elements can be found in appendix E. In table 2 a summarization of this study can be found. The elements which were mentioned by two or more researchers are included, leading to a total of 22 elements.

table 2: complexity frameworks

#	element	Gidado, Wood & Ashton (1996; 2004)	Hertogh & Westerveld (2009)	Ahmadi & Golabchi (2013)	Bosch-Rekveldt (2011)
1	clarity of goals	x			x
2	changes in scope			x	x
3	number of tasks		x	x	x
4	variety of tasks		x	x	x
5	dependency of tasks	x	x	x	x
6	experience of the project management	x			x
7	interrelations between processes	x	x		x
8	usage of new technologies		x	x	x
9	experience with used technologies	x		x	x
10	uncertainty of technological environment	x	x		x
11	project duration		x		x
12	availability of resources and skills	x			x
13	interfaces between disciplines	x			x
14	financial resources		x		x
15	amount of contracts		x		x
16	level of communication	x			x
17	changes in organisation			x	x
18	conflicting interests, perceptions and interpretations of stakeholders	x	x		x
19	political influence	x	x		x
20	level of impact on environment	x	x		x
21	uncertainty of environment (not technical)	x		x	x
22	availability of information	x		x	

As can be noted two out of the 22 elements are related to uncertainty (elements 10 and 21). This is due to the fact that uncertainty relates somehow to complexity. Perminova et al. (2008) argue that uncertainty could be caused by a project's complexity. Also Vidal (2008) shares this point of view as he states that uncertainty can be considered as a negative consequence of a project's complexity. He also argues that uncertainty is related to the interactions in a projects. Uncertainty makes a project unpredictable which he states is the "core characteristic" of a project's complexity (Vidal, 2008). So both Perminova et al. (2008) and Vidal (2008) argue that uncertainty is caused by complexity. Williams (1999) argues that uncertainty adds to a project's complexity and that it thus also can be seen as one of the characteristics of complexity. This view is shared by Bosch-Rekveldt (2011) who argues that uncertainty is not caused by complexity but causes, amongst other things, complexity. Thus, complexity causes uncertainty, but uncertainty also causes complexity. Williams (1999) provides insight in this contradiction, as he discusses that one should consider structural complexity and uncertainty as two separate concepts both adding to the "difficultness and messiness of the overall project". Which can be considered as the overall complexity of the project (Williams, 1999). Following this distinction between structural complexity and uncertainty, a similarity can be reckoned between uncertainty and dynamic complexity combined with complexity of faith, as they were mentioned by several researchers (Geraldi, 2008; Maylor & Vidgen, as cited in Whitty & Maylor, 2009; Hertogh & Westerveld, 2009). Thus in this thesis the definition of a project's overall complexity, as provided by Williams (1999), that complexity is caused by both structural complexity and uncertainty, will be followed. In table 3 the elements of the complexity framework are categorised in elements related to structural complexity, uncertainty and perceived complexity.

table 3: categorisation of elements

structural complexity		uncertainty		perceived complexity	
1	clarity of goals	2	changes in scope	6	experience of the project management
3	number of tasks	10	uncertainty of technological environment	9	experience with used technologies
4	variety of tasks	17	changes in organisation		
5	dependency of tasks	21	uncertainty of environment (not technical)		
7	interrelations between processes				
8	usage of new technologies				
11	project duration				
12	availability of resources and skills				
13	interfaces between disciplines				
14	financial resources				
15	amount of contracts				
16	level of communication				
18	conflicting interests, perceptions and interpretations of stakeholders				
19	political influence				
20	level of impact on environment				
22	availability of information				

5.2.3 SUMMARIZING COMPLEXITY AND UNCERTAINTY

In figure 5 the theories on complexity and uncertainty are summarized. Here it is assumed that structural complexity, translatable by the elements listed above the structural complexity rectangle, causes uncertainty, translatable by the elements listed above the uncertainty rectangle and being risks, known uncertainties and unknown uncertainties. Both add to the overall complexity of the project. Yet, the real overall complexity is subjected to different perceptions and thus one deals with perceived complexity, translatable by elements six and nine.

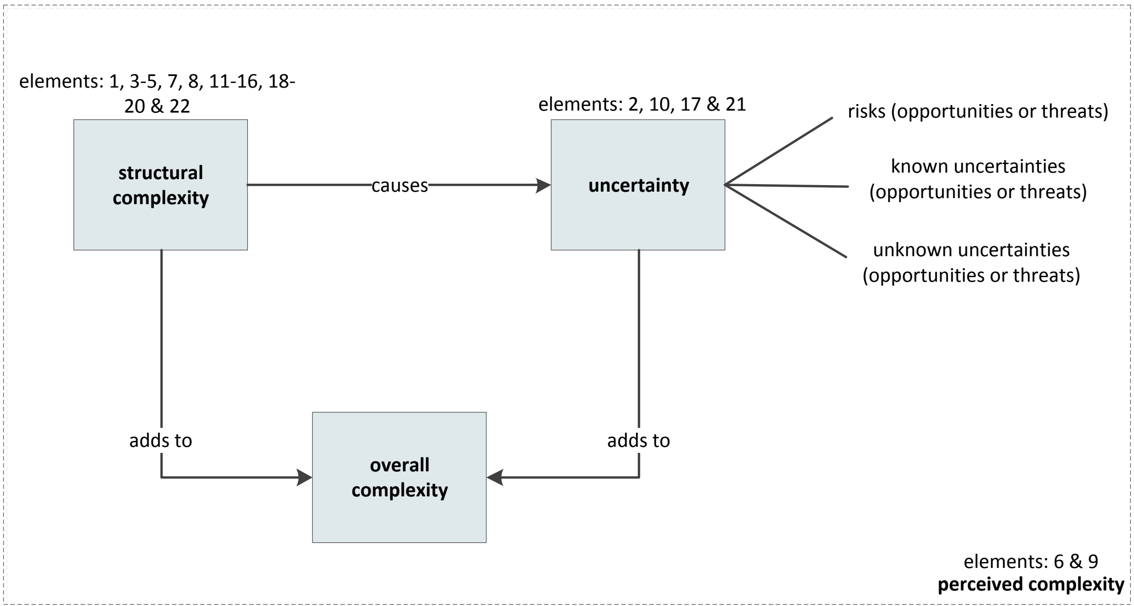


figure 5: summarization of complexity and uncertainty

5.3 WHAT IS NEEDED TO COPE WITH OVERALL COMPLEXITY?

Q1.3 What, in the field of project management, is needed to cope with complexity and uncertainty?

Complexity can both negatively, in forms of threats, and positively, in forms of opportunities, influence the project. The project should thus be managed in such a way that threats are diminished and opportunities are seized (Vidal, 2008). Since conventional project management "tends not to address many fundamental sources of uncertainty", there is need for another, or complementary kind of management (Atkinson et al., 2006). Combined with conventional project management in such a way that the pitfalls of the one are compensated by the other (Koppenjan et al., 2010). Geraldi et al. (2008) discuss that project management needs to recognize and structure the embedded chaos of a project. For this more of a "non-discipline" is needed that looks into and deals with the chaotic reality of a project (Geraldi et al., 2008). Koppenjan et al. (2010) argue that project management needs to be a combination of control and flexibility. Where control means that parameters should be specified and stuck to and flexibility means that necessary changes should be accepted. A combination of both is preferable, yet in practice one will most probably dominate the other. This means that the dominant approach should be complemented with the other approach in order to compensate for its pitfalls and weaknesses. In most cases the easy to quantify parameters time and budget can be management in the conventional way, whereas the more 'soft' and more complex parameters: scope and quality, need to be management via a more flexible approach (Koppenjan et al., 2010).

Thus conventional project management needs to be complemented with a more flexible and adaptive approach. But how can flexibility be achieved? Priemus et al. (2013) argue that adaptability is needed. Adaptability can be defined as the ability to adapt to changes (Giezen, 2012). Complex projects need adaptions to overcome internal deadlocks and external changes, this in order to manage threats and opportunities. In order to be adaptive the project needs redundancy and resilience. There needs to be a redundancy of possible alternatives. Thus all possible options should be kept open and a decision should be made at the last responsible moment. For this a redundancy in needed information and stakeholders is needed. Resilience relates to the way the project can cope with unexpected changes. Is the project able to deal with changes, without encountering deadlocks or delays. In order to create a resilient process adaptability and flexibility is needed to cope with these uncertainties. Conventional project management applies reactive resilience. The project is protected against uncertainties in order to create a stable process. A more proactive approach will require adaptation and thus implies resilience. Resilience needs redundancy. Alternatives are needed to react to unexpected changes, thus the scope of the project can change during the project (Priemus et al., 2013). Koppenjan et al. (2010) agree with the fact that flexibility is needed in order to cope with complexity and uncertainty. They named the approach based on achieving flexibility the 'prepare-and-commit approach'. For this the terms of reference or the scope description needs to be based on function specification, the tasks need to have a broader definition, there is a need for close cooperation between the involved stakeholders and also the contracts need to be based on a functional scope definition. The project needs to recon that change is inevitable and can also lead to opportunities and not only threats, hierarchical steering should be replaced by a more self-steering of the complete project team and information exchange needs to be more open and last the responsibility for managing the interfaces should be shared with all stakeholders involved (Koppenjan et al., 2010).

Giezen (2012) focuses on managing complexity. The solution put forward is to keep projects simple. By reducing the complexity of the project, also the uncertainty will be reduced, which makes the project better to predict and thus becomes better manageable. Yet there are also some disadvantages of reducing the complexity, the project could for example become too simple and consequently will ignore the project's strategic potential. The extent to which the project is kept simple or not depends on the project's context (Giezen, 2012). Perminova et al. (2008) share this view. They state that reflective learning and sense-making is needed to create flexibility. Standardization or repetitiveness of procedures will lead to reflective learning and will lead to flexibility, since reacting to changes by choosing between several alternative actions becomes easier. Yet, it does not eliminate all uncertainty, which is also not desirable. Uncertainty can be greatly reduced by reflective learning, yet some uncertainty is wished for since uncertainty can also entail opportunities. By eliminating all uncertainties opportunities cannot be seized, which will hamper evolution (Perminova et al., 2008).

Atkinson et al. (2006) discuss several strategies for reducing uncertainty. They state that replacing ambiguity by vagueness will help coping with uncertainty. The project needs to be tolerant to vagueness. They also argue that incompleteness of information and unevenly distributed information is one of the main causes for uncertainty. The most easiest way to solve this problem is by trust. Attention needs to be paid to trust amongst the stakeholders. The right balance between trust and control is needed, with trust overarching (Atkinson et al., 2006).

Q1	*In what direction does project management need to evolve?*

In order to cope with complexity and uncertainty the new or complementary approach needs to have the following characteristics:

- Considering all possible alternatives and making a decision at the last responsible moment (redundancy) (Priemus et al., 2013).
- Using standardization to an extent that fits with the project's context in order to achieve reflective learning (Giezen, 2012; Perminova et al., 2008).
- Recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats (resilience) (Priemus et al., 2013).

For this there needs to be:

- A functional scope description (Koppenjan et al., 2010).
- Close cooperation between the stakeholders (Koppenjan et al., 2010).
- Self-steering of the complete project team (Koppenjan et al., 2010).
- Open information exchange (Koppenjan et al., 2010).
- Trust (Atkinson et al., 2006).

6 LEAN AND AGILE APPROACH

In this chapter Lean and Agile will be introduced and it will be discussed how Lean and Agile can help coping with the overall complexity of a project. The first paragraph (6.1) will elaborated on Lean. Paragraph 6.2 provides a literature review on Agile. Next the Lean and Agile approach to the front-end development phases will be compared to the conventional project management approach to the front-end development phases (6.3). Finally the two parts of the theoretical framework will be linked by discussing how Lean and Agile could help coping with overall complexity (6.4). This last paragraph will provide an answer to sub research question two.

6.1 LEAN

Q2.1 What are the characteristics of the Lean approach?

Lean originates from the Toyota plant in Japan. In the early 1900's the Toyota Production System arose. Lean manufacturing emerged from the desire to apply the Toyota Production System in other manufactories besides Toyota. The desire to apply Lean manufacturing to also other fields besides manufactories let to the creation of Lean Thinking. With Womack and Jones being the founders of Lean Thinking. An introduction to the Toyota Production Systems as well as an introduction to Lean Thinking will be provided in appendix F. Studies into the applicability of Lean Thinking to the construction sector resulted in the formation of Lean Construction. Lean Construction will be elaborated in sub-paragraph 6.1.1. Since Lean Construction is the most closes to Lean applied to the front-end development of an infrastructure project, Lean Construction forms the basis for the possible application of Lean to the FED of an infrastructure project. Therefore the limitations of Lean Construction will be discussed (6.1.2), as well as the possible application to the FED of an infrastructure project (6.1.3).

6.1.1 LEAN CONSTRUCTION

Lean Thinking also found its way to the construction industry resulting in the development of Lean Construction. Lean Construction is based on the combination of three different theories of production, namely the Transformation theory, the Flow theory and the Value theory. Koskela (2000) combined these three theories and created the TFV theory. In this theory the conversion model, grounded in conventional project management, is represented by the Transformation concept. Lean Thinking is incorporated in the Flow and Value generation concepts. Koskela (2000) proposes that the TFV theory could be used as a new approach for production. This means that a (partial) shift towards the Flow and Value generation concepts is needed. Applied to construction two main flows can be formulated: (1) the design flow, and (2) the construction flow. For both flows, the value is defined by the costumer. Yet both flows have different costumers. The design phase (1) in general has two kinds of costumers: the client and the construction process. Value for the client is based on the extent to which the design follows the requirements of the client and on the impact of design errors detected after project delivery. The value for the construction phase is based on the extent to which the construction process is taken into account with making the design and on the impact of design errors detected during the construction. The construction phase (2) in general only has one costumer: the client. The value for the client is based on the degree of freedom of errors detected after project delivery (Koskela, 1992). It is on this TFV theory that Lean Construction was based upon. It can be said that all systems of project delivery complying with the goals set out by the TFV theory can be seen as Lean systems. The most current developed Lean system is the Lean Project Delivery System (figure 6). One of the key characteristics of the LPDS is that the several phases overlap and that within the phases three elements are in continuous 'conversation' with each other. As can be seen in figure 6 the LPDS consists of four different phases (Ballard, Tommelein, Koskela, & Howell, 2002).

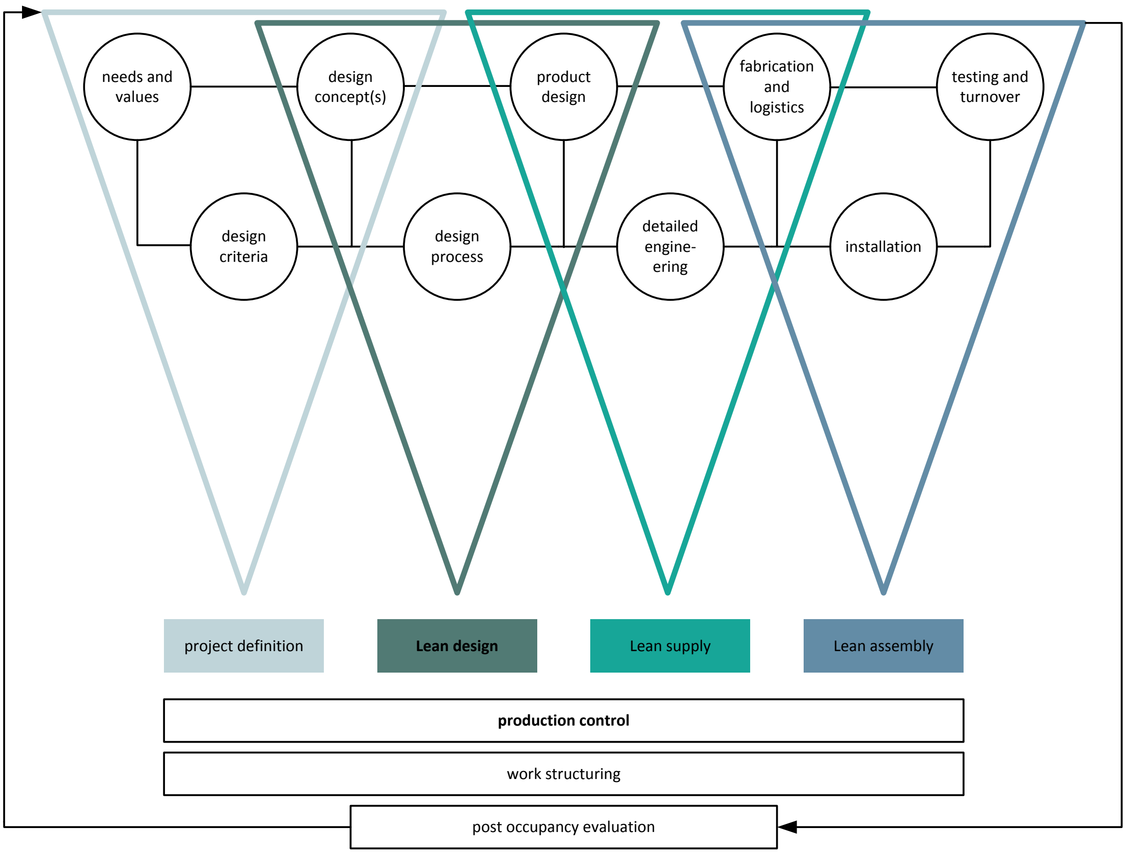


figure 6: Lean Project Delivery System (Ballard et al., 2002)

Lean Production Management: occurs in each phase of the LPDS as it entails the management over the entire LPDS. There are two core elements in Lean Production Management, being Work Structuring and Production Control. Lean Work Structuring can be compared with the more traditional Work Breakdown Structure, yet they also differ on many aspects. With applying Lean Work Structuring the product design is integrated with the process design, and thus not only the production system is broken down itself, it is even further broken down to the level of operation. Thus also how work will be performed is taken into account. Lean Production Control is achieved by applying the Last Planner System (Ballard et al., 2002). In contrast to traditional planning mechanisms the Last Planner System does not use work that SHOULD be performed as control instrument. Traditionally the performance of a project is measured by comparing what SHOULD have been done to what is done, or DID. The Last Planner System knows two procedures. First of all, work flow control. The Last Planner System is based on the idea that work which SHOULD be done, needs to first be transformed into work that WILL be done with the constrains of work that CAN be done (Ballard & Howell, 1994).

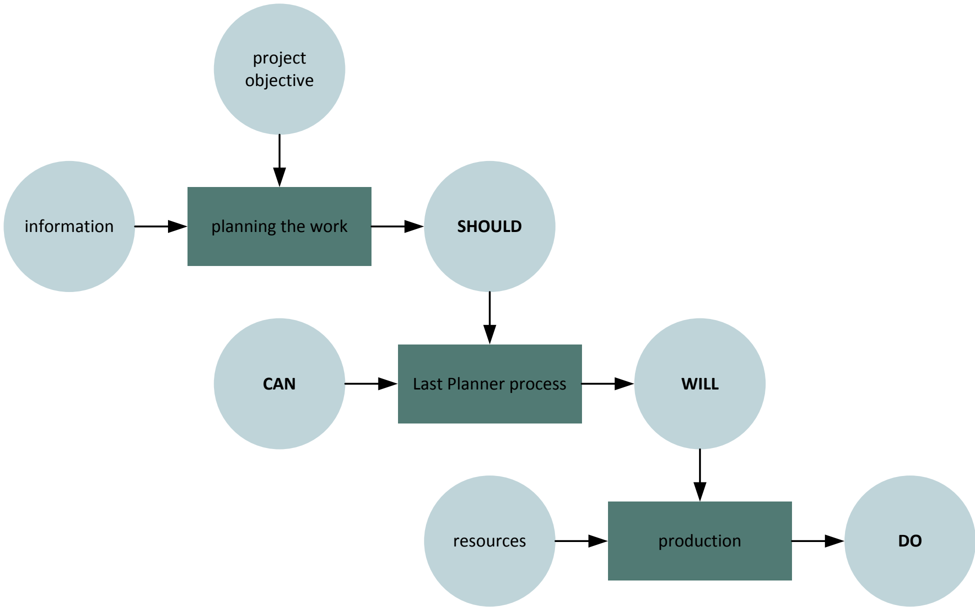


figure 7: Last Planner System (Ballard & Howell, 1994)

Combining SHOULD and CAN results into a backlog of workable assignments (Ballard & Howell, 1994). At the basis of creating this workable backlog stands the lookahead planning. A lookahead planning for creating a workable backlog can be made by using the Activity Definition Model or by applying a constraints analysis. ADM is used to formulate activities part of the schedule in more detail. This is done by identifying the input (directives, prerequisite work and resources) needed to perform the activity in order to generate the desired outcome. Constraints analysis also examines the activities, yet for the activities which start within the lookahead window, which mostly is a period of six weeks. Like the ADM it identifies the directives, prerequisite work and resources needed for the activity, but it also looks at who is responsible for the activity, the time planning, and the status of the activity. With applying ADM and constraints analysis a workable backlog can be created (Ballard et al., 2002). Based on the backlog of workable assignments, collectively with the entire team, a weekly work plan is created based on the right sequence of workable assignments and the right amount of workable assignments. Creating this weekly work plan can be seen as a commitment from the team to the work that WILL be done. Second core element of Lean Production Management is Production Control. The work that is done should be compared to the planned work. Thus a comparison between DID and WILL should be made. Dividing DID work by WILL work gives the Percent Plan Complete. The PPC can be seen as a starting point for planning improvements, since it will assess whether or not the plan succeeded in reliable forecasting the work to be performed in the last week. By doing so, in case of failure, the causes for failure can be identified early on in the process, which will help with improving the reliability of future forecasting of work (Ballard & Howell, 1994).

Lean Design: does not only imply designing the product, but also designing the process. Whereas the product design defines what will be made, the process design defines how it will be made. Ballard and Zabelle (2000) defined the steps and tools of Lean Design. In figure 8 the six steps of Lean Design can be found. Following, the different tools and techniques of Lean Design will be discussed briefly.

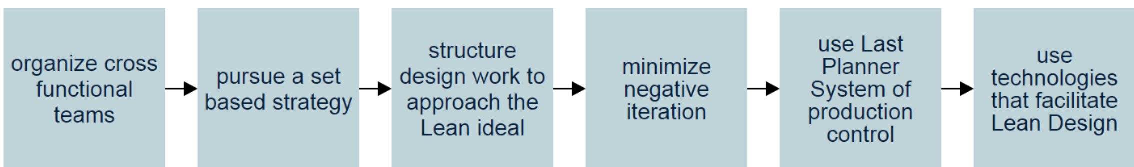


figure 8: steps of Lean Design (Ballard & Zabelle, 2000)

1. Organise cross functional teams: in the design team all stakeholder should be involved in the decision making. Yet, since not in all cases it is possible to have group meetings with all stakeholders about each decision some division of labour is needed.
2. Pursue a set based strategy: many alternatives are created and worked out, but the decision on which alternative to choose is delayed as much as possible. This leads to extra time spend on creating and working out alternatives, yet it is offset by the reduction of negative iterations needed. Because choosing one alternative as soon as possible in most cases leads to rework and thus negative iterations. For pursuing a set based strategy it is also needed that team members are willing to share incomplete information. This is needed so that all stakeholders are aware of the progress of the project and thus can make better decisions on how to continue.
3. Structure design work to approach the Lean ideal: this can be achieved by first of all simultaneously designing the product and the process, thus designing what needs to be made and at the same time designing how it will be made. Not only the direct wishes and demands of the customer should be considered in the design process, but also all phases following the design phase. Thus also consider, among others, maintenance, commissioning and logistics. Also by reducing the batch size the Lean ideal can be approached. The intermediate results, decisions and thus incomplete information should be shared amongst the team members on a more frequent basis. This creates smaller batches of output work.
4. Minimize negative iteration: negative iterations can be reduced by using a pull planning, but also by for example using a Design Structure Matrix. DSM is a tool which can be used to resequence the tasks based on a minimization of dependency loops. Negative iterations can be seen as waste from a Lean perspective. This is why negative iterations have to be reduced in order to achieve Lean Design.
5. Use the Last Planner System of production control (see the previous part on Lean Production Management).
6. Use technologies that facilitate Lean Design: several tools are available which will facilitate the Lean Design process. Tools that integrate the product model and the process model. So a 3D image of the product can be created but also the maintenance, commissioning and logistics etcetera can be modelled. By working in one integrated model also interfaces will be reduced, information is shared and the progress is visible to the entire design team.
   (Ballard & Zabelle, 2000)

Next to Lean Production Management and Lean Design also Lean Supply and Lean Assembly are part of the LPDS. Since both are beyond the scope of this study this sub-paragraph will not further elaborate on them. In appendix F a short description of both can be found.

6.1.2 LIMITATIONS OF LEAN CONSTRUCTION

Even though Lean Construction is still quite new, it was introduced by Lauri Koskela in 1992 (Koskela, 1992), the industry is already moving further, since some limitations of Lean Construction as it is were detected. This is illustrated by the fact that many construction companies are struggling with the implementation of Lean Thinking (Demir, Bryde, Fearon, & Ochieng, 2012). Bertelsen (2003) argues that a construction project should be seen as a complex system, instead of a simple system. Lean's main concern is reducing this complexity by reducing the effect of both dependence and variation, which increases as the project duration decreases (Howell, 1999). Lean Construction does this well when looking at reducing dependencies and variations in the product and production process itself. Yet, complexity is not only influenced by those factors. The project's environment also leads to complexity. It is for this kind of complexity that Lean Construction does not offer tools to reduce or manage the dependencies and the variation. Ballard and Tommelein (2012) recognise this knowledge gap. They state that recent studies focus more on reducing uncertainty, and little on how to manage a project which is subjected to uncertainty and complexity (Ballard & Tommelein, 2012). Also Bertelsen (2002) emphasises this knowledge gap. He states that the stakeholder system causes complexity because of the fact that the project team is a "temporary human system" and also because of the fact that each stakeholder has his own perception of value, which is not only personal but also situational. He emphasises the importance of understanding these stakeholder systems and their effects on the project (Bertelsen, 2002). These different perceptions of value and also the changing perceptions of value, makes it hard to create a clear definition of the value at the beginning of the process. Which was one of the principles of Lean Construction. There is even a third cause leading to difficulties around creating a clear definition of the value, and that is the fact that first one should know and realize who the client is. This because the client is key in defining the value. It sounds simple, the client is the party how gave you the assignment. Yet, in some cases it is not that simple. This because in some projects the party that finances the project is not the same as the party who orders the project and both could even differentiate from the party who will eventually make use of the end product (Salvatierra-Garrido & Pasquire, 2011). And even if one knows who his client is, it is hard to make a clear definition of the value, since in a lot of cases the client will not know exactly what he or she wants (Tommelein, 2014). Therefore the fact that Lean Construction is based on the principle that a clear definition of the required value at the beginning of the process is needed, leads to some limitations in the applicability of Lean Construction to the FED phases of an infrastructure project which are characterised by a complex and changing project environment.

6.1.3 APPLICABILITY OF LEAN TO THE FRONT-END DEVELOPMENT

Most literature on Lean Construction focuses on the application of Lean to the execution phase of a construction project, and not so much on the application of Lean to the front-end development of a construction project (Marzouk et al., 2011). In general the FED phases are less researched and paid less attention to (Verworn & Herstatt, 1999). This is regrettable when one considers the impact of the FED on the performance of the project. During the FED phases the uncertainty is considerably higher compared to the subsequent phases of the project. This is due to the fact that over the course of time the amount and reliability of information increases and the corresponding learning curve of the project's stakeholders, the uncertainty decreases as the project evolves (Verworn & Herstatt, 1999; Kerzner, 2009). Thus the FED phases differentiate from the execution phase in their level of uncertainty. During the FED phases the definition of value is much more uncertain compared to the definition of value during the execution phase. In fact a sufficient FED should lead to a clear definition of value, thus should minimize the uncertainty during the execution phase. As mentioned, Lean Construction is mostly applied to the execution phase. This means that most tools and methods described by Lean Construction are based on the fact that a clear definition of value is present at the start of the project. When applying Lean Construction to the FED phases one should consider this limitation of Lean Construction to cope with an uncertain definition of value.

From the tools and methods described in Lean Construction literature Lean Production Management and Control and Lean Design can be applied to the FED phases. Where Lean Production Management and Control is executed by means of the Last Planner System. Several principles of the Toyota Production System and Lean Thinking are evident in Lean Production Management and Control and Lean Design, yet there are also some principles not evident. Two principles not evident in Lean Production Management and Control and/or Lean Design are the principles related to the reporting of problems and standardization. Yet, since both are assumed to be applicable to the FED of an infrastructure project it was decided to, besides the principles captured in Lean Production Management and Control and/or Lean Design, include them in the preceding of this research.

6.2 AGILE

Q2.2 What are the characteristics of the Agile approach?

Unlike Lean, Agile did not emerge from the evolution of one specific case. Agile emerged from the desire of several experts in the ICT-world to form an alternative for the existing more heavyweight software development processes. These experts all came from different fields in software development and they all represented a different software development tool (Extreme Programming, Crystal, Scrum, etc.). In 2001 they came together to discussed what each of their tools had in common. From this the Agile manifesto arose, with Agile Software Development as their umbrella name (Highsmith, 2001). Since Agile is truly an umbrella name it, in itself, cannot be seen as a tool. In order to describe the more practical application of the Agile idea it was chosen to describe one of the most applied and most popular Agile methods: Scrum (Agile Methodology, 2014). This also because of the interest in Scrum from the corporate sector (illustrated by the interest of Antea Group on this subject). Thus in order to capture and describe Agile the Scrum methodology will be used. In the first sub paragraph (6.2.1) the history of Scrum up until the emerging of Agile will be discussed. Next the Scrum process will be explained, this will be done in sub-paragraph 6.2.2. Thereafter the possible application of Agile and Scrum to the construction sector will be elaborated (6.2.3) and finally the possible application of the Agile ideal to the front-end development of an infrastructure project will be discussed in sub-paragraph 6.2.4.

6.2.1 BACKGROUND SCRUM AND AGILE

The basis of Scrum is developed by Hirotaka Takeuchi and Ikujiro Nonaka (1986). In their article: *The new new product development game* they described a new approach for the development of products. They called this new approach the rugby approach to make the comparison to the traditional, relay-race approach, clear. In the rugby approach a multi-skilled team works together on the development of a new product from start to finish. Whereas in the relay-approach several specialists work sequential and according to prescribed processes on the development of a new product (Takeuchi & Nonaka, 1986). They based this new rugby approach on six principles:

- Build-in instability: tension is intentionally created by giving the project team a challenging assignment, which is of great importance for the company. And also by giving the team a substantive amount of freedom in executing the project.
- Self-organizing project teams: by giving the team a substantive amount of freedom, the process will start to form itself. In order to create a self-organizing project team, three conditions have to be met. First of all there has to be autonomy, a low level of top-down intervention. Second, self-transcendence; the team must strive for perfection, by creating their own goals and evaluation of those goals. Third, cross-fertilization; a multi-skilled team should be able to share all information.
- Overlapping development phases: since the project team is multi-skilled it will soon start sharing knowledge and synchronizing their paces. This leads to the team starting to work as a unit. Which also means the different phases in the project will start to overlap. Because of this overlap team members have to interact with each other and also with suppliers. In the relay-race approach most problems occur at the point where one phase ends and the next starts. This is not the case with overlapping phases, therefore the flexibility and the speed will increase. But also human resource related aspects will positively be influenced by overlapping phases.
- Multi-learning: because of the trail-and-error character of the process, the project team members will learn from their mistakes and because of the interaction with the external environment the members will also be able to respond to changes in market conditions. Learning will not only happen on the individual level, but also on the group and corporate level. And the team members will not only learn in their specific field of knowledge, but will also learn in other fields of knowledge.
- Subtle control: the rugby approach implies little control from the management. The management will set some check-points, but will not control the process like it does when using the relay-race approach. This creates room for more creativity on behalf of the project team members.
- Transfer of learning: learning does not only happen within the project team, but the project team members also transfer their knowledge outside of their project team. They can use their gained knowledge for future projects, but also learning in forms of standardization of successful elements will take place.
  (Takeuchi & Nonaka, 1986)

In 1993 Jeff Sutherland translated this rugby approach to the current Scrum methodology and he was also the first one to use Scrum. Together with Ken Schwaber he introduced Scrum at the OOPSLA conference of 1995 (Scrum Foundation, n.d.). Like the rugby approach, the essence of Scrum is that the process gives space to changing the product according to changing insights of the client and the project team itself. This is achieved by working in short cycles or *sprints*, which at the same time will lead to higher quality and higher customer satisfaction. It will lead to a higher predictability for the customer, and therefore positively influence the customer satisfaction. In traditional project management all specifications and detailed designs are made at the beginning of the process, with Scrum this is not the case. This is only done for the most important part of the product according to the costumer, since this part will be the focus point of the first *sprint*. In this *sprint* the part that will add the most value to the end product will be made and completed. This will in most cases be done in a time period of one to four weeks. After this *sprint* there will also be room for the costumer to give feedback, which in the end leads to a lot more feedback points in the whole process (Van Solingen & Rustenburg, 2010).

In 2001 Jeff Sutherland and Ken Schwaber came together with fifteen other ICT professionals to talk about software development and what their software development processes had in common. They decided to group their methods and tools under one umbrella by the name: Agile. From this the Agile Software Development Manifesto emerged which gives a nice overview of the principles of Agile developments:

"We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan
- That is, while there is value in the items on the right, we value the items on the left more"
  (Beck, 2001)

Also twelve more concrete principles were set up. These are listed below.

- "Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
- Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
- Business people and developers must work together daily throughout the project.
- Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
- The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
- Working software is the primary measure of progress.
- Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
- Continuous attention to technical excellence and good design enhances agility.
- Simplicity - the art of maximizing the amount of work not done - is essential.
- The best architectures, requirements, and designs emerge from self-organizing teams.
- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behaviour accordingly"
  (Agile Manifesto, n.d.)

6.2.2 THE SCRUM PROCESS

For this thesis it was chosen to follow the guideline for Scrum as set up by Jeff Sutherland and Ken Schwaber (2013). Below the guidelines will be discussed briefly.

In the guide Sutherland and Schwaber (2013) first provide the definition of Scrum: "A framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value" (Sutherland & Schwaber, 2013). With applying Scrum the predictability and risk control will increase, due to the incremental approach. Scrum is based on three main principles: transparency, inspection and adaption. The process must be transparent to all the members of the project team. This transparency is created by formulating clear standards in order to make sure there will be no differentiating interpretations. Inspections must take place continuously throughout the process in order to monitor the progress and to detect problems as early as possible. Adaption implies that once problems, which hamper the progress towards the goal, are detected the process should be adjusted accordingly (Sutherland & Schwaber, 2013).

The main <u>characteristics</u> of Scrum Teams are self-organizing and cross-functional. The Scrum Team guides itself and contains all expertises needed. In the Scrum Team three roles can be distinguished. First of all the Team knows a Product Owner. The Product Owner is responsible for value maximization and is for managing the Product Backlog. The items is the Product Backlog must be clear, ordered and visible to all the Scrum Team members. Also the Development Team is part of the Scrum Team. The Development Team consists of the people responsible for creating an Increment of the product at the end of each Sprint. Like the whole Scrum Team, also the Development Team is self-organizing and cross-functional. The Development Team should exist of three to nine members. Last role in the Scrum Team is the Scrum Master. The Scrum Master is the person responsible for ensuring that all the Scrum Team member fully understand and work according to Scrum. He is also the one that organizes and facilitates the Scrum events (Sutherland & Schwaber, 2013).

Within the Scrum process several <u>events</u> can be distinguished. These events all have a set time-span and they offer the opportunity for inspecting and adopting, two of the main principals of Scrum. First and most important event in the Scrum process is the Sprint. A Sprint can be seen as a project and has a time-span of no longer than one month. This, since for longer time-spans the requirements for the Product Increment may change and the complexity and risk may increase. Due to the Sprints the predictability rises, since there are more inspection and feedback points. At the beginning of each Sprint a Sprint Planning is made. During the Sprint Planning meeting it is decided what is going to be made and how this will be done. The Product Backlog forms the input for what needs to be done. Based on the capacity of the Development Team and their previous performances items from the Product Backlog are chosen to be performed in the upcoming Sprint. Also the Sprint Goal will be set. Together with the plan on how to deliver the chosen Product Backlog items, the Product Backlog items form the Sprint Backlog (Sutherland & Schwaber, 2013).

Also each day a Daily Scrum will be held. These Daily Scrums are short daily meetings of about fifteen minutes. The Daily Scrums offer the Development Team the opportunity to synchronize their activities and to determine what they will do that day. During this meeting each member of the Development Team explains what he or she did yesterday, what he or she is going to do today and if he or she encountered problems which could hamper the progress of the Sprint. After the Daily Scrum, which in fact creates an opportunity for inspection, it might be needed to adapt or replan some of the remaining work. The Daily Scrums improve the communication and enables the early removal of impediments to the progress. At the end of each Sprint a Sprint Review meeting is held. During this meeting the Product Increment created during the Sprint is inspected and, in case it's necessary, the Product Backlog will be adjusted. Together with the most important stakeholders, the Scrum Team discusses what has been done in the Sprint, the things that went well but also the problems encountered and how these problem were solved. Also the progress of the total project, are we on schedule?, will be elaborated based on the progress to date. It is discussed what the most value adding things are that can be done next and also the framework of time, budget and quality for the next Sprint will be reviewed. At the end of the Sprint Review meeting an altered Product Backlog is set up, which can be used as input for the next Sprint. Last event is the Sprint Retrospective meeting. During this three hour meeting the Scrum Team discusses what went well and what did not went well regarding the process and identifies what should be improved and how improvements can be made during the next Sprint (Sutherland & Schwaber, 2013).

The Scrum process knows several artifacts. First there is the Product Backlog, which lists in an ordered way all the things needed to create the product. The Product Backlog is thus comparable to a list of requirements for the end product. The Product Backlog changes throughout the project in order to correspond with the current state of the project environment. This to make sure that the value of the end product corresponds with the required value at the end of the process instead of with the required value at the beginning of the process. Thus in the Product Backlog only the requirements, or items, that are known and understood at that point in time are included. The top items are more detailed and clear compared to the lower items on the Product Backlog list. The Product Backlog items chosen for the upcoming Sprint are included in the Sprint Backlog. The Sprint Backlog also includes a plan on how to deliver all the Backlog items and a plan how the Sprint Goal will be met. The Sprint Backlog should be detailed to make sure that progress changes can be understood during the Daily Scrum meetings. Next to the two Backlogs, also the progress of both the total project and the Sprint will be measured and visualised. The progress of the total project is measured by adding up the work remaining for delivering the end product. This is done at least once every Sprint during the Sprint Review meeting. The actual progress will be compared to the required progress based on the deadline for delivering the end product. Also for each Sprint the progress is monitored. The remaining work in the Scrum Backlog should be added up at least once a day, during the Daily Scrum. The actual progress will be compared to the required progress based on the time-span of the Sprint and the Sprint Goal. The last artifact is the Product Increment, which represents the in previous Sprints created value plus the Product Backlog items completed during the Sprint. The Product Increment is the outcome of the Sprint and must meet the set definition of 'Done'. The definition of 'Done' is a standard definition of when a product is considered to be done which is clear and transparent to all stakeholder to make sure there will be no differentiating interpretations (Sutherland & Schwaber, 2013).

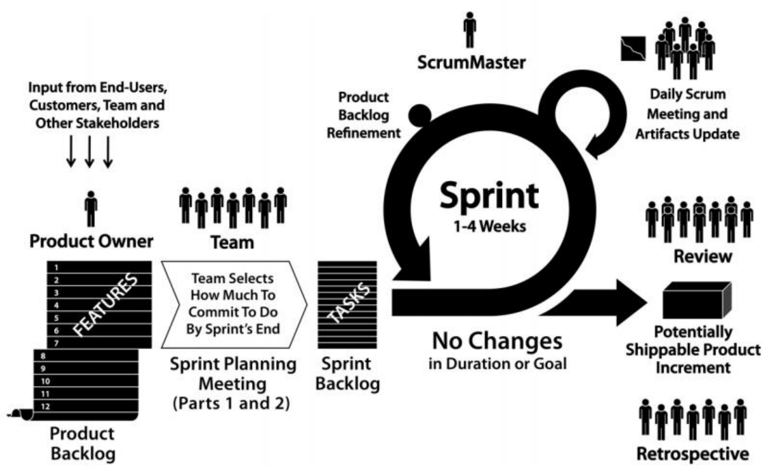


figure 9: Scrum process (Verheulen Consultants, n.d.)

6.2.3 AGILE PROJECT MANAGEMENT IN CONSTRUCTION

As concluded in the section about Lean, Lean Construction has its limitations when looking at the changing and dynamic project environment. This is not only stipulated by Bertelsen (2002), but also Ward (1994) already concluded that Lean Construction does not provide a method to cope with a changing project environment (Ward, 1994). This is why recent research is done into how a project could cope with this type of complexity. Agile has been put forward to fill this gap (Demir et al., 2012). Even though Agile methods are currently merely applied in the construction industry, it does not mean that Agile methods are not applicable or successful in the construction sector (Owen & Koskela, 2006). Since Agile is merely applied to construction projects, little is known about it. Yet, the interest of the construction industry on the subject is rising (Demir et al., 2012). Since Lean Construction has its limitations related to the project environment, the construction sector is looking for (complementary) methods that do provide tools to handle this kind of complexity.

But why are they searching in the direction of Agile methods? One of the main characteristics of complex systems is that they are capable of self-organisation (Bertelsen & Koskela, 2004). They do not need a detailed plan, but attention should be paid to creating a clear objective and the improvement of the reliability (Bertelsen & Koskela, 2004). This fits well with the Agile concept. Owen, Koskela, Henrich, & Codinhoto (2006) elaborately discussed the applicability of Agile Project Management to the construction sector in their paper: *is Agile Project Management applicable to construction?*. Agile Project Management is based on the idea that change can be transformed into added value for the costumer. The scope of the project, and a corresponding planning, are only defined as far as value for the costumer at that moment is known and can be specified. This makes it possible to deliver value on the short-term. By receiving early and recurrent feedback, continuous learning will be achieved. This will lead to a continuous evolving of the value for the costumer. Which results in an end-value which satisfies the costumer's requirements at the end of the process, instead of an end-value which meets the value as defined at the beginning of the process. To see change as something positive, as an opportunity to improve customer value, a more proactive organization is required compared to Lean organizations (Owen, Koskela, Henrich, & Codinhoto, 2006).

The process of recurrent feedback and learning is shown in figure 10. From this figure it can be obtained that once a part of the value is identified, and translated into a design, the costumer gets the chance to give feedback. With this feedback the design will be altered and is ready to be build. While building takes place, the value, and thus the design, will continue to evolve. This will result in maximized value at the end of the process. From this figure it also seem like decisions are being made right from the commence of the project. Yet, only operational decisions are made incrementally. The strategic decisions are delayed as much as possible. This creates a more flexible system, and thus the ability to respond to feedback is increased (Takeuchi & Nonaka, 1986).

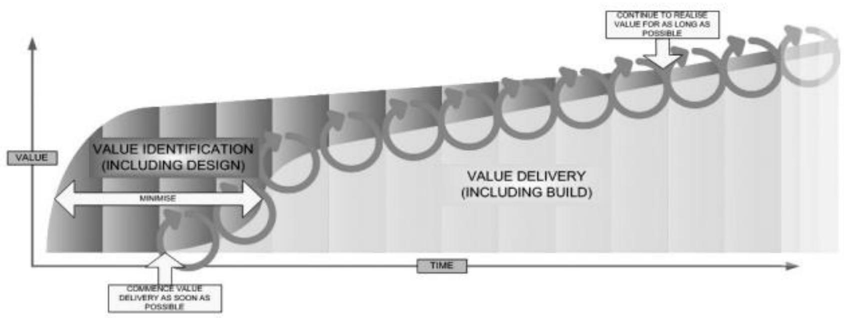


figure 10: Agile process (Owen et al., 2006)

6.2.4 APPLICABILITY OF AGILE TO THE FRONT-END DEVELOPMENT

Applying Agile to construction projects is merrily done. Some literature describe the possibilities for applying Agile to construction, yet hardly any discuss the practical applicability (Maylor, 2010). Since Agile in itself does not provide any practical tools, only some principles, it was chosen to focus on one specific Agile method: Scrum. This decision is also based on the fact that Scrum is the most practical and most popular Agile method (Agile Methodology, 2014). But most of all because of the fact that Scrum could, unlike several other Agile methods, be applied to other projects besides ICT projects.

The Agile methods were created specifically for software development. This leads to the assumption that Agile methods are well applicable to the front-end development phases of a construction project and less to the subsequent phases of a construction project. This because the software development process largely consists of front-end development. The actual execution or building of the software mostly entails one push of a button. Also the fact that the FED of a construction project is characterised by high uncertainty fits well with the flexibility provided by the Agile methods. The Scrum process is arranged in such a way that changes in the definition of value are fostered. Agile and Scrum, unlike Lean, are not based on a clear and complete definition of value at the beginning of the process. It is thus assumed that Agile methods, like Scrum, in theory would be well applicable to the FED of an infrastructure project.

6.3 COMPARING LEAN AND AGILE TO CONVENTIONAL PROJECT MANAGEMENT

Q2.3 How do Lean and Agile differ from conventional project management?

In order to assess how Lean and Agile could help coping with overall complexity, entailing uncertainty and structural complexity, it would be useful to examine how they differentiate from conventional project management. This examination into the differences will be executed in this paragraph. In sub paragraph one (6.3.1) Lean, with the Last Planner System, will be compared to conventional project management. In sub paragraph two (6.3.2) this will be done for Agile with Scrum.

6.3.1 LEAN WITH LAST PLANNER SYSTEM COMPARED TO CONVENTIONAL PROJECT MANAGEMENT

Planning processes: The Last Planner System can be used as a Lean tool for planning. The planning of conventional project management is based on what SHOULD be done. The Last Planner System also recognizes that what SHOULD be done can only be performed in case all prerequisite input is readily available. Here the idea of the *Kanban* card is incorporated. This creates a lookahead planning consisting of tasks that CAN be done. The work actually to be performed in the upcoming week is planned in the weekly work plan. In this weekly work plan the work that WILL be performed is included. The work that WILL be performed reflects the work that the team members promise to perform the following week. This creates commitment, which is strengthened by the fact that at the end of the week the team members have to report on the whether or not the work is completed (Koskela & Howell, 2002). Thus, instead of a planning that pushes work, the Lean approach adopts a planning that pulls work.

Monitoring and controlling processes: Lean Construction is based on the combination of three different theories of production, namely the Transformation theory, the Flow theory and the Value theory. Thus the Transformation principle, which forms the basis of conventional project management, is combined with the Flow and Value principle. The Flow principle implies that flow needs to be created in processes and by doing so waste can be reduced. Waste is formed by non-value adding activities. The Value principle implies that the focus of your process should be on maximizing the value for the customer. Conventional project management implies that a project can be divided into several separated, independent, yet sequential sub-projects (Koskela & Howell, 2002). The Lean approach states that the design of the product and the design of the process should be performed simultaneously, which in the Lean Thinking group of methods is called concurrent engineering. Thus, what is to be made is simultaneously designed with how it should be made. The project can simply not be broken down merely based on the end product itself. Sequentially executing the sub-tasks could lead to difficulties, since subsequent phases are not taken into account in the design phase. This could lead to rework, negative iterations and thus waste (Koskela, 1992). The Lean approach is to consider subsequent phases in the design process, thus also considering maintenance, commissioning and logistics etc. in the design phase. Also a shift of the detailed design to the specialty contractor could help with achieving the Lean approach. Cross-functional teams should be created and downstream stakeholder should be involved in the upstream decision making process (Ballard & Zabelle, 2000). Under the Toyota Production System this was called *ringi* decision making (Liker, 2004).

For measuring progress The Percent Plan Complete, part of the Last Planner System, is used which compares the work which is actually done with the work planned out in the weekly work plan (Ballard & Howell, 1994). Instead of assessing the quality by means of standards, comparing the output quality to a quality standard and in case of deviation focussing on adjusting the process in order to achieve the quality standard, the Lean approach focuses on solving the root causes that lead to the deviation (Koskela & Howell, 2002). This emphasis on eliminating root causes and thus employing continuous learning can already be found in the Toyota Production System, in the right pillar of the 'Lean house' (see appendix F) solving root causes of problems can be found, which can be done by using the 5 why's (Liker, 2004) or the technique of Grasping The Situation (Dennis, 2007). Liker (2004) also included this idea in the fourteenth principle of the Toyota Production System: "become a learning organization through relentless reflection (*hansei*) and continuous improvement (*kaizen*)" (Liker, 2004).

Product-oriented processes:
The traditional approach considers a construction project as an unique and one-of-a-kind project (Koskela, 1997; PMI, 2013). With applying the Lean approach tasks and processes, thus design elements itself and the processes related to designing, should be standardized as far as this is possible. This idea results from the sixth principle of the Toyota Production System. By practicing standardization continuous improvement can take place (Liker, 2004). Also Koskela (1997) pinpointed that standardization could reduce the uniqueness and one-of-a-kind features of a construction project (Koskela, 1997). When applying the traditional approach it often happens that once a design is handed over to the contractor, the contractor himself will start from scratch with making a detailed design. Since this can be considered as rework it forms waste. By shifting the detailed design work to the specialty contractor and by applying standardization this waste can reduced considerably. This idea of shifting detailed work and using standardization is included in the Lean approach (Ballard & Zabelle, 2000).

According to the traditional approach funnelling of the alternatives should take place as soon as possible. This is in contrast with the Lean approach. For achieving the Lean ideal a set based strategy needs to be pursued. The set based strategy is based on the thirteenth principle of the Toyota Production System: *nemawashi*, which states that decisions should be based on a consideration of all possible options followed with a delayed decision making process (Liker, 2004). Thus many alternatives should be created and worked out, but the decision on which alternative to choose should be delayed as much as possible. This leads to extra work, since more alternatives are worked out in more detail, yet it reduces the need for rework, which in most cases is a consequence of making a decision as soon as possible. Thus both approaches, the traditional and the lean approach, will create waste. For the traditional approach waste is created in forms of rework and for the Lean approach waste is created in forms of extra time spend on working out multiple alternatives. Yet, the waste creation of working out multiple alternatives is considerable less then rework as result of negative iterations (Ballard & Zabelle, 2000).

Other distinguishing features of Lean: The Lean approach to communication is that it is a two-way process. Due to the fact that the Lean approach uses cross functional teams and employee involvement. All team members are involved in the decision making processes, *ringi* decision making, but also in the problem solving processes and processes related to continuous improvement of the system, which makes that one can speak of a two-way communication process.

The Lean approach does not only use progress meetings to communicate work to team members. It does also use visual management to make the process, goals, personal tasks and progress clear to all team members. A3-reports, dashboards, Operator Balance Charts and Value-Stream maps are visual tools which could be used (Marchwinski et al., 2009). Even though in conventional project management the tasks are orally communicated and communicated in writing, perceptions might still differ. By making information visible to all team members, thus by adopting visual communication, perceptions of reality become more accurate (Greif, 1991). Another advantage of visual management is that problems become visible, which is the seventh principle of the Toyota Production System (Liker, 2004). It ensures that problems do not only come to the table at the end of the project, which helps with solving the problem as soon as possible. In the 'Lean house' this idea was captured in *jidoka*. To achieve *jidoka* automatic stops or *andon* can be applied. This idea of stopping to fix problems as soon as they occur is captured in the fifth principle of the Toyota Production System (Liker, 2004).

6.3.2 AGILE WITH SCRUM COMPARED TO CONVENTIONAL PROJECT MANAGEMENT

Planning processes: The Scrum approach to planning differs from the traditional approach to planning. In Scrum all project team members are involved in the planning process. During the Sprint Planning meeting a Sprint Backlog is formed based on the Product Backlog, which entails all the requirements of the client in prioritised order, the capacity of the project team and previous performances. In the Sprint Backlog all tasks which will be worked on in the coming one to four weeks are included. In the Sprint Backlog tasks are not yet assigned to team members and there is also not yet decided on a sequence of performance. During the Daily Scrum Meetings a more detailed planning is made, since during these meetings team members assign tasks to themselves which they will perform during that day. Since team members themselves assign task, thus due to the self-organizing character, more commitment to the planning is created. Also the fact that during the Daily Scrum Meeting each team member has to report on his or her progress creates commitment.

Monitoring and controlling processes: Agile applied to construction is mostly based on a combination of the Flow and Value principle. The Transformation principle is hardly present. The Flow principle is present in the Agile approach first of all since, due to the self-organizing character of the teams, information can flow more freely between the different specialists. Due to the daily meetings, which are both part of the Agile principles as well as the practices of Scrum, information is shared more frequently and not only once complete. Flow is also created by the early and continuous delivery of value and the corresponding recurrent feedback loops. Which was apparent in the first and the third principle of Agile. The Value principle is advocated by the Agile approach in the second and the tenth principle. Which states that change is harnessed "for the customer's competitive advantage" (Agile Manifesto, n.d.) and that "continuous attention to technical excellence and good design enhances agility" (Agile Manifesto, n.d.). The Value principle is also present in Scrum in forms of the Product Backlog. The customer can put all his requirements in this Product Backlog and can prioritize them. But the Scrum approach also recognizes that it is not possible for the customer to formulate all his requirements at the beginning of the process. The Scrum process leaves room for the customer to change his requirements corresponding new insights and ideas during the process (Koskela & Howell, 2002). figure 11 illustrates this difference between conventional project management and Agile. In conventional project management it is assumed that the customer sets the scope for the project at the beginning of the process and does not change the scope throughout the process as variances from the predetermined scope, or thus changes of the scope, are considered highly undesirable (Koppenjan et al., 2010). Thus the scope is fixed and the time and resources, costs, can vary in order to cope with problems. In contrast with the Agile approach, in which the scope can vary, corresponding new insights and ideas of the customer, and the resources and time are fixed. Change is seen as something positive, as it provides for opportunities to improve and maximize the costumer's value.

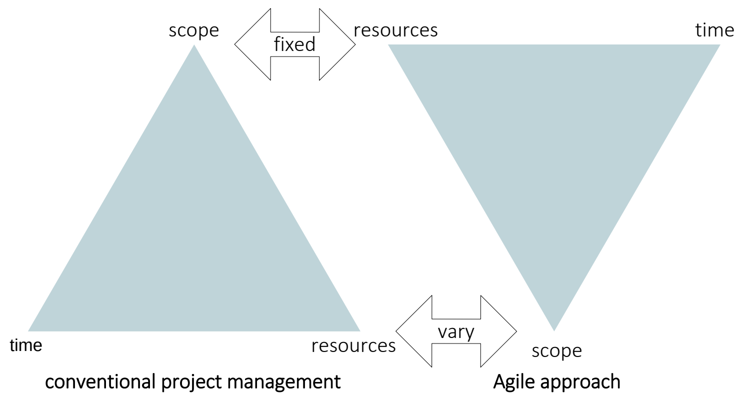


figure 11: Scrum compared to conventional project management. Adapted from Owen et al. (2006)

In Scrum the Sprint progress is measured each day, based on what is actually done and what should have been done. The progress and performance of the total project is measured at the end of each Sprint, during the Sprint Review meeting (Sutherland & Schwaber, 2013). Performance is monitored and controlled by means of the Daily Scrum Meetings. During the Daily Scrum Meetings the team members are presumed to address problems or impediments they have encountered and to report on the progress of their performed tasks (Koskela & Howell, 2002). This also makes that problems can be detected as soon as possible, instead of at the end of the process and since problems or impediments are announced during the Daily Scrum Meetings, at which all team members are present, all team members are involved in the problem solving and decision making processes.

Other distinguishing features of Agile: The Agile approach rests on self-organizing project teams, as emphasized by the eleventh principle (Agile Manifesto, n.d.). One could thus speak of low or even non-existent hierarchical steering. In Scrum, team members decide what will be done the coming day and also decide themselves what they individually will do. In order to keep the project manageable the team members must work together on a daily basis (principle four) and communication must happen face-to-face (principle six). The Agile approach also emphasizes the need for team reflection in order to assess what could and should be improved (principle twelve).

6.4 LEAN AND AGILE APPROACH TO COPE WITH OVERALL COMPLEXITY

Q2 Can Lean and Agile be applied to the front-end development to cope with complexity and uncertainty?

In the preceding both Lean and Agile were compared to conventional project management. From this comparison it can be noted that there is some overlaps between Lean and Agile. How do Lean and Agile compare to each other? The biggest difference between Lean and Agile is that Lean is based on a clear and definite definition of value at the beginning of the process, whilst Agile is based on the fact that this is not possible. Lean is thus created for optimizing processes for which it is possible to create a clear definition of value and Agile is created for optimizing processes for which it is not possible to create a clear definition of value. Since for most front-end development phases of infrastructure projects defining value lies somewhere in between a combination of both methods would be applicable. In fact some overlaps in the methods can be noted, especially when applying both Lean and Agile to the FED phases of an infrastructure project. In the preceding the, distinguishing from the conventional management approach to the FED phases of a project, elements of both Lean and Agile were discussed. In figure 12 these elements are shown side by side to assess where overlaps is evident. In this figure on the left the Lean elements are shown. The elements in the green shaded area are the elements of Lean assumed to be applicable to the FED phases of an infrastructure project. Majority of these elements are obtained from the theory on Lean Design, as discussed in paragraph 6.1.1, two other applicable elements are based on remaining Lean principles which are assumed to be applicable to the FED phases of an infrastructure project. To the left of this green shaded area corresponding element of the Toyota Production System and Lean Thinking are shown. On the right the Agile elements are shown. The elements in the green shaded area are the elements of Agile assumed to be applicable to the FED phases of an infrastructure project. Majority of these elements are obtained from the theory on Scrum. One applicable element is obtained from the theory on Agile Project Management, as discussed in paragraph 6.2.3. Another distinct element of Agile Project Management was that the design still evolves during execution, so no strict separation between the FED phases and the execution phase is assumed. Due to the fact that this study focuses on the FED phases, it was decided to not take this element of Agile Project Management into account. On the right of this green shaded area corresponding element of the Agile principles are shown.

The dark blue outlines show were overlaps is present between applicable elements of Lean and Agile. As can be noted *cross functional teams* is both advocated by Lean and Agile. Between these elements overlaps is thus present. Also the ideal of a pull planning as observed in Lean is evident in Agile. Mostly due to the fact that Agile is guided by the principle that change is positive and with applying Scrum one is able to manage changes. Without preplanning and focusing on changes made by the client in fact a pull planning is used. Here some overlaps is thus evident between Lean and Agile. A comparison between the Last Planner System and the Scrum process can be made. The LPS makes use of a lookahead planning. This lookahead planning is used for the creation of a workable backlog for the coming lookahead window, which in most cases is a period of six weeks. In this backlog only tasks for which all prerequisites are met are obtained. Also who is responsible for the activity, the time planning, and the status of the activity are considered with making the lookahead planning. This lookahead planning can be compared with the Sprint Backlog as used in the Scrum process. In which all tasks decided to be performed during the following Sprint are obtained. This task selection is done on the basis of the capacity and the previous performances of the team, but also on the prioritisation of the client. The weekly work plans of the LPS can be compared to the daily Scrum meeting and the self-assignment of tasks during these meeting. A weekly work plan exists of a detailed planning for the coming week, which is created in consultation with the Last Planners. During the daily Scrum meeting also a detailed planning is made, yet merely for the coming day. Here all team members decide on the tasks to be performed. Last comparison between the LPS and the Scrum process can be made regarding progress monitoring. The LPS knows the Percentage Plan Complete in which progress is tracked, likewise the Scrum process makes use of a daily and visual progress monitoring. Fourth comparison between Lean and Agile can be made looking at how problems are treated. Lean advocated that problems are reported as soon as they occur, with applying the Scrum process and thus using Agile ideals problems are reported on a daily basis, during the daily Scrum meetings. Also the Lean ideal of solving root causes is evident in the Scrum process, and thus also advocated by Agile, in the review and retrospective meetings.

Now it is assessed where Lean and Agile applied to the FED of an infrastructure project show overlap their combined capability to cope with overall complexity, or structural complexity and uncertainty, can be examined. Resulting from the literature study on complexity and uncertainty was a list of criteria needed for coping with complexity. In table 4 these criteria are coupled with elements of Lean and Agile in which these criteria are evident.

table 4: Lean and Agile for coping with complexity

criteria	Lean and Agile element
considering all possible alternatives and making a decision at the last responsible moment (redundancy)	Lean: set based strategy through many alternatives and late decision
using standardization to an extent that fits with the project's context in order to achieve reflective learning	Lean: continuous learning through standardization of the product and process
recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats (resilience)	Agile: see change as added value and managing change by applying Scrum process Lean: small batches
functional scope description	Agile: no complete and definite definition of scope is needed
close cooperation between the stakeholders	Lean: involve all stakeholders in decision making, share incomplete information, considering subsequent phases, cross functional teams Agile: cross functional teams
self-steering of the complete project team	Agile: self-organizing teams
open information exchange	Lean: share incomplete information, information visible to all stakeholders Agile: daily meetings
trust	Lean: involve all stakeholders in decision making, share incomplete information, information visible to all stakeholders Agile: cross functional teams, daily meetings

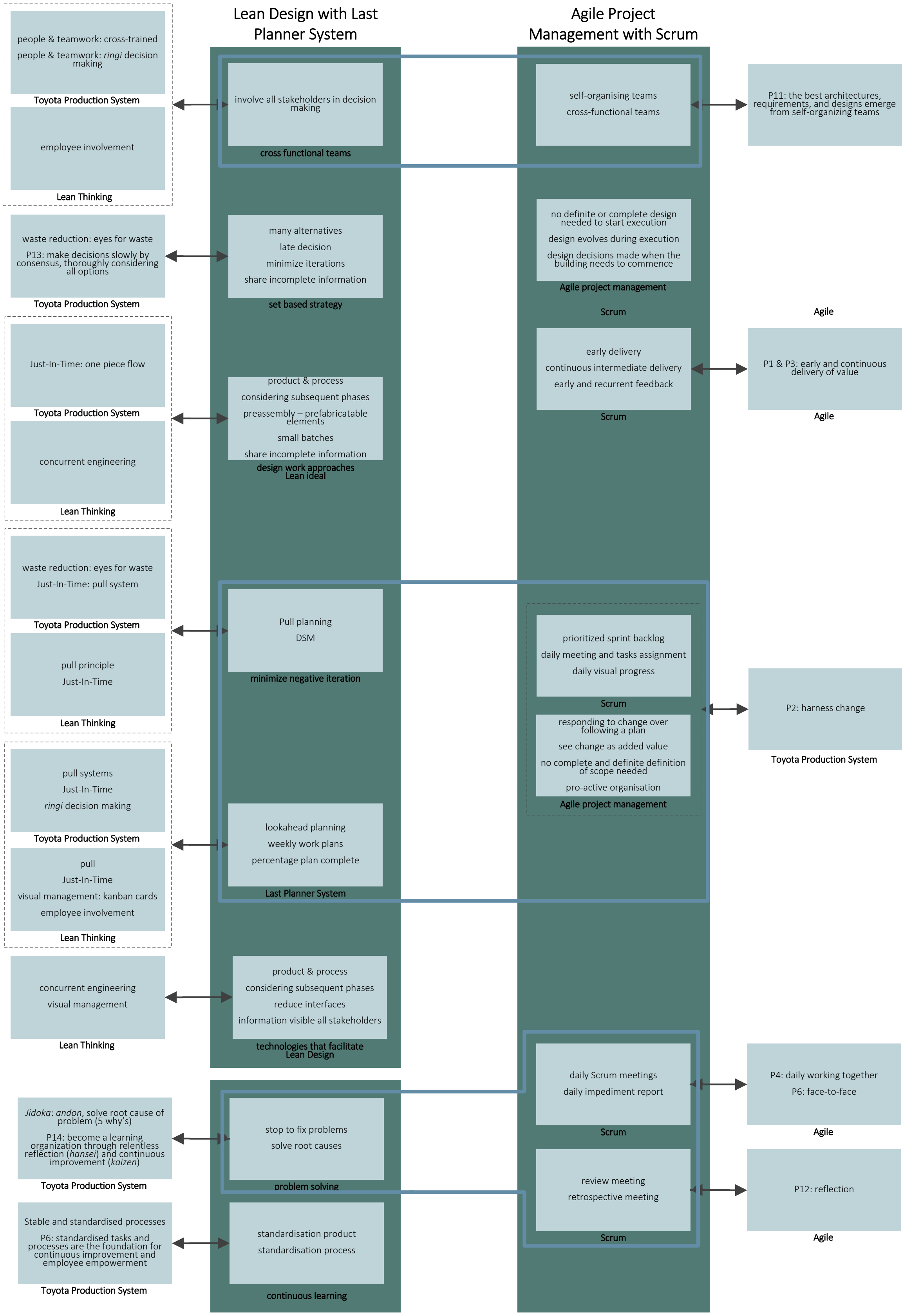


figure 12: applicable elements Lean and Agile

THREE//

THE RESEARCH

7 DATA GATHERING

In this chapter the data gathering for both the Q sorting and the correlation analysis will be discussed. The way the questionnaires were created as well as the way the possible participants were selected will be explained. This will first be done for the Q sorting research, in paragraph one, and thereafter for the correlation analysis, in paragraph two.

7.1 DATA GATHERING Q SORTING

In this paragraph data gathering activities for the Q sorting research will be discussed. In the Q sorting research participants will rank, in a predefined score sheet, several elements of Lean and Agile on their ability to cope with the overall complexity of a project. Thus participants should be selected as well as statements on Lean and Agile. Sub-paragraph one will elaborate on the chosen strategy for the Q sorting data gathering. In sub-paragraph two the creation of the Q sort questionnaire will be discussed and in sub-paragraph three the way the possible participants were selected is explained. Finally, sub-paragraph four will elaborate on the actual Q sorting process.

7.1.1 STRATEGY FOR DATA GATHERING Q SORTING

The purpose of a Q sorting research is to distinguish several general points of view existing on a specific topic. In this case, existing points of view on the helpfulness of Lean and Agile to deal with complexity in the FED of an infrastructure project. In order to do so a questionnaire entailing statements on this topic should be set up and sent to a certain set of possible participants. In this research the data gathering for the Q sorting will be done by means of a digital questionnaire sent via email. Due to a limited amount of tools available online for conducting a Q sort, it is chosen to create an Excel file. This Excel file will be attached to an email and sent to the possible respondents. The possible respondents are asked to fill out the Excel file and to email this filled out file back to the researcher. For analysing the Q sorts it was chosen to use the software program PQMethod. This software program allows the user to enter the Q sorts in the same way as they were collected, which makes the software user-friendly. This, in combination with the fact that PQMethod is a commonly used software program for analysing Q sorts (Schmolck, 2014), led to the decision to make use of this software program for analysing the Q sort.

7.1.2 THE CONCOURSE AND Q SAMPLE

The concourse represents all opinions or personal views existing on a specific topic. From this concourse the Q sample should be selected. The Q sample represents the set of statements, based on the chosen opinions or personal views, included in the questionnaire. The topic subject of this Q sorting research is the capability of Lean and Agile to deal with complexity. Since this topic is relatively new, the concourse selection is merely based on the literature study as conducted in the preceding chapter. In this chapter a literature study on Lean and Agile was conducted. This literature study can be seen as the concourse. The Q sample, selected from this concourse, is based on the comparison made with conventional project management. Resulting from this comparison several applicable and distinguishing elements of Lean and Agile were obtained. These elements were set side by side to define where they showed overlaps. In figure 13 these elements are shown once more. This time all distinguishing elements are defined and numbered, as well as the elements that showed overlaps, which are now merged into one element (these are delineated with a green line). As can be noted some elements are given a number individually as well as being part of a merged element. This decision was made because of the fact that in those cases the merged element does not cover the individual element entirely. For each merged element an explanation of what is included in the merged element and what not, what is thus part of the individual element, will be provided below.

Merged element 10: this first merged element exists of Lean element one and Agile element six. The overlaps, and thus the subject of this merged element, is related to cross functional teams. Lean element one is also about involving all stakeholders in the decision making process. Since this is not necessarily the case for cross functional teams, Lean element one is also individually included. Also Agile element six is maintained as individual element, since this element, besides cross functional teams, entails the self-organising character of the teams. This again is not necessarily part of cross functional teams, and is thus not covered by merged element ten.

Merged element 11: merged element eleven relates to the way the project is managed. Thus how a planning is made and how control is exercised. For Lean this is done by means of applying the Last Planner System, for Agile this can be done by means of applying the Scrum process. Due to similarities between the LPS and the Scrum process, as discussed in paragraph 6.4, it was decided to merge these elements. Merged element eleven thus implies the Lean and Agile management strategy. Agile element seven is also included as individual element, this because of the daily character of progress tracking and the prioritized character of the planning.

Merged element 12: merged element twelve relates to reporting problems. It includes the idea that all sorts of problems, even the smaller ones, should be reported as soon as they occur and should also made insightful to all team members. Agile element eight entails that this can be done during a daily communication moment, yet since Lean does not give guidelines for daily communication moments Agile elements eight is also maintained as individual element.

Translating the elements shown in figure 13 into statements results in the Q sample as can be found in table 5. The Q sort will be conducted in Dutch, due to the fact that all aspired participants are Dutch, yet in table 5 the English translation of the Q sample can be found. It was decided to categorize the statements based on their field of application, and not based on whether they imply a Lean element, an Agile element or a merged element. This in order to avoid that participants might recognize that the statements imply the usage of Lean and Agile, which could influence the objectivity. As can be obtained from table 5 for *contractor involvement* it was chosen to consider the involvement of the contractor in the design process instead of the involvement of the contractor in the FED phases. This decision was made based on the fact that the concept of FED phases might be unclear to the participants. Therefore the most tangible phase of the FED phases, the design phase, was chosen to replace the FED phases in statement five. In order to review the Q sample several test persons, both with knowledge on the topic and without knowledge on the topic, were asked to review the statements and their corresponding chosen names. This was done to ensure that the statements would be understandable to all participants, but also to ensure that there would only be one possible interpretation of the statements, which is important for the comparability of the Q sorts.

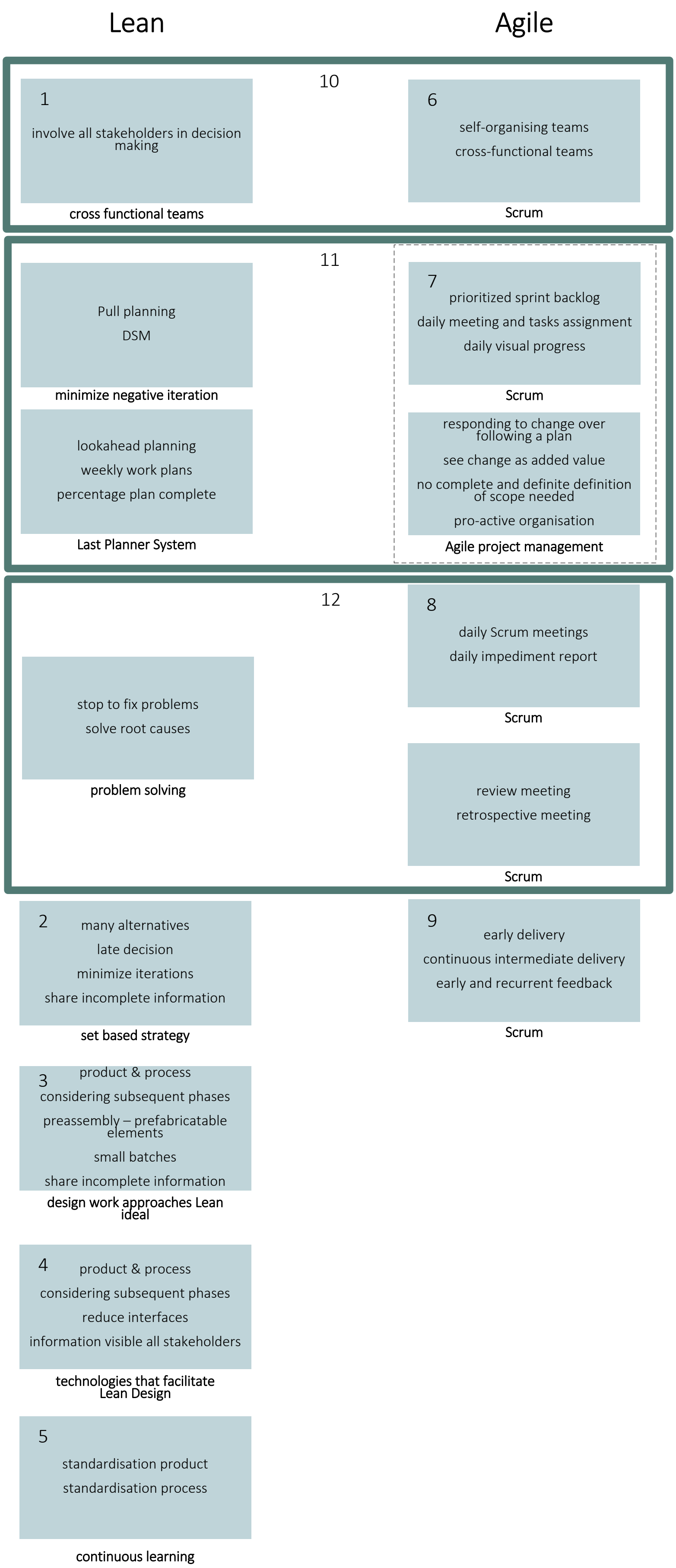


figure 13: final applicable elements

table 5: final Q sample

element #	statement name	definition
design related statements		
5	Design standardization	Standardizing parts of the design would help coping with complexity.
5	Process standardization	Standardizing parts of the project management processes would help coping with complexity.
3	Prefabrication	Including prefabricatable parts in the design would help coping with complexity.
design process related statements		
3	Practicability	Keeping the practicability of the design in mind would help coping with complexity.
1	Contractor involvement	Involving the contractor in the designing process would help coping with complexity.
9	Partial assignments	Dividing the assignment in several partial assignments which will also incrementally be delivered to the client would help coping with complexity.
2	Alternatives detail	Developing all relevant alternatives in detail would help coping with complexity.
2	Delayed decision	Delaying the decision related to the alternatives to the last responsible moment would help coping with complexity.
communication related statements		
8	Daily communication	A daily moment of communication with the entire team (+/- 15 minutes at the beginning of the day) would help coping with complexity.
4	Visual action plan	Visualizing problems and corresponding action plans and making those insightful to all team members would help coping with complexity.
11	Visual progress	Visualizing the progress and making this insightful to all team members would help coping with complexity.
7	Tracking progress daily	Tracking the progress on a daily basis would help coping with complexity.
4	Visual steps	Visualizing all administrative steps which need to be taken and making those insightful to all team members would help coping with complexity.
planning related statements		
11	Weekly planning	Creating the planning on a weekly basis including merely the coming week, instead of creating one planning at the beginning of the process, would help coping with complexity.
7	Priority tasks planning	Including merely tasks with a high priority (according to the client) in the planning would help coping with complexity.
10	Involving team members planning	Involving team members whilst creating the planning would help coping with complexity.
6	Team members decide tasks	Letting team members decide for themselves which tasks they will perform would help coping with complexity.
12	Insightful what to do/is done	Encouraging team members to make insightful for all other team members what they will do the coming day and what they have done the previous day would help coping with complexity.
problem related statements		
12	Reporting problems immediately	Encouraging team members to report problems when they occur would help coping with complexity.
12	Reporting small problems	Encouraging team members to report all sorts of problems, even the small/easy to solve ones, would help coping with complexity.
12	Problems insightful	Encouraging team members to make problems insightful to all other team members would help coping with complexity.

7.1.3 DEFINING THE P SET

The P set represents the set of selected possible participants. Due to the fact that Q sorting research examines qualitative differences, and is thus not aimed at quantitative data, only a limited amount of participants is needed. There is no need for many participants per viewpoint, only three or four participants per viewpoint will be sufficient. For most Q sorting researches this means that no more than 40 participants are needed (Brown, as cited in Ward, 2009). Yet, it is important to carefully select the participants, since it is important that all possible points of view are represented in the Q sorting (Brown & Ungs, as cited in Ward, 2009).

The preconditions for the P set of this study are determined by the scope of the study. The possible application of Lean and Agile elements to the FED phases of an infrastructure project will therefore be assessed by persons working on infrastructure projects in the FED phases as an employee of a civil engineering firm. Due to the fact that this study will be performed for Antea Group it was decided to limit the civil engineer firm scope aspect to civil engineering firm Antea Group. Since all statements are related to management decisions it was further decided to limit the amount of possible participants to merely project leaders. Being project leader at Antea Group is a role and not a job. Project leaders are thus employees who fulfil a certain main job but who, for some projects, take on the role of project leader. Due to the scope condition related to infrastructure projects only project leaders of Antea Group's infrastructure business line will be selected. In the infrastructure business line four departments are present:

1. Rail
2. Roads
3. Engineering Constructions
4. Contracting

Projects conducted by these departments practically all are FED projects. Yet, since the projects executed by the Contracting department do not fit well with the statements part of the Q sample, it was decided to only pick participants from the Rail, Roads and Engineering Constructions departments. This results in a total of 53 possible participants. After considering that the Q sort Excel file will be send during the vacation period an expected responds of 50 per cent is estimated. In the end it is expected that 26 to 27 participants will participate in the Q sorting research.

In figure 14 the main characteristics of the P set are shown. Majority of the possible participants are located in either Almere of Heerenveen. Only one possible participants is located in Geleen. Remarkable about the department of which the possible participants are part of is that only three out of 53 possible participants are part of the Rail department. The remainder of the participants are almost equally divided over the Engineering Structures department and the Roads department. The majority of the participants has either project engineer of project manager as main job and a striking amount of participants is male, only four possible participants are female.

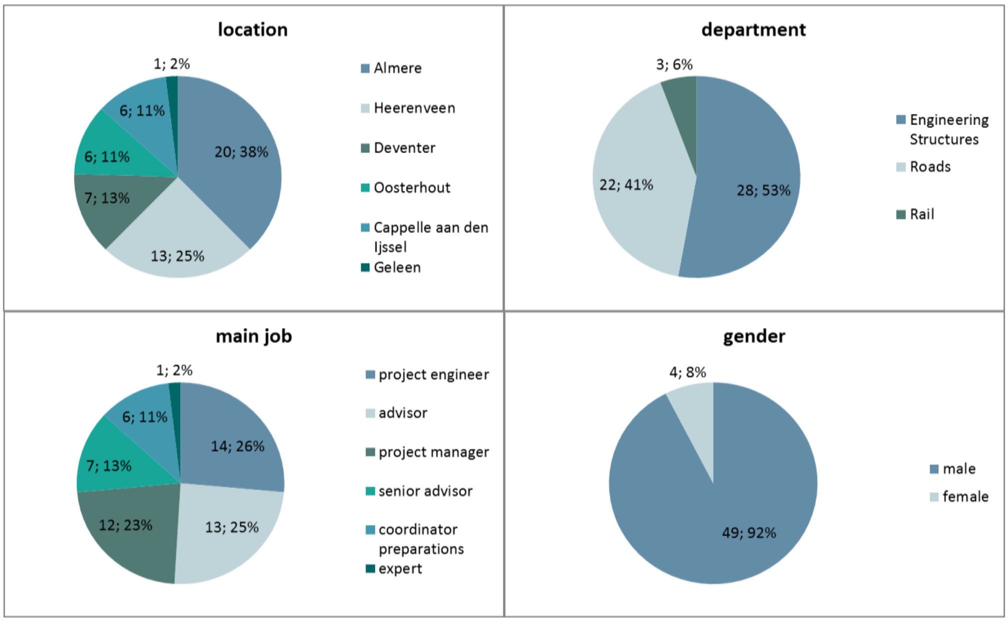


figure 14: characteristics P set

7.1.4 THE Q SORTING PROCESS

For the Q sorting an Excel file questionnaire was set up. The first step for developing the Excel file was searching for existing example Q sorting Excel files. One was found and reviewed resulting in the initial Excel file questionnaire. This initial Excel file was based on the brief review of the Excel file as set up by Gijzel (2014) and was further altered in a way that the Excel file would be suitable for this specific research. Next the Excel file was reviewed by two persons, one with knowledge on Q sorting research and one without knowledge on Q sorting research. After this review it was decided to make two different versions of the Excel file, one in which the participants were asked to place 'cards' with the statements on the predefined Q sorting score sheet and one in which the participants were asked to rank the statements on a scale from most agree to most disagree with scoring the most agree statement with a one and the most disagree statement with a 21. The Excel files were then tested by again two persons, yet this time two persons who were unfamiliar with Q sorting research. After their testing they concluded that ranking the statements was more clear. Thus it was decided to use the ranking Excel file questionnaire. In the following the Excel file questionnaire will briefly be discussed. For the entire Excel file questionnaire as used in this research the reader is referred to appendix G.

The final Excel file questionnaire was sent via email to the selected participants. In this email they were asked to fill out the Excel file questionnaire and sent the filled out file back via email to the researcher. With including their name in the Excel file name. The final Excel file starts with an introduction to the research and the purpose of the questionnaire. It instructs the participants to start with step one, move on to step two and three and end with step four. Each of the steps is presented on a different sheet. At the top of each sheet a short instruction on how to proceed in that step is provided. These instructions were set up to be as clear and specific as possible, to ensure that all participants would be able to understand and carry out the instructions. To make sure that this would be the case, the instructions were read by two test persons without knowledge on Q sorting and subsequent alterations were made. In the first step of the Excel file questionnaire the participants were asked some general questions. This in order to define the characteristics of the participants and to assess whether these characteristics influence their point of view on the application of Lean and Agile elements. In the second step the participants were presented with the 21 statements and were asked to roughly sort them. The participants could respond that they agreed with the statement, that they were neutral on the statement or that they disagreed with the statement. In the third step the participants were presented with a listing of all the statement names, at the top all statement names they had agreed with, following with the statement names they were neutral on and ending with the statement names they had disagreed with. In this step the participants were asked to rank the statements, with one being most agree and 21 being most disagree. The statement names were then automatically filled out in the predefined scoring sheet according to their ranking (figure 15).

-3	-2	-1	0	+1	+2	+3
21	20	17	13	8	4	1
	19	16	12	7	3	
	18	15	11	6	2	
		14	10	5		
			9			

figure 15: predefined score sheet with statement rankings

In the final step of the Excel file questionnaire the participants were again presented with a listing of the statement names and were asked to provide some of the statements with a remark related to their scoring. These remarks are useful for interpreting the final factors and final points of view on the application of the Lean and Agile elements.

7.2 DATA GATHERING CORRELATION ANALYSIS

In this paragraph the preparatory activities for the correlation analysis will be discussed. For the correlation analysis several complex projects will be used as cases. From these complex projects team members will be asked to fill out a questionnaire. In this questionnaire the participants will be asked to assess the complexity of the project they are currently working on and they will be asked to assess the implicit usage of Lean and Agile. Thus complex projects should be selected as well as statements for assessing the complexity of the project and statements about the implicit usage of Lean and Agile. In sub-paragraph 7.2.1 the strategy for the data gathering will be explained. The selection of statements for the questionnaire will be discussed in the second sub-paragraph and the selection of the cases, and thus the selection of the possible respondents, will be discussed in the third sub-paragraph.

7.2.1 STRATEGY FOR DATA GATHERING CORRELATION ANALYSIS

The data gathering for the correlation analysis will be done by means of conducting a digital questionnaire. This choice is made based on the fact that in order to make the results generalizable many respondents are needed and also because of the fact that the questions asked will all be closed-ended questions which are suitable for conducting a digital questionnaire. The software program SurveyMonkey will be used as format for the questionnaire. This because the company for whom this research will be conducted, Antea Group, has access to this survey tool. For analysing the data several tools are available. Most commonly used tools are: Statistical Analysis System or SAS, as developed by SAS Institute, Inc.; S-PLUS, as developed by Insightful Inc.; Statistical Package for Social Sciences or SPSS, as developed by SPSS Inc. but now part of IBM and R, a programming language (Yan & Gang Su, 2009). Due to the researcher's experience with SPSS and due to the fact that this tool is specifically applicable to social sciences studies, this tool was chosen for analysing the data.

7.2.2 DEFINING THE QUESTIONNAIRE QUESTIONS

The questionnaire for the correlation analysis is set out in three parts. In the first part several general questions about the respondent him-/herself are asked. This in order to assess whether these characteristics influence the way the respondents assess the complexity of the project at hand or the implicit usage of Lean and Agile. The second part will consist of several statements for assessing the complexity of the project at hand and the third part of the questionnaire consists of several statements for assessing the implicit usage of Lean and Agile. With compiling the questionnaire it was kept in mind that the amount of questions asked should be limited. This in order to get as many responds as possible. The longer the questionnaire the less respondents are willing to fill out the questionnaire. The goal was to make the questionnaire that concise that the respondents would be able to fill out the questionnaire in fifteen minutes. Yet, it was also be kept in mind that the questionnaire should not be too concise, as this could decrease the completeness and corresponding the validity of the results. In the following the decisions regarding the questions, or statements, will be discussed.

General questions: in order to provide some context for the results from the correlation analysis and in order to assess whether or not characteristics of the respondents influence the way the respondents assess the complexity of the project at hand or the implicit usage of Lean and Agile, some general questions were created. With creating these general questions it was considered that the questionnaire should be anonymous, thus no too specific questions could be asked, as this would decrease the anonymity. Also the amount of questions should be kept in mind, since asking too many question might cause people to abandon the questionnaire before completion. It was decided to limit the amount of questions asked in this first part to six. In table 6 the general questions can be found.

table 6: general survey questions

#	question	possible answers
1	gender	male/female
2	age	open
3	name of project	open
4	role in project team	project manager/project leader /advisor/designer/drafter/engineer/other, namely…(open)
5	years of relevant working experience	open
6	highest level of education	VMBO/HAVO/VWO/MBO/HBO/WO

Perceived complexity: for assessing the perceived project's complexity of the respondents the framework as set up in chapter five will be used. This framework was based on the framework as set up by Bosch-Rekveldt (2011), but was reduced by looking at other frameworks found in literature. Due to the made reduction the framework also becomes more appropriate for this questionnaire, since a limit amount of questions is aimed for. The final framework consisted of 21 elements. These 21 elements were translated into seventeen statements for which the respondents were asked to assess them on a five point Likert scale ranging from totally disagree to totally agree. It was decided to use the same scale for all statements. This in order to keep the questionnaire simple and quick to fill out. A five point scale was chosen because this provides the respondents with the opportunity to take a neutral position. Even though neutral assessments are not beneficial for the results of the correlation analysis, they are in fact meaningless, the threat of people abandoning the questionnaire before completion due to the fact that they are forced into a direction which they find undesirable outweighs this adverse effect. In table 7 the elements and corresponding statements are presented.

table 7: survey questions part two

#	element	#	statement
1	clarity of goals	1	The goals of the project are clear to me.
2	changes in scope	2	Scope changes happen quite often.
3	number of tasks	3	The project exists of many different tasks, which are interdependent.
4	variety of tasks		
5	dependency of tasks		
6	experience of the project management	4	The project management has much experience.
7	interrelations between processes	5	There are many dependencies between the different disciplines/sub-team.
13	interfaces between disciplines		
8	usage of new technologies	6	In this project many new technologies are used.
9	experience with used technologies	7	The project team in general has much experience with the used technologies.
10	uncertainty of technological environment	8	The project's environment is very uncertain.
21	uncertainty of environment (not technical)		
11	project duration	9	The duration of the project is high.
12	availability of resources and skills	10	All resources needed for this project are readily available.
14	financial resources		
15	amount of contracts	11	The amount of contracts in this project is high.
16	level of communication	12	The amount and level of communication in this project is high.
17	changes in organisation	13	Changes in the organisation of this project happen a lot.
18	conflicting interests, perceptions and interpretations of stakeholders	14	The stakeholders involved in this project have many different interests, perceptions and interpretations.
19	political influence	15	The political influence is considerable.
20	level of impact on environment	16	The level of impact on the environment is high.
22	availability of information	17	Information is available to all team member on any given moment of the day.

As can be noted from table 7 several elements were merged into one statement. Where merging elements was possible this was done in order to keep the amount of statements limited. Elements three, four and five were merged in one statement, statement three. This decision was made because all three elements say something about the tasks as part of a project, therefore these three elements were easy to capture in one statement. Also elements seven and thirteen were merged into one statement, statement five. This decision was made based on the fact that both elements might be interpreted by the respondents in the same way, which might be confusing. Likewise elements ten and 21 were merged into one statement, statement eight. Finally elements twelve and fourteen were merged into statement ten, because they both are related to the availability of resources, as resources might both indicate financial resources and labour resources. Therefore merging these elements into one statement mentioning merely resources might result in the respondents interpreting this statement in both ways, financial and labour resources. It should be mentioned that by merging the elements the accuracy decreases, yet it is assumed that assessing the perceived complexity by means of these seventeen statements will still provide in a reliable estimate of the respondent's perceived complexity.

Another note is that most statements are directed towards higher complexity. Agreeing with the statement then means that the project is considered to be complex. Yet, not all statements are formulated in this way. This decision was made in order to keep the statements clear and understandable for the respondents. In table 8 the way the statement should be interpreted is summarized.

table 8: interpreting the answers of part two

#	agree = complex	#	disagree = complex
2	Scope changes happen quite often.	1	The goals of the project are clear to me.
3	The project exists of many different tasks, which are interdependent.	4	The project management has much experience.
5	There are many dependencies between the different disciplines/sub-team.	7	The project team in general has much experience with the used technologies.
6	In this project many new technologies are used.	10	All resources needed for this project are readily available.
8	The project's environment is very uncertain.	12	The amount and level of communication in this project is high.
9	The duration of the project is high.	17	Information is available to all team member on any given moment of the day.
11	The amount of contracts in this project is high.		
13	Changes in the organisation of this project happen a lot.		
14	The stakeholders involved in this project have many different interests, perceptions and interpretations.		
15	The political influence is considerable.		
16	The level of impact on the environment is high.		

Implicit usage of Lean and Agile: for assessing the implicit usage of Lean and Agile the distinguishing elements of Lean and Agile applicable to the FED phases of an infrastructure project, as they were presented in paragraph 7.1, were used as a basis. In table 9 the Lean and Agile elements and their corresponding survey questions are presented, as well as their order of occurrence in the questionnaire.

table 9: survey questions part three

Lean elements	Lean statement	order
5	Standardization is used in this project.	1
3	The constructability of the project is taken into consideration.	2
1	All specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process.	3
2	All relevant alternatives are considered and worked out.	5
2	The decision making process related to the alternatives is delayed as much as possible.	6
4	Much information, like problems and corresponding action plans and the project's performance, is visualized and insightful to me at any given moment.	8
Agile elements	**Agile statement**	
9	The work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback.	4
8	The team or sub-team meets on a daily basis.	7
7	Performance is tracked on a daily basis	9
6	I have selected the tasks I am performing myself.	13
8	Amongst the team everyone is aware of who is doing what, since we often align this.	14
merged elements	**merged statement**	
11	A detailed planning was not made at the beginning of the process, but a one week/month planning is made on a weekly/monthly basis.	10
11	In the planning only tasks with high priority (according to the customer) and for which all prerequisites are met are included.	11
10	I was involved in the planning process.	12
12	Problems, even the smaller once, are reported when the occur and made insightful to all team members.	15

Due to the fact that most participants will be familiar with Lean, yet not so much with Agile it was decided that both Lean and Agile would not be mentioned explicitly, since this might influence the objectivity of the assessment of the statements. This is also the reason for not maintaining the categorization as presented in table 9, but to mix the statements. The order of occurrence in the survey is show in the right column of table 9.

For this second set of statements also a five point Likert scale ranging from totally disagree to totally agree is used. This decision was made in order to keep the survey simple and quick to fill out. For this set of statements agreeing with the statements means that the Lean and Agile ideal is applied, whilst disagreeing with the statements means that the Lean and Agile ideal is merely applied. Thus all statements can be interpreted in the same way.

The questionnaire will be conducted in Dutch, due to the fact that all possible respondents are Dutch. The original version of the questionnaire can be found in appendix H.

7.2.3 CHOOSING THE POSSIBLE RESPONDENTS

The respondents are selected based on whether they are working on a complex project. The preconditions for selecting complex projects are determined by the scope of this research. The complex projects should therefore be FED infrastructure projects performed by a civil engineering firm. Due to the fact that this study will be performed for Antea Group it was decided to limit the civil engineer firm scope aspect to civil engineering company Antea Group. Thus complex infrastructure projects performed by Antea Group could all be possible projects of which respondents can be selected. Due to the fact that this research is interested in infrastructure projects, for this research only the departments: Rails, Roads and Engineering Constructions will be taken into account, like was done for the Q sorting research. In total six complex projects currently performed by Antea Group were selected resulting in a total of 120 possible respondents.

8 ANALYSES AND RESULTS

In this chapter both analyses, the Q sorting and the correlation analysis, will be discussed. The first paragraph will elaborate on the Q sorting research and the second paragraph will elaborate on the correlation analysis. Both paragraphs will end with an intermediate conclusion based on the results of the analysis discussed in that paragraph.

8.1 THE Q SORTING RESEARCH

In this paragraph the Q sorting research results will be discussed. The results will provide an answer to research question 3.1. This answer will be provided in the last sub-paragraph, 8.1.7, of this paragraph. First, in sub-paragraph 8.1.1, the respondents of the Q sorting research will be discussed. What are their characteristics and how will these influence the results of the research. In the next sub-paragraph, 8.1.2, the factor analysis used to define the perspectives will briefly be discussed. In the following three sub-paragraphs each of the perspectives will be elaborated and in sub-paragraph 8.1.6 the perspectives will be compared and evaluated. In the last sub-paragraph a conclusion will be drawn up and, as already mentioned, an answer to research question 3.1 will be formulated.

8.1.1 THE RESPONDENTS OF THE Q SORTING RESEARCH

In figure 16 the characteristics of the respondents of the Q sorting research are shown. The P set consisted of 53 possible respondents. Out of those 53 possible respondents 28 people responded and filled out the questionnaire. Unfortunately three of the 28 respondents did not fill out the questionnaire as asked. Since a total of 25 respondents is a reasonable number, it was decided to exclude the three respondents which did not fill out the questionnaire as asked from the further research. Thus in total 25 respondents contributed to the research.

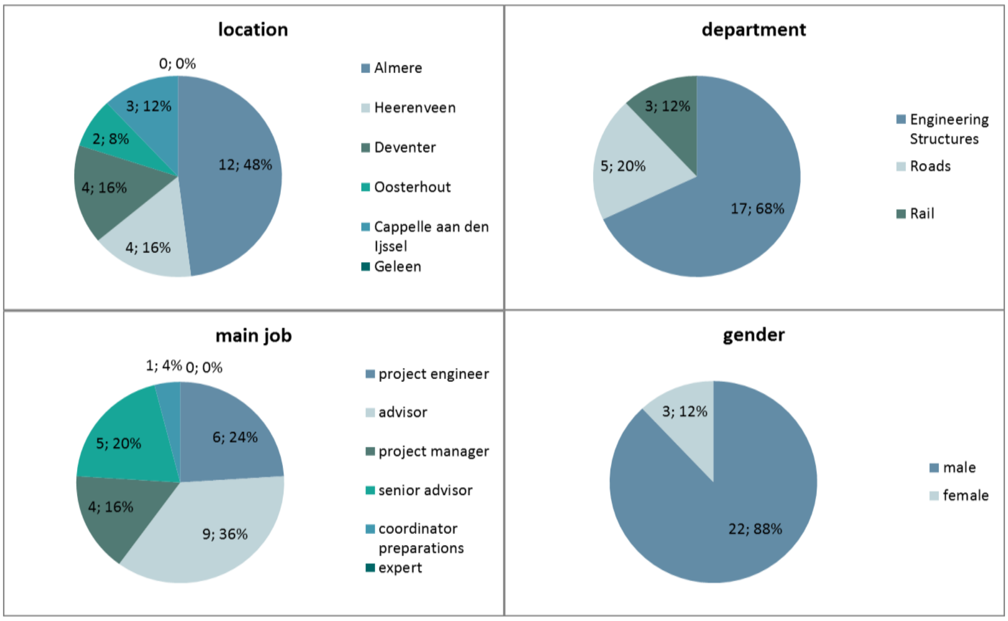


figure 16: characteristics respondents Q sorting

Notable is the difference between the representation in the group of respondents and the P set of the employees working in the Almere and the Heerenveen office. The responds of the Almere office employees is considerably higher compared to the responds of the employees of the other offices. The responds of the Heerenveen office employees on the other hand is much lower compared to the responds of the employees at the other offices. This results in a less even distribution in the set of respondents then in the P set. Yet, it is expected that this will not influence the results of the research. Looking at the distribution related to the department at which the respondents are employed it is notable that the representation of employees employed at the Roads department is considerable lower for the set of respondents then for the P set. Since it is assumed that each department somewhat has its own culture, it is to be expected that the not truthful underrepresentation of the Roads department leads to results slightly differentiating from reality. Looking at the distribution of the main jobs of respondents it should be noted that the responds of advisors is considerably higher compared to the responds of the other employees. It is assumed that this can be assigned to the fact that for advisors the subject of the questionnaire corresponds with their interests. For project managers one would expect that this also applies to them, yet it is assumed that the representation of project managers in the set of respondents is somewhat disappointing due to the fact that project managers are busy people who have less time for filling out a questionnaire. The underrepresentation of preparation coordinators assumingly is assigned to the fact that for them the subject of the questionnaire corresponds less with their interests. This unrealistic distribution of main jobs amongst the set of respondents is expected to influence the final outcome of the research. This because project engineers for example are people with different characteristics compared to senior advisors, and it is thus also expected that project engineers will have a different opinion about Lean and Agile compared to senior advisors. The distribution of gender is somewhat representative.

8.1.2 DEFINING THE PERSPECTIVES

In order to define the amount of points of view or perspectives a factor analysis was performed. The way this factor analysis was performed can be found in appendix I. Resulting from the factor analysis was a total of three factors. Each factor represents a perspective on the usage of Lean and Agile in order to cope with complexity shared by a group of respondents. Each of the three perspectives is assigned a name. Below these names can be found alongside the amount of respondents associated with this perspective. In the following three sub-paragraphs each of these perspectives will be discussed.

4. Commitment and alignment: eleven respondents
5. Simplification and no hassle: four respondents
6. Collaboration restricted by role division: eight respondents

8.1.3 PERSPECTIVE ONE: COMMITMENT AND ALIGNMENT

Characteristics respondents perspective one

In figure 17 the characteristics of the respondents contributing to this first perspective are shown. In total eleven respondents attribute to this perspective. Thus eleven respondents share this same point of view.

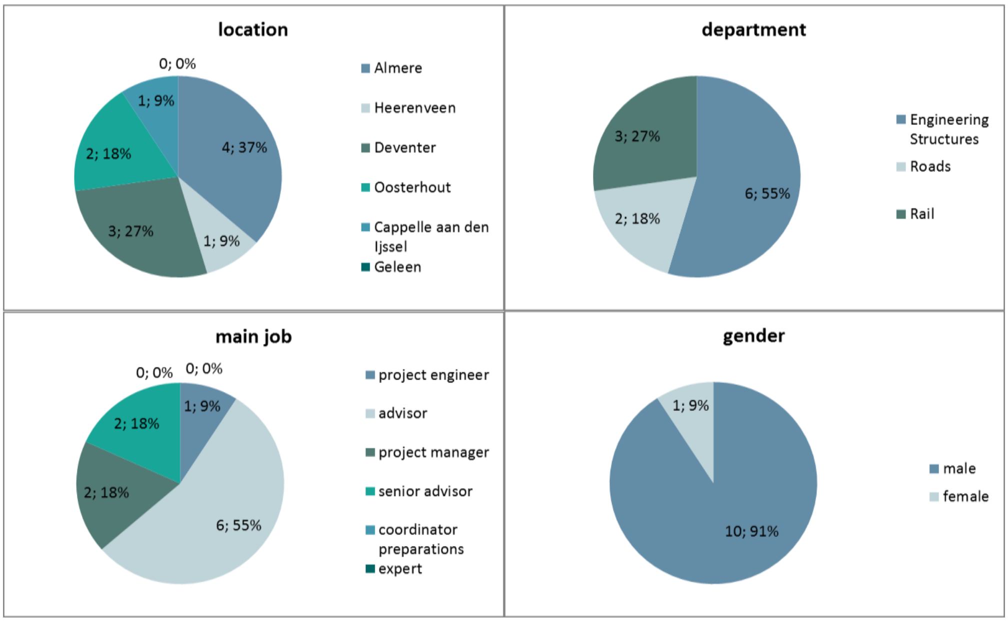


figure 17: general characteristics respondents perspective one

Notable is the difference between the representation in the group of respondents and the P set of the employees working in the Almere, Heerenveen, Deventer and Oosterhout office. The representation of employees from the Almere and Heerenveen office for this perspective is less compared to their representation in the total set of respondents. For the Deventer and Oosterhout the opposite goes. Since it was assumed that the location at which the respondents are located does not influence their culture, this difference will not contribute to interpreting this perspective. The distribution of the departments over the set of respondents for perspective one is somewhat comparable to the distribution of the departments over the total set of respondents. Looking at the distribution of main jobs it can be noted that the amount of project engineers contributing to this perspective is less compared to the total amount of project engineers. For advisor the opposite goes, considerable more advisors attribute to this perspective compared to the total amount of advisors. It is assumed that a respondent's main job influences a respondent's character, or this could also be the other way around: persons with specific characteristics search for and fulfil specific, connecting thereto, jobs, this difference in distribution will influence the interpretation of this perspective. It is assumed that the difference between advisors and project engineers is mostly related to soft and hard skills. Advisors are more focussed on soft skills whilst project engineers are more focussed on hard skills. Thus advisors will likely be drawn to more personal and emotional, soft, tools for managing complexity and project engineers will likely be drawn to more measurable, hard, tools for managing complexity. Since considerably more advisors attribute to this perspective compared to their representation in the total set of respondents and considerably less project engineers attribute to this perspective compared to their representation in the total set of respondents, this perspective to managing complexity aims at using soft tools. The distribution of gender is comparable to the distribution of gender amongst the total set of respondents.

In the questionnaire questions to assess some more character describing aspects were asked. In table 10 the results of the first three questions are shown. As can be noted the averages of the respondents attributing to perspective one are comparable to the averages of the total set of respondents. Therefore these characteristics did not influence the interpretation of this perspective.

table 10: other characteristics respondents perspective one

	min	max	average	average total respondent set
age	39	61	47.4	41.682
years of working at Antea	1	29	9.1 (one missing value)	10.5
years of relevant working experience	15	40	21.7 (two missing values)	17.8

Also questions about previous employers and educational background were asked. These results are summarized in figure 18. Compared to the characteristics of the respondents for the other two perspectives, for this perspective more respondents have an earlier working experience at a contractor. Regarding the educational background for this perspective one respondent is educated in two different fields. Even though engineering studies are overrepresented in the set of respondents attributing to perspective one, also a respondent with a business background is present as well as a respondent who had a complete other education.

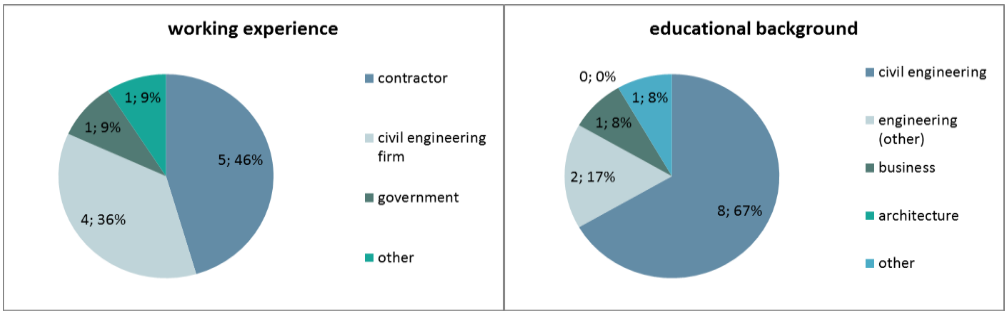


figure 18: other characteristics respondents perspective one

Assessment statements respondents perspective one

In figure 19 the average assessment of the respondents attributing to this perspective is summarized. As can be seen *process standardization* is assessed as the most helpful tool for coping with complexity. Respondent 1 gives the remark: “process standardization can be used to prevent errors or misunderstandings from happening”. Respondent 21 mentions: “by standardizing processes all team members will be aware of what is expected of him and it also enables fast learning”. Also *design standardization* scores high. Most respondents recognize the added value of standardizing parts of the design. Respondent 1 states: “considering the competitive position of Antea, one should make maximum use of previous experiences with the usage of standardized and available elements”. Yet respondents 9 and 20 also see some limitations of the usage of standardized elements. Respondent 9 mentions: “using standardization is only partially possible, it should therefore only be used where possible”. Respondent 20 remarks: “It is important, yet it comes with the risk that something will be copied blindly”. *Practicability* is anther high scoring element. Most respondents are quite positive about considering the *practicability* of the design. Respondent 2 states: “what we draw on paper should be feasible”. Respondent five mentions: “from behind our desks we can come up with a lot, yet how this should be implemented in practice…”. Respondent 9 emphasizes that this is where it often goes wrong, “it is therefore important to pay more attention to the practicability”. Respondent 20 remarks: “it prevents questions to be asked or problems to arise during the execution phase”.

Alternatives detail is averagely ranked lowest and does, according to this perspective, not help with coping with complexity. Respondent 20 makes the remark: “alternatives should be considered in advance, only chosen alternatives should be worked out in detail”. Respondent 1 states that it depends on the client: “if the client pays for a ‘six’, it is not feasible to work out all alternatives in detail”. Also respondent 9 stipulates the time and money consuming aspect of working out more alternatives in detail. Next to *alternatives detail*, also *delayed decision* was assessed poorly. Respondent 20 emphasises the danger delaying such decision for the planning of the project. Respondent 21 agrees: “procrastination will only lead to much work at the end of the process”. Yet, respondent 5 states that without delaying your decision “it should be possible to, in exceptional situations, get back to your original decision, for example in case of changed insights”. Also *team members decide tasks* did not receive a great score. Respondent 1 responds: “also the less fun tasks have to be executed, the person best suitable for executing such a task is the person who should perform that task”. Respondents 20 believes that letting the team members decide for themselves which tasks they will perform will only lead to chaos. Yet, respondent 9 also sees the usefulness: “it is fine to involve the team members, this could lead to commitment, yet this is not always possible, all work must simply be performed”.

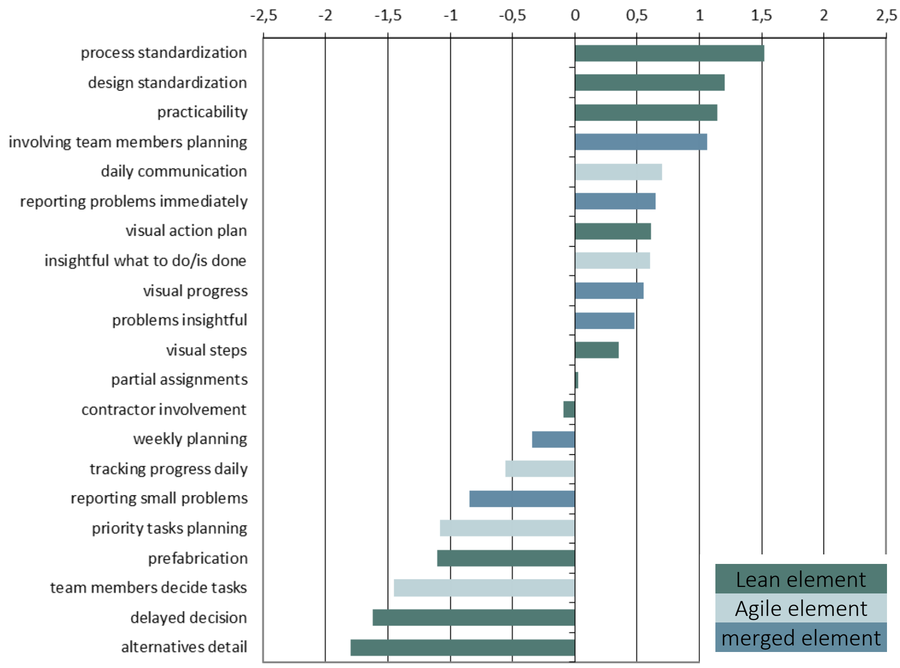


figure 19: assessment perspective one

Even though the most and least helpful assessed elements give a nice overview of the perspective shared by these respondents, it does not completely explains what sets this perspective apart from the other two perspectives. Maybe all three perspectives agree upon the most and least helpful elements. For explaining what sets this perspective apart from the other two perspectives the differently assessed elements will be explored. These distinguishing elements are listed in table 11. The elements marked with an asterisk are significant at the 0.01 level. The others are significant at the 0.05 level.

table 11: distinguishing elements perspective one

#	statement	Z-score factor 1	Z-score factor 2	Z-score factor 3	Z-score placement
1	design standardization	1.20*	2.02	-0.70	in between
16	involving team members planning	1.06*	-0.50	0.34	higher
9	daily communication	0.70*	-0.90	-0.51	higher
18	insightful what to do/is done	0.60	-0.87	0.11	higher
13	visual steps	0.35*	-1.23	-0.56	higher
6	partial assignments	0.03*	-1.02	1.40	in between
5	contractor involvement	-0.09*	0.74	0.81	lower
20	reporting small problems	-0.84*	0.54	0.39	lower
3	prefabrication	-1.11*	1.15	-0.10	lower

Below only the higher or lower assessed elements will be discussed, since the ‘in between’ assessed elements are less interesting for interpreting this perspective.

Perspective one is considerably more positive about *involving team members planning* compared to the other perspectives. Respondent 1 responds: “this makes it harder for the team members to accuse the planning of being unrealistic later on in the project, the planning has the be supported by all team members”. Also respondent 5 emphasizes the importance of a supported planning: “it creates commitment with both the planning and the budget”. Respondent 18 and respondent 20 also make the remark that involving the team members in the planning process will give the team members a sense of responsibility, with the extra benefit of that it will become easier to address planning deviations. Respondent 21 sees another benefit: “planning interfaces can be discussed”.

Another distinguishing element is *daily communication*. Whilst the other two perspectives on this elements are rather negative, this perspective on *daily communication* is more positive. Respondent 1, 18 and 25 all pinpoint the fact that *daily communication* can help with keeping track on progress, alignment, providing insight in who is doing what, also to bring interfaces to the surface, and it can help controlling and managing the project. Respondent 9 remarks: “it appears to be necessary when much disciplines are involved, yet geographically it turns out to be difficult, project rooms only are not sufficient”.

Insightful what to do/is done implies that all team members are aware of what all other team members are doing. Also this elements was assessed more positive compared to the other perspectives. Respondent 1 agreed that this would help coping with complexity, as he states: “the project team members can, if necessary, adjust their activities to the progress of other team members”. Respondent 5 remarks that it will also create more team spirit. Respondent 20 has a more neutral perspective on this element, he remarks: “I believe that doing so on a daily basis is a bit exaggerating”.

The *visual steps* element was about visualizing all administrative steps in order to make them clear to all team members. Perspective one respondents were more positive about this elements compared to the other respondents. Respondent 1 agreed that this would help coping with complexity: “visualizing would work enlightening for not only the team members, but also for the client”. Respondent 21 emphasizes the need to do so in order to create more alignment, which is necessary for complex projects.

Involving the contractor in the FED phases, or *contractor involvement*, is also a distinguishing element for perspective one. Respondent 9 and 18 both agree that this would help coping with complexity. This because they both see the added value a contractor can bring to the project. The contractor has certain knowledge about the practicability of the design which only he has. Respondent 7 and 20 take a more neutral position. Respondent 7 thinks that you should only involve the contractor once the scope is established, thus the costs, planning and quality are clear. Respondent 20 states: “it could work, yet it could also lead to increased complexity”. Respondent 1 disagrees with the fact that involving the contractor could help coping with complexity. Respondent 1’s response: “we are a consultancy- and engineering firm which operates independently from a contractor, if the project requires the involvement of the contractor this should off course be done”.

Reporting small problems implied that all problems, even the small ones, should be reported. This elements received a considerable lower score of the perspective one respondents compared to the other respondents. Respondent 20 states: “when a problem is easy to solve, there is no need to report it and it will also stimulate the independent work ethos of the team members”. Respondent 21 remarks that it will only distract from the problems that truly matter. Respondent 2 takes a more neutral position: “the risk here is that it might lead to focussing on problems and making problems more severe than they actually are, reporting problems would help, yet one should also bring a solution to the table”. Respondent 1 is more positive about *reporting small problems*. He believes that this could be included in the daily communication moment.

Last distinguishing element for perspective one is *prefabrication*. Respondent 2 and 20 both were negative about this element. Respondent 2 made the remark: “we do not work with toddlers”. Respondent 20 believes that this falls outside the scope of their activities. Respondent 5 takes a more neutral position. He states that prefabrication not necessarily leads to a less complicated design, yet in some cases it could work. Respondent 1 is more positive about *prefabrication*. He states: “this could lead to reduced costs for Antea”.

8.1.4 PERSPECTIVE TWO: SIMPLIFICATION AND NO HASSLE

Characteristics respondents perspective two

In figure 20 the characteristics of the respondents contributing to this second perspective are shown. In total four respondents attribute to this perspective. Thus four respondents share this same point of view.

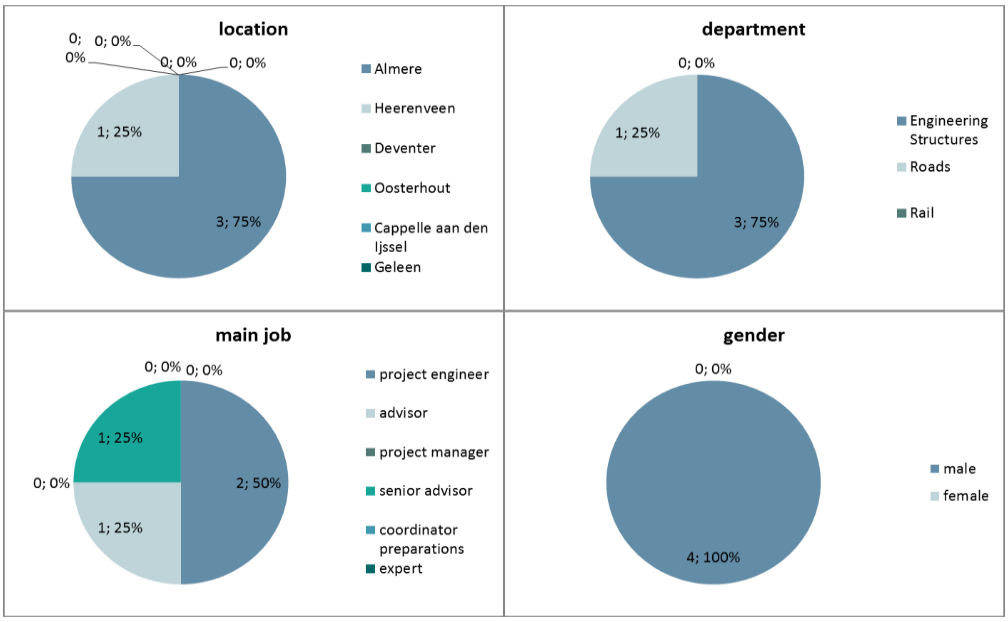


figure 20: general characteristics respondents perspective two

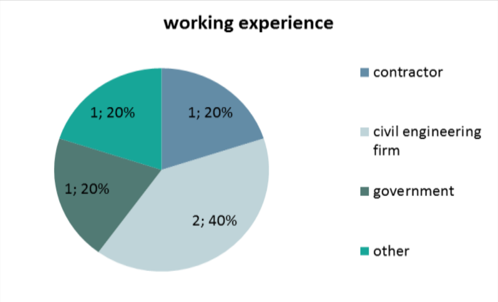
The distributions are in most cases comparable. Only the main job characteristic deviates. For this perspective relatively more project engineers contributed compared to their representation in the total set of respondents, whilst relatively less advisors contributed to this perspective compared to their representation in the total set of respondents. As already mentioned, it was assumed that a respondent's main job influences a respondent's character, the other way around. It was assumed that the difference between advisors and project engineers is mostly related to soft and hard skills. Advisors are more focussed on soft skills whilst project engineers are more focussed on hard skills. Thus project engineers will likely be drawn to more measurable, hard, tools for managing complexity and advisors will likely be drawn to more personal and emotional, soft, tools for managing complexity. Since considerably more project engineers attribute to this perspective compared to their representation in the total set of respondents and considerably less advisors attribute to this perspective compared to their representation in the total set of respondents, this perspective to managing complexity aims at using hard tools.

In the questionnaire questions to assess some more character describing aspects were asked. In table 12 the results of the first three questions are shown. As can be noted the averages of the respondents attributing to perspective two are comparable to the averages of the total set of respondents. Therefore these characteristics did not influence the interpretation of this perspective.

table 12: other characteristics respondents perspective two

	min	max	average	average total respondent set
age	28	47	36.25	41.682
years of working at Antea	4	25	12.25	10.5
years of relevant working experience	5	25	12.75	17.8

Also questions about previous employers and educational background were asked. These results are summarized in figure 21. Compared to the characteristics of the respondents for the other two perspectives, for this perspective more respondents have an earlier working experience at a civil engineering firm. One respondent has both earlier working experience at an engineering firm as well as at a governmental body. One respondent has earlier working experience at a contractor and one has another type of earlier working experience. Regarding the educational background in this perspective two respondents are educated in two fields. Notably is the representation of architectural educated respondents. Three respondents studied civil engineering and one respondent is educated in the field of business.



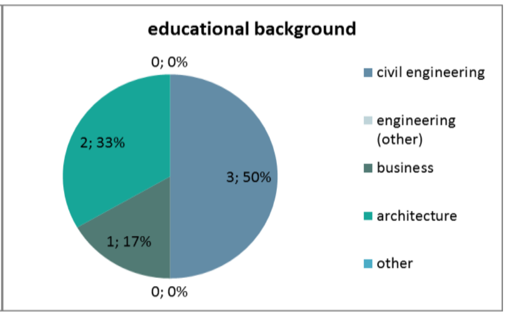


figure 21: other characteristics respondents perspective two

Assessment statements respondents perspective two

In figure 22 the average assessment of the respondents attributing to this perspective is summarized. As can be seen *design standardization* was assessed as the most helpful tool for coping with complexity. Respondent 16 made the remark: “through standardizing designs multiple departments will be forced to think along, which will lead to an optimal usages of standardised designs in the future”. Respondent 23 remarks: “design standardization will be beneficial for all parties, as it lowers the risk of failure costs”. Respondent 27 also agrees, he states that his department still makes little use of standardization, these days even less than in the past. Next to *design standardization* also *practicability* is scored highly. Unfortunately none of the respondents commented on their decision. Third element with a high score is *prefabrication*. Respondent 23 states: “the design will become better crystallized and operationally better attuned in advance, the quality of prefab mostly is higher due to conditioned circumstances”.

Assessed as least helpful is *delayed decision*. Respondent 23 states that he does not advocate making delayed decisions because of the chance on changes and thus failure costs. Respondent 27 remarks: “the more variation the more ambiguity and complexity, making late choices often leads to a more busy planning which on its turn will make the project more complex”. Also *visual steps*, visualizing all the administrative steps, received a low score. Yet, for this element none of the respondents made a comment. Last poorly ranked elements is *team members decide tasks*. Respondent 16 states: “team members are just assigned the work they need to perform, otherwise the team members are most certainly only going to perform the fun tasks, whilst the less fun tasks remain undone”.

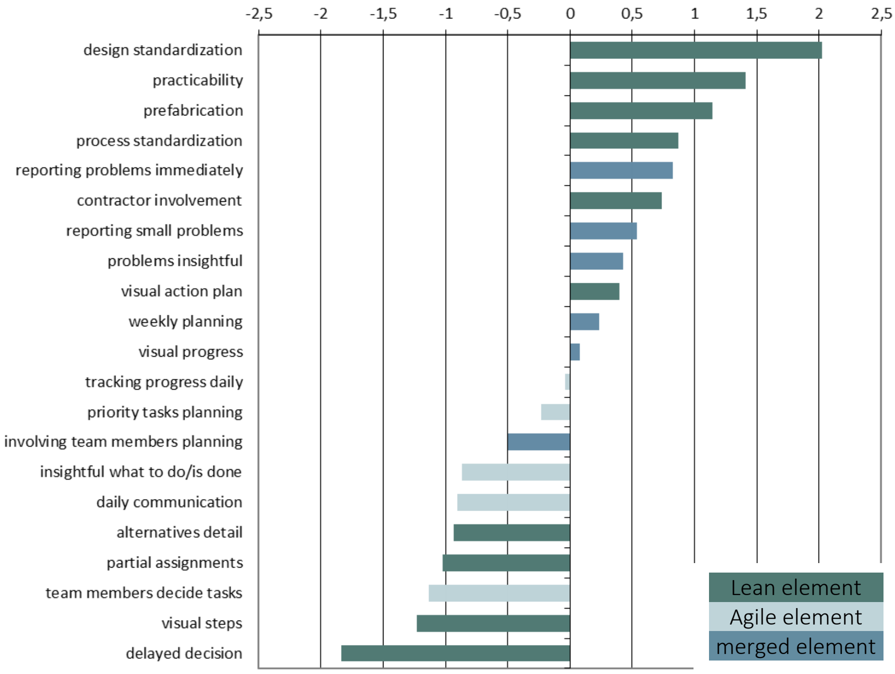


figure 22: assessment perspective two

Also for this second perspective the distinguishing elements will be discussed. These distinguishing elements are listed in table 13. The elements marked with an asterisk are significant at the 0.01 level. The others are significant at the 0.05 level.

table 13: distinguishing elements perspective two

#	statement	Z-score factor 2	Z-score factor 1	Z-score factor 3	Z-score placement
1	design standardization	2.02*	1.20	-0.70	higher
3	prefabrication	1.15*	-1.11	-0.10	higher
15	priority tasks planning	-0.23*	-1.08	-1.17	higher
16	involving team members planning	-0.50*	1.06	0.34	lower
18	insightful what to do/is done	-0.87*	0.60	0.11	lower
7	alternatives detail	-0.93*	-1.80	-1.91	higher
6	partial assignments	-1.02*	0.03	1.40	lower
13	visual steps	-1.23	0.35	-0.56	lower

First distinguishing element is *design standardization*, which is ranked must higher by this second perspective compared to the other two perspectives. The same goes for *prefabrication*. Since both elements were ranked in the top three comments on both elements were already discussed in the proceeding. *Priority tasks planning*, ranked higher compared to the ranking of the other perspectives, is also a distinguishing element for this perspective, yet unfortunately none of the respondents remarked on their scoring. Also for elements *alternatives detail*, scored higher, and *visual steps*, scored lower, none of the respondents made remarks. Therefore below only the elements for which comments were made will be discussed.

Involving team members planning, involving the team members in the planning making process, was scored considerably lower by perspective two compared to the other perspectives. Respondent 23 took a neutral position on this element as he remarked: “in my opinion it is not necessary to involve all team members in the planning making process”. Element *insightful what to do/is done*, encouraging all team members to keep all other team members up to date regarding their activities, is scored lower by this perspective compared to the other perspectives. Respondent 16 states: “I believe this is not necessary, the team members collaborate quite well and are largely aware of the other team members' activities". Last commented distinguishing element for this perspective is *partial assignment*, or dividing the project in several smaller assignments. This element is assessed much poorly by this second perspective compared to the other perspectives. Respondent 16 makes the remark: "this would be easy for the larger projects, yet in my experience for medium to small projects this is impossible". Respondent 23 states: "the chance on losing a complete overview of the project will increase and it will also require more (sub) project leaders".

8.1.5 PERSPECTIVE THREE: COLLABORATION RESTRICTED BY ROLE DIVISION

Characteristics respondents perspective three

In figure 23 the characteristics of the respondents contributing to this second perspective are shown. In total eight respondents attribute to this perspective. Thus eight respondents share this same point of view.

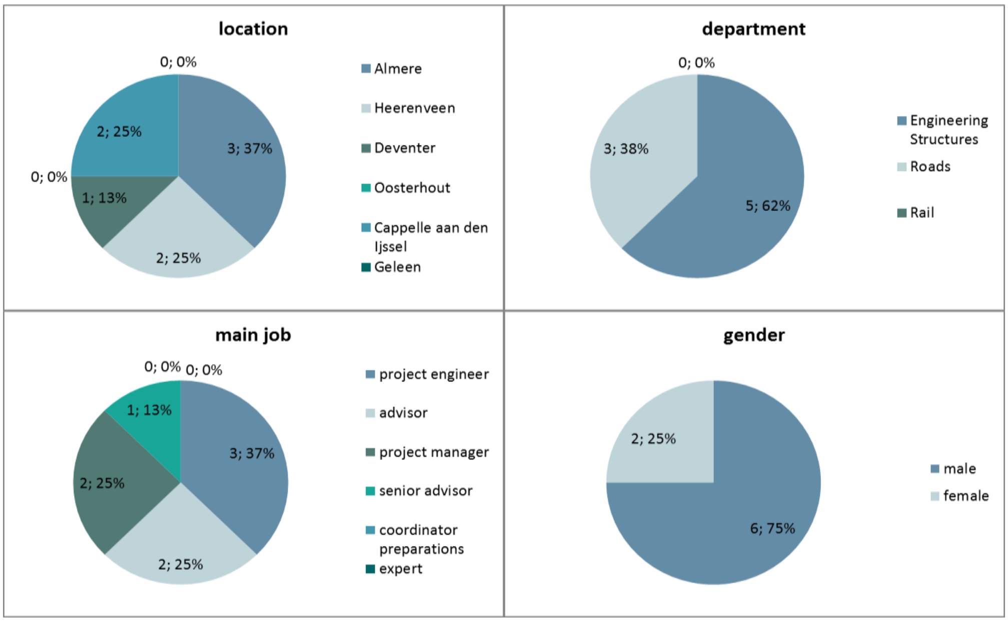


figure 23: general characteristics respondents perspective three

Looking at the distribution of location it can be noted that the amount of employees working at the Capelle aan den IJssel office are overrepresented in the set of respondents attributing to perspective three compared their representation in the total set of respondents. Since it was assumed that the location at which the respondents are located does not influence their culture, this difference will not contribute to interpreting this perspective. The distribution of the respondents contributing to perspective three over the different departments is comparable to the distribution of the total set of respondents over the different departments. Looking at the respondents' main jobs it should be noted that for this perspective considerably less advisors as well as senior advisors are represented compared to the total set of respondents. Considerably more project managers are represented in this perspective. Being a project manager means that you mostly fulfil a commercial role and keep contact with the client. As project manager you are less involved, or not involved in the execution of the project (in this case the FED). When a project manager takes on the role of project leader this changes, as he then becomes involved in the project on a day to day basis. The fact that the project manager is hardly ever involved in the execution of the projects, when he does not take on the role of project leader, most probably influences his point of view to the use of Lean and Agile in projects. It is assumed that a project manager will hold on more firmly to a traditional role division. A project manager will most likely advocate a clear division between the project management and the project team members. The distribution of gender is comparable to the distribution of gender amongst the total set of respondents.

In the questionnaire questions to assess some more character describing aspects were asked. In table 14 the results of the first three questions are shown. As can be noted the averages of the respondents attributing to perspective three are comparable to the averages of the total set of respondents. Therefore these characteristics did not influence the interpretation of this perspective.

table 14: other characteristics respondents perspective three

	min	max	average	average total respondent set
age	29	50	38.33	41.682
years of working at Antea	7	18	10.22	10.5
years of relevant working experience	5	25	12.75	17.8

Also questions about previous employers and educational background were asked. These results are summarized in figure 24. Compared to the characteristics of the respondents for the other two perspectives, for this perspective most respondents had previous working experience at a civil engineering firm. Twenty per cent previously worked at a contractor and the last twenty per cent at another kind of employee. All respondents has an educational background in civil engineering.

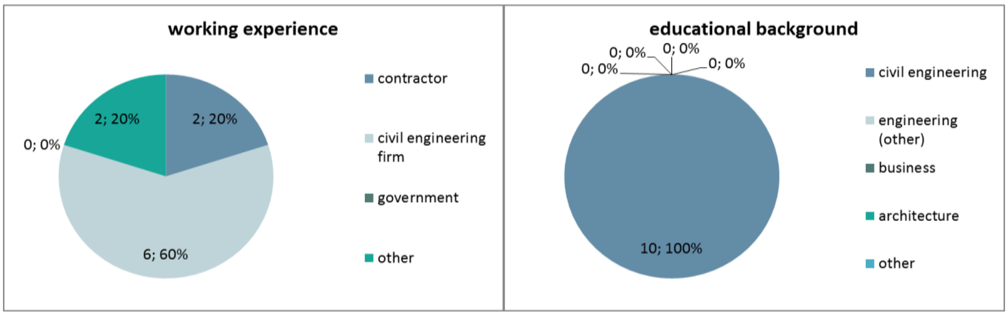


figure 24: other characteristics respondents perspective three

Assessment statements respondents perspective three

In figure 25 the average assessment of the respondents attributing to this perspective is summarized. As can be seen *reporting problems immediately* is averagely ranked the highest. Respondent 4 commented: “by reporting problems, an individual problem becomes a shared problem of the entire project team, which makes the problem easier to solve”. Respondent 6 responds that it will prevent time and budget changes from happening. Respondent 11 agrees, it will spare costly time and money, since “the right people for solving the problem can be sought after at once”. Respondent 24 believes that it will also lead to a maximized usage of the knowledge, insights and creativity of the team members. Next to *reporting problems immediately*, also *partial assignments* received a high score. Respondent 4 responds: “the complexity of a project has to do with the size of the project, when it is possible to break the project up in several smaller pieces this will make the project much easier to handle”. Respondent 11 remarks: “with partial assignments and intermediate deliveries a planning and budget related overview is easier to create, also intermediate deliveries can be seen as the departure point for the following phase, this makes that extra work due to changes are easier to make insightful”. Also *practicability* was ranked quite high by most respondents attributing to this perspective. Respondent 6 remarks: “it could decrease or prevent failure costs”. Respondent 24 states: “the end result should always be practicable, otherwise the risk that you will need to start over and adapt your design will become really high”. Respondents 4 and 11 also agree, yet question whether it will help coping with complexity. Respondent 4 remarks: “this is a must, each design should be practicable in the end, whether it truly makes a project less complex I question”.

Alternatives detail was averagely ranked the lowest. Respondent 4 states: “this will create more work, choices need to be made before the detailed design”. Respondent 6 remarks: “this is part of the tasks of the contractor, we need to focus ourselves on the bigger picture”. Respondent 11 responds by saying: “alternatives are best to be investigated merely on the outlines, otherwise it will cost too much time and money, though it is important to look at several alternatives”. Respondent 19 states: “working alternatives which are unfeasible or unrealistic out in detail means extra ballast which will be experienced as not useful, for realistic alternatives though this will be a good idea". Respondent 24 believes that funnelling and making choices related to the alternatives is necessary, but states that in most cases no time and money is available to do so. Next to *alternatives detail*, also *delayed decision* received a low score. Most remarks correspond to the remarks made for *alternatives detail*. Respondent 4 states: "the opposite, this can most often be seen as a disadvantage instead of an advantage". Respondent 6 remarks: "people believing that they can make changes even at the last moment are truly harmful to the project, since the project becomes harder to control". Respondent 11 agrees as he states that by delaying decisions problems will only get bigger. Respondent 17 even calls *delayed decisions* fatal for all projects: "making changes at the last moment makes that many products need to be adjusted which increases the risk on making errors". Last low scoring element to be discussed is *priority tasks planning*. Respondent 4 states that not only tasks with priority should be included in the planning, but all tasks. Respondent 11 remarks: "regarding the planning it is important to create a complete overview, though it is possible to make a distinction in this overview between critical and less critical tasks".

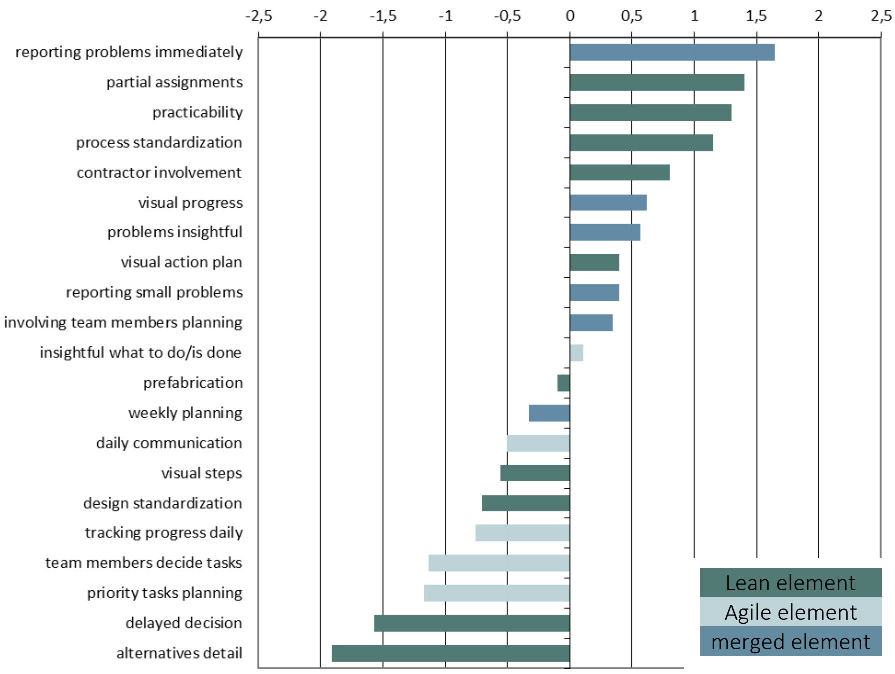


figure 25: assessment perspective three

Also for this third perspective the distinguishing elements will be discussed. These distinguishing elements are listed in table 15. The elements marked with an asterisk are significant at the 0.01 level. The others are significant at the 0.05 level.

table 15: distinguishing elements perspective three

#	statement	Z-score factor 3	Z-score factor 1	Z-score factor 2	Z-score placement
19	reporting problems immediatly	1.64*	0.65	0.82	higher
6	partial assignments	1.40*	0.03	-1.02	higher
16	involving team members planning	0.34*	1.06	-0.50	in between
18	insightful what to do/is done	0.11	0.60	-0.87	in between
3	prefabrication	-0.10*	-1.11	1.15	in between
13	visual steps	-0.56	0.35	-1.23	in between
1	design standardization	-0.70*	1.20	2.02	lower

Below only the higher or lower assessed elements will be discussed, since the 'in between' assessed elements are less interesting for interpreting this perspective.

Both *reporting problems immediately* and *partial assignments* were scored considerable higher by the respondents attributing to this perspective compared to the scoring performed by the other respondents. Since both were already discussed in the proceeding, they will not be discussed here.

Interestingly is the average assessment of *design standardization*. This element received a considerably lower score from the respondents attributing to this perspective compared to all other respondents. Respondent 11 states: "standardization of the work can make it more easy, yet when a standardized part under certain circumstances does not fit with the rest of the design it could in fact lead to increased complexity, in my experience the work my department performs is mostly customized work and should properly be aligned with all different stakeholders". Respondent 13 remarks: "for some parts it could work, yet the risk of standardization lies in the fact that it could lead to over generalization and to work not being performed project specific anymore or not contemplated at all". Respondents 19 and 24 are more positive as they state that *design standardization* should be used where possible.

8.1.6 COMPARING THE PERSPECTIVES

For some elements all perspectives share a somewhat same point of view, whilst for some elements the perspectives have completely different points of view. In the following the consensus as well as the disagreement elements will be discussed.

Consensus elements

In figure 26 a graphic representation of the consensus elements is shown. The consensus elements are the elements that did not add to the distinguishing of any of the perspectives. One could say these are the elements for which all respondents share the same point of view. These elements are therefore important to discuss, since they will provide much insight in the practical usefulness of the elements. Agreement about the usefulness of an element amongst all respondents could mean that the element will truly be useful and could thus also truly help coping with complexity. Whilst agreement about the uselessness of an element amongst all respondents could mean that the element will not be useful and would thus not help coping with complexity.

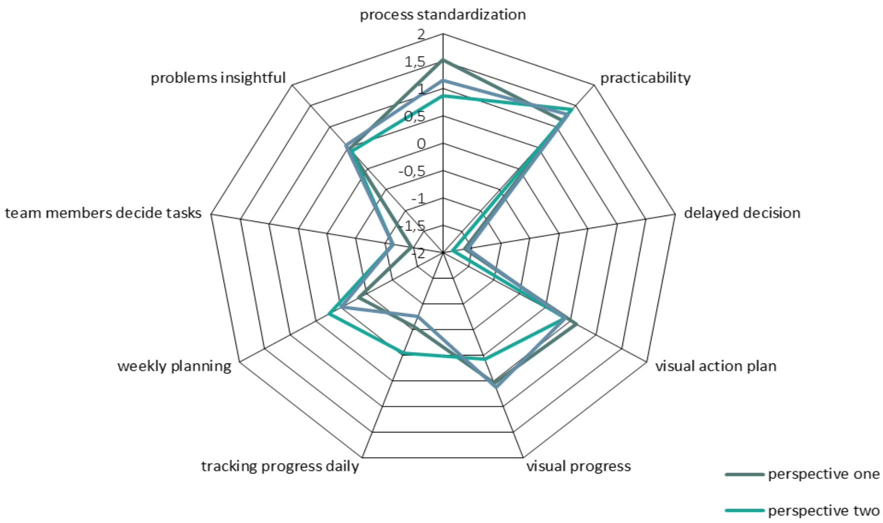


figure 26: consensus elements

In table 16 the Z-scores assigned by the different perspectives to the consensus elements are shown. Each of the elements will be discussed below. First the elements with a relative high average Z-score will be discussed, followed by a discussion of more neutral scored elements and ending with a discussion of the elements with a relative low average Z-score.

table 16: consensus elements

#	element	Z-score factor 1	Z-score factor 2	Z-score factor 3	average Z-score
2	process standardization	1.52	0.87	1.15	high
4	practicability	1.15	1.41	1.30	high
8	delayed decision	-1.62	-1.83	-1.57	low
10	visual action plan	0.61	0.39	0.40	neutral
11	visual progress	0.55	0.08	0.62	neutral
12	tracking progress daily	-0.56	-0.04	-0.76	neutral
14	weekly planning	-0.34	0.23	-0.33	neutral
17	team members decide tasks	-1.45	-1.14	-1.14	low
21	problems insightful	0.48	0.42	0.57	neutral

* high - an average score of 1 or more, neutral - an average score between -1 and 1, low - an average score of -1 or less.

Process standardization and *practicability* both received a high score of each of the perspectives. It can thus be concluded that according to all respondents standardizing the FED processes as well as keeping the practicability of the design made in the FED in mind would help coping with a project's complexity.

Visual action plan, visual progress, tracking progress daily, weekly planning and *problems insightful* were all assessed more neutral by the three perspectives' respondents. Three reasons can be thought of: (1) the respondents all were unsure of the extent to which the element could help, (2) the points of view of the respondents attributing to one of the perspectives differs, thus there is disagreement within the three general perspectives on these elements, or (3) the respondents did not understand or interpreted the elements and related statements incorrectly. To assess which of these reasons goes for the elements mentioned above one could look at the remarks made by the respondents. In table 17 the amount to which for each perspective a respondent replied agree, neutral or disagree, is shown. In this table the neutral elements negatively assessed are shaded grey. As can be seen for *visual action plan, visual progress* and *problems insightful* the first reason can be applied, the respondents are unsure of the extent to which it could help. For *tracking progress daily* and *weekly planning* the second reason can be applied. As can be seen there is much disagreement amongst all the respondents on these elements. It could therefore be concluded that the neutral assessment on these elements is the result of averaging disagrees and agrees. That is why for these elements the neutral assessment is somewhat meaningless.

table 17: neutral consensus elements

	# agree			# neutral			# disagree		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
visual action plan	9	4	4	2	0	4	0	0	0
visual progress	11	3	7	0	0	0	0	1	1
tracking progress daily	5	2	1	4	1	1	2	1	6
weekly planning	4	2	2	5	1	1	2	1	5
problems insightful	11	4	6	0	0	1	0	0	1

Delayed decision and *team members decide tasks* both received a low score of each of the perspectives. It can thus be concluded that according to all respondents delaying the decision regarding the alternatives and letting team members decide themselves which tasks they will perform, thus self-assignment of tasks, will little help managing complexity.

Disagreement elements

In figure 27 a graphic representation of the disagreement elements is shown. The disagreement elements are the elements that distinguish the perspectives. One could say these are the elements for which the perspective truly differ. These elements are important to discuss, since they show for which elements there is much disagreement. Disagreement about the usefulness of the elements could result in a grouping of elements for each perspective in which elements will help coping with complexity and which elements will little help coping with complexity, in their point of view.

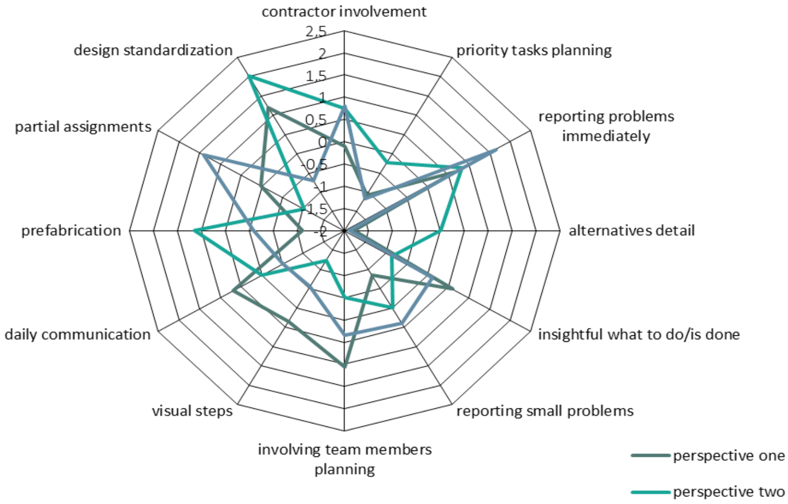


figure 27: disagreement elements

In table 18 the Z-scores assigned by the different perspectives to the disagreement elements are shown. As can be noted there are considerably more elements on which the perspectives disagree upon, compared to the elements on which the perspectives agreed upon. Regarding these disagreement elements it is interesting to see whether all perspectives show disagreement with each other or whether for two there is consensus and one disagreed with those two. In table 18 the grey shaded elements are elements for which two perspectives showed consensus and one disagreed. In the last column the disagreeing perspectives are listed. As each of these elements were already explored in the individual discussion of each perspective's distinguishing elements these elements will not be discussed in this section.

table 18: disagreement elements

#	element	Z-score factor 1	Z-score factor 2	Z-score factor 3	distinguishing
5	contractor involvement	-0.095	0.739	0.806	P1
15	priority tasks planning	-1.082	-0.229	-1.165	P2
19	reporting problems immediately	0.646	0.825	1.644	P3
7	alternatives detail	-1.797	-0.931	-1.907	P2
18	insightful what to do/is done	0.603	-0.868	0.111	
20	reporting small problems	-0.842	0.537	0.393	P1
16	involving team members planning	1.062	-0.496	0.342	
13	visual steps	0.353	-1.227	-0.556	
9	daily communication	0.697	-0.902	-0.509	P1
3	prefabrication	-1.108	1.145	-0.099	
6	partial assignments	0.026	-1.020	1.404	
1	design standardization	1.201	2.022	-0.702	

8.1.7 CONCLUSION Q SORTING RESEARCH

3.1 Which elements of Lean and Agile can, and which elements cannot, be used in practice?

Three perspectives were defined: commitment and alignment, simplification and no hassle and collaboration restricted by role division. For each the high and low scoring elements were discussed, as well as the most distinguishing scored elements. Yet, what does this say about the practical use of the Lean and Agile elements? In order to come to a conclusion first in figure 28 the average ranking over all three perspectives and the individual ranking of each of the perspectives are set side by side. In this figure the disagreement or distinguishing elements are highlighted. Concluding, in the last ranking of figure 28 merely the consensus elements are included. This ranking all respondents agreed upon.

figure 28: element rankings

What can be concluded from the disagreement elements? Below for each perspective a conclusion on its distinguishing elements will be provided.

Perspective one: commitment and alignment

For this perspective it was found that compared to the other two perspectives the most advisors taking on the role of project leader belonged to the group of respondents. It could therefore be concluded that advisors will most likely take this point of view towards the usage of Lean and Agile. In order to assess which elements, according to their point of view, would help the most for coping with complexity in table 19 the distinguishing elements for the commitment and alignment perspective are listed. Next to the helpful consensus elements, according to this point of view also *involving team members planning, daily communication, insightful what to do/is done, visual steps, design standardization* and *partial assignments* would help to deal with complexity. Yet, for *design standardization* and *partial assignments* it should be noted that there is another perspective which is more convinced of the helpfulness. The highlighted elements are elements which were only distinguishing for perspective one. Thus this perspective towards *daily communication, contractor involvement* and *reporting small problems* differs from the perspective shared by perspectives two and three. Regarding *daily communication* this perspective is more positive compared to the shared perspective for this element of perspectives two and three on this element. Whilst regarding *contractor involvement* and *reporting small problems* this perspective is more negative compared to the shared perspective for these elements of perspectives two and three.

table 19: conclusion perspective one

higher		in between		lower	
Most	least	most	least	most	least
involving team members planning		design standardization			contractor involvement
daily communication		partial assignments			reporting small problems
insightful what to do/is done					prefabrication
visual steps					

Perspective two: simplification and no hassle

For this perspective it was found that compared to the other two perspectives the most project engineers taking on the role of project leader belonged to the group of respondents. It could therefore be concluded that project engineers will most likely take this point of view towards the usage of Lean and Agile. In order to assess which elements, according to their point of view, would help the most for coping with complexity in table 20 the distinguishing elements for the simplification and no hassle perspective are listed. Next to the helpful consensus elements, according to this point of view also *design standardization* and *prefabrication* would help coping with complexity. *Priority tasks* and *alternatives detail* were assessed as less helpful elements, yet were assessed more positively by this perspective compared to all other perspectives. The highlighted elements are elements which were only distinguishing for perspective two. Thus this perspective towards *priority tasks planning* and *alternatives detail* differs from the perspective shared by perspectives one and three on these elements. Regarding both this perspective is more positive compared to the shared perspective for these elements of perspectives one and three.

table 20: conclusion perspective two

higher		in between		lower	
most	least	most	least	most	least
design standardization	priority tasks planning				involving team members planning
prefabrication	alternatives detail				insightful what to do/is done
					partial assignments
					visual steps

Perspective three: collaboration restricted by role division

For this perspective it was found that compared to the other two perspectives the most project managers taking on the role of project leader belonged to the group of respondents. It could therefore be concluded that project managers will most likely take this point of view towards the usage of Lean and Agile. In order to assess which elements, according to their point of view, would help the most for coping with complexity in table 21 the distinguishing elements for the collaboration restricted by role division perspective are listed. Next to the helpful consensus elements, according to this point of view also *reporting problems immediately, partial assignments, involving team members planning* and *insightful what to do/is done* would help coping with complexity. The highlighted element is an element which was only distinguishing for perspective two. Thus this perspective towards *reporting problems immediately* differs from the perspective shared by perspectives one and two on this elements. This perspective is more positive compared to the shared perspective for this element of perspectives one and two element.

table 21: conclusion perspective two

higher		in between		lower	
most	least	most	least	most	least
reporting problems immediately		involving team members planning	prefabrication		design standardization
partial assignments		insightful what to do/is done	visual steps		

8.2 THE CORRELATION ANALYSIS

In this paragraph the correlation analysis will be discussed. In the first sub paragraph the characteristics of the respondents will be discussed. In the resulting correlation matrix will be discussed. Sub paragraph 8.4.3 will elaborate on the significant correlations and finally in the last sub paragraph a conclusion will be drawn up and an answer to research question 3.2 will be given.

8.2.1 THE RESPONDENTS OF THE CORRELATION ANALYSIS

The way the respondents were selected was already discussed in chapter seven. Eventually the survey was sent to 120 possible respondents. There were 82 persons who filled out the questionnaire, yet only 67 who actually completed the entire questionnaire. Therefore in the total amount of respondents is 67. In figure 29 the amount of respondents per week is shown. In the first week the questionnaire was sent to the possible respondents of two projects. The week thereafter no new questionnaires were sent. In the week of the fourth of August the questionnaire was sent to three more projects. In the week of the eleventh of August reminders to possible respondents of the first two projects were sent as well as a first mail to the possible respondents of the sixth project. In the week of the 18th of August the last reminder emails were sent to the possible respondents of the third, fourth and fifth projects.

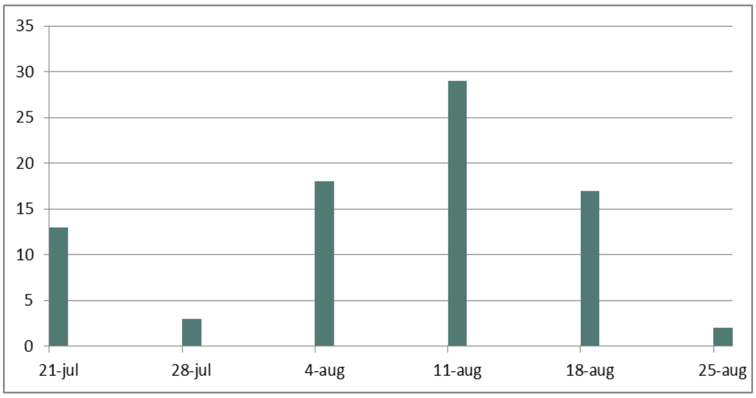


figure 29: respondents per week

In figure 30 some characteristics of the respondents are summarized and in table 22 the distribution of age and years of working experience are presented.

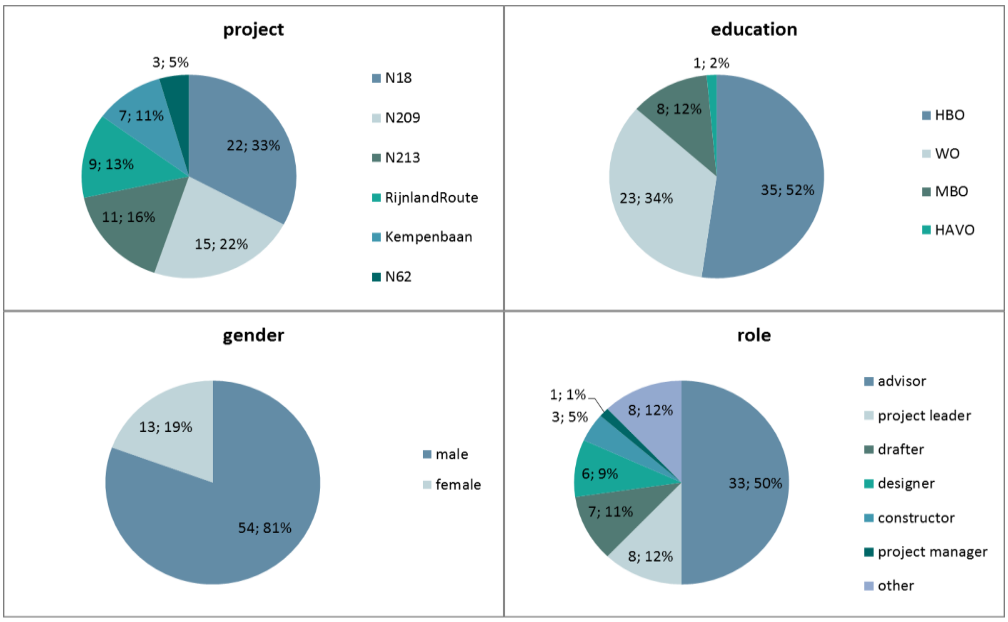


figure 30: characteristics correlation analysis respondents

table 22: age and working experience

	min	max	average	median
age	26	63	39	37
working experience	1.5	40	14	12

8.2.2 THE CORRELATION MATRIX

In order to assess the questionnaire statements the respondents were asked to score the statements on a Likert scale of totally disagree to totally agree. Whether the Likert scale is a ordinal measuring scale or a ratio measuring scale is under ongoing debate in literature. Due to the fact that adopting the ordinal scale ideal some valuable results might get lost, it was decided to tread the Likert scale as a ratio measuring scale for this research. Performing a correlation analysis for ratio variables is mostly done by means of Pearson's correlation. Therefore it was decided to perform a Pearson's correlation. For this correlation a two-sided approach was adopted. Two-sided implies that the direction of independence cannot be defined. This decision was made based on the fact that a one-sided directed dependence, thus complexity depends on the implicit usage of Lean and Agile, could not be presumed. As well as the fact that also relations the other way around, the implicit usage depending on the complexity of the project, are interesting to define and discuss. Therefore the conceptual model as shown in figure 31 was used as starting point for this correlation analysis.

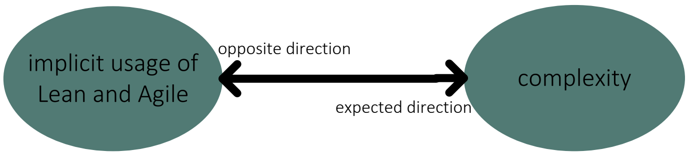


figure 31: conceptual model

This means that the null hypothesis for this research implies that there is no correlation, dependency or relation, between the two. The hypothesis to be researched implies that there is a correlation, dependency or relation, between the two.

By means of a Pearson's correlation matrix all seventeen complexity statements and fifteen Lean and Agile elements were correlated, leading to a 32 (17+15) by 32 matrix. This matrix also obtained the correlations amongst the complexity statements and amongst the Lean and Agile statements. Since these correlations are not relevant to this research they were not obtained in the final correlation matrix. In the final correlation matrix only the correlations between the complexity statements and the Lean and Agile statements were including, leading to a correlation matrix of fifteen by seventeen. Thus 255 correlations were calculated. The final entire correlation matrix can be found in appendix J. In total 51 significant correlations were found. These significant correlations will be discussed in the next sub paragraph.

8.2.3 DISCUSSION SIGNIFICANT CORRELATIONS

In this sub paragraph the significant correlations will be discussed. In total thirteen out of fifteen Lean and Agile elements had a significant correlation with one or more complexity statements. Only the elements seven and twelve did not show any significant correlations with one or more complexity statements. For each of the elements a short description will be provided relating the correlations with the complexity statements.

Lean element 1

Lean element one was represented in the second part of the questionnaire by statement three. In table 23 the significant correlations between this Lean statement and the complexity statements are shown. In this table all grey shaded complexity statements are the statements for which an increase leads to an increased level of dealing with complexity, whilst the not shaded complexity statements are statements for which an increase leads to an decreased level of dealing with complexity.

table 23: significant correlations Lean element 1

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process (S2_3)	the goals of the project are clear to me (S1_1)	0.284	weak	0.020	+ →
	scope changes happen quite often (S1_2)	-0.273	weak	0.025	− →
	the project management has much experience (S1_4)	0.540	strong	0.000	+ ←
	in this project many new technologies are used (S1_6)	0.323	medium	0.008	+ ←
	all resources needed for this project are readily available (S1_10)	0.255	weak	0.037	+ →
	the amount and level of communication in this project is high (S1_12)	0.696	strong	0.000	+ →
	changes in the organisation of this project happen a lot (S1_13)	-0.561	strong	0.000	− →
	the political influence is considerable (S1_15)	0.303	medium	0.013	+ ←
	the level of impact on the environment is high (S1_16)	0.346	medium	0.004	+ ←
	information is available to all team members on any given moment of the day (S1_17)	0.385	medium	0.001	+ →

The first significant correlation is between *all specialists work together* and *the goals of the project are clear to me*. They have a positive correlation, which means that in case one increases by one unit the other increases with 0.284 units. For estimating the direction of the correlation assumptions will be made. For this correlation it is assumed that working together as one team, instead of dividing the project in several parts and merging them at the end leads to a better understanding of the overall goals of the project. This because when one works on one individual part of the project, he might not be aware of the goals of the other individual parts, whilst in case all team members work together as one team they will all be aware of each other's goals, and thus they will understand the goals of the total project.

The second significant correlation for *all specialists work together* is with *scope changes happen quite often*. There is a negative correlation, thus in case one increases by one unit the other decreases by 0.273 units. Here it is assumed that in case all team members work together as one team, less scope changes will happen. This because all team members will better be aware of the activities performed by the other team members. Therefore (interface) problems will rise to the surface earlier on in the project and can be aligned. This will decrease the risk of problems getting bigger and bigger and only rising to the surface at the end of the project, mostly leading to unfavourable scope changes.

Third significant correlation is found between *all specialists work together* and *the project management has much experience*. For this correlation a opposite direction is assumed. Here it is assumed that a more experienced project management will advocate a project in which all team members work together. It is not assumed that the experience of the project management will increase when all team members work together. Thus it is assumed that when the experience of the project management increases by one unit the level of specialists working together as one team will increase by 0.540 units.

Fourth correlation is between *all specialists work together* and *in this project many new technologies are used*. Here a positive correlation was found. Due to the fact that it is not assumed that in case all team members work together as one team, more new technologies will be used, here also an opposite correlation is expected. Thus in case a project uses more new technologies the project team will work more closely together. This correlation direction is assumed, since it would only be logical that in case new and thus more intricate technologies are used team members will help each other, since two persons know more than one.

Fifth significant correlation for *all specialists work together* is with *all resources needed for this project are readily available*. Here it is assumed that in case all team members work together the of availability of the resources increases. This because all team members also have and/or are specific resources. In case all team members work together each other's resources are better available to them compared to in case all team members work on individual projects. It is therefore assumed that in case *all specialists work together* increases by one unit, *all resources needed for this project are readily available* increases by 0.255 units.

The correlation between *all specialists work together* and *the amount and level of communication in this project is high* was also found to be significant. Here a positive correlation of 0.696 was found. It is assumed that in case all team members of the project work together as one team, the communication level will increase. Team members will communicate more easily with other team members when they truly work together, instead of them all working on their own individual projects. Therefore it is assumed that in case *all specialists work together* increases by one unit *the amount and level of communication* increases by 0.696 units.

The seventh significant correlation for *all specialists work together* was found with *changes in the organisation of this project happen a lot*. It is assumed that in case all team members work together as one team there will be less organizational changes. This because team members will feel more committed to the overall project when they all work together compared to when they all are working on their own individual sub project. Due to an increased commitment level of the team members less organizational changes will occur. Therefore it is assumed that in case *all specialists work together* increases by one unit, the amount of organizational changes will decrease by 0.561 units.

Also a significant correlation between *all specialists work together* and *the political influence is considerable* was found. Here a correlation of 0.303 was found. Since it is not assumed the working together as one team could lead to less political influence, an opposite directed correlation is assumed. Likewise for the usage of new technologies, more political influence will lead to more risks and difficulties occurring during the project. In order to handle these risks and difficulties the team will work together, as two persons know more than one.

For the correlation between *all specialists work together* and *the level of impact on the environment is high* the same explanation can be applied. Therefore also for this correlation an opposite direction is assumed.

Last significant correlation found here is between *all specialists work together* and *information is available to all team members on any given moment of the day*. A positive correlation of 0.385 was found. Here it is assumed that working together as one team will increase the amount of information available. This because the team members will more easily share information in case they work together compared to when they all work on their own individual sub projects. Therefore it is assumed that in case *all specialists work together* increases by one unit the availability of information increases by 0.385 units.

Lean element 2

Lean element two was represented in the second part of the questionnaire by statements five and six. In table 24 the significant correlations between the Lean statements and the complexity statements are shown. Here again all grey shaded complexity statements are the statements for which an increase leads to an increased level of dealing with complexity, whilst the not shaded complexity statements are statements for which an increase leads to an decreased level of dealing with complexity.

table 24: significant correlations Lean element 2

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
all relevant alternatives are considered and worked out (S2_5)	the project team in general has much experience with the used technologies (S1_7)	0.275	weak	0.024	+⇦
the decision making process related to the alternatives is delayed as much as possible (S2_6)	the goals of the project are clear to me (S1_1)	0.275	weak	0.024	?
	the project management has much experience (S1_4)	0.268	weak	0.028	+⇦
	the project's environment is very uncertain (S1_8)	0.337	medium	0.005	+⇦
	the political influence is considerable (S1_15)	0.367	medium	0.002	+⇦
	the level of impact on the environment is high (S1_16)	0.397	medium	0.001	+⇦

First significant correlation found is between *all relevant alternatives are considered and worked out* and *the project team in general has much experience with the used technologies*. There is a positive correlation of 0.275. The direction of this correlation is assumed to be opposite. This because it is not assumed that in case all relevant alternatives are considered the experience of the project team with the used technologies will increase. It is assumed that in case the project team has much experience with the used technologies it might be capable to create and work out more alternatives.

Second significant correlation found here is between *the decision making process is delayed* and *the goals of the project are clear to me*. Here a positive correlation of 0.275 was found. Yet, no logical underlying reasoning is assumed here. This because it is not assumed that a more delayed decision making process will lead to a better understanding of the goals as well as it is not assumed that a better understanding of the goals leads to a more delayed decision making process.

Also a correlation between *the decision making process is delayed* and *the project management has much experience* was found. Here again there is a positive correlation, this time of 0.268. Since it is not assumed that delaying the decision making process could lead to an increase in the experience of the project management, here an opposite directed correlation is assumed. A more experienced project management is capable of delaying decisions to the last responsible moment. This because a more experienced project management is better at estimating what the appropriate time is to make a decision.

Fourth significant correlation found here is between *the decision making process is delayed* and *the project's environment is very uncertain.* A positive correlation of 0.337 was found. Here also an opposite directed correlation is assumed. In case the project's environment is highly uncertain decisions might be delayed since the project team is aware that changes will happen. Therefore most decisions will be delayed until there is certainty. The same goes for the correlation between *the decision making process is delayed* and *the political influence is considerable*. Here also an opposite correlation is assumed.

For the last significant correlation, between *the decision making process is delayed* and *the level of impact on the environment is high*, a positive correlation of 0.397 was found. A project for which the impact on the environment is high more risks and difficulties are to be expected. In order to cope with these risks and difficulties the decision relating the alternatives might be delayed as much as possible.

Lean element 3

Lean element three was represented in the second part of the questionnaire by statement two. In table 25 the significant correlations between this Lean statement and the complexity statements are shown.

table 25: significant correlations Lean element 3

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
the constructability of the project is taken into consideration (S2_2)	the goals of the project are clear to me (S1_1)	0.340	medium	0.005	+ →
	the project management has much experience (S1_4)	0.485	medium	0.000	+ ←
	there are many dependencies between the different disciplines/sub-teams (S1_5)	0.272	weak	0.026	?
	the amount and level of communication in this project is high (S1_7)	0.435	medium	0.000	+ ←
	changes in the organisation of this project happen a lot (S1_13)	-0.332	medium	0.006	?
	the political influence is considerable (S1_15)	0.379	medium	0.002	+ ←
	the level of impact on the environment is high (S1_16)	0.376	medium	0.002	+ ←
	information is available to all team members on any given moment of the day (S1_17)	0.242	weak	0.048	+ ←

For Lean element three eight significant correlations were found. The first one being between *the constructability is taken into consideration* and *the goals of the project are clear to me*. Here a positive correlation of 0.340 was found. It is assumed that keeping the constructability of the project in mind makes that the project goals become more clear. This because in almost all cases the constructability of the project in fact makes up a big part of the goals of the project. Thus when the constructability is kept in mind, also a big part of the goals are kept in mind, and are thus clearer. Therefore it is assumed that in case the level of consideration of the constructability increases with one unit the clarity of the goals increases with 0.340 units.

Second significant correlation found here is between *the constructability is taken into consideration* and *the project management has much experience*. It is assumed that a more experienced project management is also better in taking the constructability into consideration, therefore an opposite directed relation is assumed. When the level of experience of the project management increases with one unit, the extent to which the constructability of the project is taken into consideration will increase with 0.485 units.

Third significant correlation is between *the constructability is taken into consideration* and *there are many dependencies between the different disciplines/sub-teams*. There is a positive correlation of 0.272. For this correlation no clear direction could be thought of. Therefore this correlation is not assigned a direction.

Another significant correlation was found between *the constructability is taken into consideration* and *the amount and level of communication in this project is high.* Here it is assumed that an increased level of communication leads to the fact that the constructability is increasingly taken into consideration. This because team members communicate more, and are thus also more aware of whether or not the constructability is still taken into consideration by all other team members. They can help and remind each other to take the constructability into consideration. In case the level of communication is low, this will not be the case. Therefore here an opposite directed correlation is assumed.

Fifth significant correlation found here is between *the constructability is taken into consideration* and *changes in the organisation of this project happen a lot*. Here a negative correlation of -0.332 was found. No direction is assumed. It seems unlikely that there is a direct correlation between the level of taking the constructability into consideration and the amount of organizational changes happening.

For the significant correlation between *the constructability is taken into consideration* and *the political influence is considerable* an opposite directed correlation is assumed. High political influence forces the project team to stay focussed. Staying focussed also means that the constructability of the project should be taken into consideration. Therefore it is assumed that in case the political influence increases by one unit, the level of taking the constructability into consideration increases by 0.379.

For the seventh found correlation somewhat the same reasoning applies. An increased level of impact on the environment forces the project team to stay focussed and thus also to take the constructability into consideration. Since it is not assumed that an increased level of taking the constructability into consideration could lead to an increased level of impact on the environment, the first reasoning seems more plausible. Therefore in case the level of impact on the environment increases by one unit, it is assumed that the level of taking the constructability into consideration increases by 0.376 units.

Last significant found correlation here is between *the constructability is taken into consideration* and *information is available to all team members on any given moment of the day*. Here a positive correlation of 0.242 was found. An opposite directed correlation is assumed. This because it seems likely that in case the availability of information increases the level of taking the constructability into consideration increases. The availability of more information makes it easier to take the constructability into account.

Lean element 4

Lean element four was represented in the second part of the questionnaire by statement eight. In table 26 the significant correlations between this Lean statement and the complexity statements are shown.

table 26: significant correlations Lean element 4

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
much information, like problems and corresponding action plan and the project's performance, is visualized and insightful to me at any given moment (S2_8)	the project team in general has much experience with the used technologies (S1_4)	0.297	medium	0.015	?
	the amount and level of communication in this project is high (S1_12)	0.458	medium	0.000	+
	information is available to all team members on any given moment of the day (S1_17)	0.541	strong	0.000	+

For the first significantly found correlation relating to Lean element four no logical underlying reasoning could be thought of. It seems not likely that *visualizing information* makes the project team more experienced with the used technologies, yet it does also not seems likely that an increase of the project team's experience with the used technologies would increase the level of visualized information.

The second significant correlation is found between *visualizing information* and *the amount and level of communication in this project is high*. The correlation found is a positive correlation of 0.458. Here it is assumed that visualizing more information leads to an increased amount and level of communication. This because visualizing information and making this visualised information insightful to all team members in fact is a way of communicating. Information is shared and thus the communication level increases.

For the last significant correlation, which is a positive correlation, the reasoning is somewhat inherent. Visualizing information and making this information insightful at any given moment inherently leads to the fact that information is available to all team members on any given moment of the day. Therefore it is assumed here that in case *visualizing information* increases by one unit, *information is available to all team members on any given moment of the day* increases by 0.541 units.

Lean element 5

Lean element five was represented in the second part of the questionnaire by statement one. In table 27 the significant correlations between this Lean statement and the complexity statements are shown.

table 27: significant correlations Lean element 5

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
standardization is used in this project (S2_1)	the project management has much experience (S1_4)	0.413	medium	0.001	+ ⇨
	all resources needed for this project are readily available (S1_10)	0.327	medium	0.007	+ ⇨
	the political influence is considerable (S1_15)	0.240	weak	0.050	?
	the level of impact on the environment is high (S1_16)	0.265	weak	0.030	+ ⇨
	information is available to all team members on any given moment of the day (S1_17)	0.248	weak	0.043	+ ⇨

The first significant correlation found here is between *standardization is used in this project* and *the project management has much experience*. A positive correlation of 0.413 was found. Here it is assumed that using more standardization in a project could lead to an increased level of experience of the project management. Since using more standardization means that the project becomes more similar to other (previously performed) projects and which thus also means that the project management most likely already has some experience with a somewhat similar project. Thus it is assumed that in case the level of standardization used in the project increases with one unit, the level of experience of the project management increases with 0.413 units.

Second significant correlation is between *standardization is used in this project* and *all resources needed for this project are readily available.* Here a positive correlation of 0.327 was found. It is assumed that in case the standardization usage increases the amount of readily available resources also increases. This because using more standardization also means that more standard resources are used. Since the availability of standard resources is higher compared to the availability of uncommon resources it seems plausible that using standardization increases the amount and level of readily available resources. Therefore it is assumed that in case the level of standardization used in the project increases with one unit, the amount and level of readily available resources increases by 0.327 units.

The third significant correlation found related to the fifth Lean element is between *standardization is used in this project* and *the political influence is considerable*. A positive correlation of 0.240 was found. For this correlation no plausible reasoning could be thought of. It is not assumed that an increased level of standardization could lead to an increased level of political influence. Yet, it also seems not plausible that an increased level of political influence could lead to an increased usage of standardization. Therefore no plausible direction was defined for this correlation.

Fourth correlation found is between *standardization is used in this project* and *the level of impact on the environment is high*. Here a positive correlation of 0.265 was found. It is assumed that an increased level of standardization usage could lead to an increased level of impact on the environment. This because using more standardization means that less is customised to the specific circumstances, and thus the impact on the environment will be higher compared to when more is customized to the specific circumstances and thus less standardization is used. Therefore it is assumed that in case the usage of standardization increases with one unit, the level of impact on the environment increases by 0.265 units. Thus here Lean would not help managing complexity.

Last correlation found for Lean element five is the correlation between *standardization is used in this project* and *information is available to all team members on any given moment of the day*. Here a positive correlation of 0.248 was found. It is assumed that an increased level of standardization leads to an increase level of information availability. This because using standardization means that also information is more standardised. The level of availability for standardised information is much higher compared to the availability of not standardised information. Standardised information can mostly be found is existing guidelines, whilst not standardised information has to be specifically compiled for the project. This could lead to information not being complete or not being clear to all team members. Therefore using standardised information increases the availability of the information. It is thus assumed that in case the usage of standardization increases by one unit, the availability of information increases by 0.248 units.

Agile element 6

Agile element six was represented in the second part of the questionnaire by statement thirteen. In table 28 the significant correlations between this Agile statement and the complexity statements are shown.

table 28: significant correlations Agile element 6

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
I have selected the tasks I am performing myself (S2_13)	the project management has much experience (S1_4)	0.292	medium	0.016	⇦ +
	the amount of contracts in this project is high (S1_11)	0.340	medium	0.005	⇦ +

For this first Agile element two significant correlations were found. The first one being between *I have selected the tasks I am performing myself* and *the project management has much experience.* Here a positive correlation of 0.292 was found. An opposite directed correlation is assumed, this because it is not plausible that self-assignment of tasks will increase the level of experience of the project management. Yet, it could be the case that an highly experienced project management is more willing to let team members select tasks themselves. Therefore an opposite directed correlation is defined.

Second significant correlation found is between *I have selected the tasks I am performing myself* and *the amount of contracts in this project is high*. Also here a positive correlation was found, a correlation of 0.340 was found. An opposite directed correlation is assumed. This because it is assumed that a high amount of contracts in a project makes that the project management is more willing to let the team members self-assign tasks. A high number of contracts in most cases also means a high number of team members. The higher the number of team members the less overview the project management has. The project management is not able to define for each team member which specific tasks he or she needs to perform, since this would be a very time consuming thing to do. It is therefore likely that in case the amount of contracts increases the level of self-assignment also increases.

Agile element 7

Agile element seven was represented in the second part of the questionnaire by statement nine. For this element no significant correlations with one of the complexity statements was found. Two reasons for the non-existence of these correlations can be thought of: (1) there is truly no correlation *between tracking performance on a daily basis* and complexity, or (2) for non or a small minority of the projects performance was tracked on a daily basis and therefore no significant correlations were calculated. Looking at the dataset the second reasoning seems to be applicable here. This means that even though no correlations were found, it could not be concluded that *tracking performance daily* does not help coping with complexity.

table 29: significant correlations Agile element 7

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
performance is tracked on a daily basis (S2_9)	-	-	-	-	-

Agile element 8

Agile element eight was represented in the second part of the questionnaire by statements seven and fourteen. In table 30 the significant correlations between these Agile statements and the complexity statements are shown.

table 30: significant correlations Agile element 8

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
the team or sub-team meets on a daily basis (S2_7)	-	-	-	-	-
amongst the team everyone is aware of who is doing what, since we often align this (S2_14)	the project management has much experience (S1_4)	0.356	medium	0.003	⇦ +
	all resources needed for this project are readily available (S1_10)	0.371	medium	0.002	+ ⇨
	the amount and level of communication in this project is high (S1_12)	0.438	medium	0.000	+ ⇨
	information is available to all team members on any given moment of the day (S1_17)	0.370	medium	0.002	+ ⇨

For *the team or sub-team meets on a daily basis* no correlations were found. As discussed in the preceding the non-existence of correlations could have two reasons. Looking at the dataset the second reasoning seems to be applicable here. This means that even though no correlations were found, it could not be concluded that meeting on an daily basis does not help managing complexity.

First significant correlation found related to Agile element eight is between *everyone is aware of who is doing what* and *the project management has much experience*. Here a positive correlation of 0.356 was found. It is assumed that a more experienced project management leads to a better awareness amongst the team members of who is doing what since a more experienced project management is expected to be better in aligning the team members or encouraging the team members to align on a more regular basis. Therefore it is assumed that in case the level of experience of the project management increases by one unit, the level of awareness amongst the team members of who is doing what will increase by 0.356 units.

The second significant correlation found is between *everyone is aware of who is doing what* and *all resources needed for this project are readily available.* Here it is assumed that an increased level of awareness amongst the team member of who is doing what will lead to an increase in the availability of the resources. This because all team members also have and/or are specific resources. In case each team members is perfectly aware of what the other team members are doing, he is thus also aware of who entails which resources. Due to the fact that he is better aware of who entails which resources in general the availability of the resources increases as the awareness of the availability of the resources increases. It is therefore assumed that in case *everyone is aware of who is doing what* increases by one unit, *all resources needed for this project are readily available* increases by 0.371 units.

Third significant correlation found is again a positive correlation. This time between *everyone is aware of who is doing what* and *the amount and level of communication in this project is high*. It is assumed that in case the awareness of who is doing what increases the level and amount of communication also increases. This correlation in fact is inherent, the awareness of who is doing what is caused by aligning this frequently. Aligning frequently increases the amount of communication.

Last a correlation between *everyone is aware of who is doing what* and *information is available to all team members on any given moment of the day*. Here a positive correlation of 0.370 was found. Being aware of who is doing what by aligning this often increases the availability of communication. Therefore it is assumed that in case the awareness level of who is doing what increases by one unit, the availability of information increases by 0.370 units.

Agile element 9

Agile element nine was represented in the second part of the questionnaire by statement four. In table 31 the significant correlations between this Agile statement and the complexity statements are shown.

table 31: significant correlations Agile element 9

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
the work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback (S2_4)	the goals of the project are clear to me (S1_1)	0.276	weak	0.024	+
	the project management has much experience (S1_4)	0.312	medium	0.010	+
	the amount and level of communication in this project is high (S1_12)	0.244	weak	0.047	+
	changes in the organisation of this project happen a lot (S1_13)	-0.289	weak	0.018	–
	the level of impact on the environment is high (S1_16)	0.250	weak	0.041	?

First significant correlation here is between *smaller batches* and *the goals of the project are clear to me*. A positive correlation of 0.276 was found. It is assumed that cutting the project into smaller batches, or mini projects, with intermediate deliveries will lead to a better understanding of the goals of the project. This because for a mini project there are less goals and thus the goals can be made more clear compared to a large project for which the vague overall goal mostly consists of many smaller goals. Therefore it is assumed that an increase of the level of *smaller batches* by one unit will cause an increase of the clarity of the goals by 0.276 units.

Second significant correlation is between *smaller batches* and *the project management has much experience*. Also here a positive correlation was found, a correlation of 0.312. Only several project managers have much experience with large projects, yet many have experience with smaller projects. Therefore cutting a large project into several mini projects with intermediate delivery will increase the level of experience of the project management. It is therefore assumed that an increased level of *smaller batches* leads to an increased level of the project management's experience.

Also a significant correlation was found between *smaller batches* and *the amount and level of communication in this project is high*. It is assumed that in case the project is divided into smaller batches, with intermediate delivery and thus also a feedback moment, the amount and level of communication in the project will increase. This because more feedback moments, or communication moments, with the client are created. Therefore it is assumed that in case *smaller batches* increases by one unit, the amount and level of communication increases by 0.244 units.

Third a correlation between *smaller batches* and *changes in the organisation of this project happen a lot* was found. Here a negative correlation of -0.289 was found. It is assumed that an increased level of dividing the work in smaller batches, with intermediate delivery and feedback moments decreases the amount of organizational changes happening. This because by increasing the amount of feedback moments the project can be adjusted along the way. By making small adjustments along the way, instead of being forced to make big adjustments at the end of the project, makes that the client, as well as the team members themselves, will stay more positive. People feeling positive about a project are less likely to abandon such project, as well as that there will be less need to force people to abandon the project. Therefore it is assumed that *smaller batches* lead to an decreased amount of organisational changes happening.

Last significant correlation found is between *smaller batches* and *the level of impact on the environment is high*. Here no applicable underlying reasoning could be thought of. Neither creating smaller batches leading to a higher level of impact on the environment nor an increased level of impact on the environment leading to creating more smaller batches sounds plausible. Therefore no direction was defined for this correlation.

Merged element 10

Merged element ten was represented in the second part of the questionnaire by statement twelve. In table 32 the significant correlations between this merged statement and the complexity statements are shown.

table 32: significant correlations merged element 10

Lean and Agile statement	complexity statement	correlation	strength	significance	*direction*
I was involved in the planning process (S2_12)	the project management has much experience (S1_4)	0.355	medium	0.003	+ ⇦
	there are many dependencies between the different disciplines/sub-teams (S1_5)	0.241	weak	0.049	?
	the amount and level of communication of this project is high (S1_12)	0.279	weak	0.022	+ ⇨
	changes in the organisation of this project happen a lot (S1_13)	-0.402	medium	0.001	− ⇨

For the first merged element, element ten, four significant correlations were defined. The first one being between *I was involved in the planning process* and *the project management has much experience*. Here a positive correlation of 0.355 was found. It is not assumed that involving team members in making the planning makes that the project management has much experience. Therefore an opposite directed correlation is assumed. The more experience the project management has, the more they will involve the team members in the planning process.

Also the correlation between *I was involved in the planning process* and *there are many dependencies between the different disciplines/sub-teams* showed to be significant. It seems unlikely that involving team members in the planning process would lead to more dependencies between different disciplines. Yet, also more dependencies between the different disciplines leading to an increase level of involvement of team members in the planning process seems unlikely. Next to these assumptions the significance of this correlation is sufficient, but rather low. 0.049 just falls under the significance level of 0.05. This means that the correlation is weak. Therefore it was chosen to not define a direction for this correlation.

Third significant correlation is between *I was involved in the planning process* and *the amount and level of communication of this project is high*. A positive correlation of 0.279 was found. It is assumed that involving team members in the planning process leads to an increased level of communication. This because involving team members in the planning process in fact is an extra and high level communication moment. Therefore it is assumed that in case the level of involvement in the planning process increases by one unit, the amount and level of communication increases by 0.279 units.

Last significant correlation found is between *I was involved in the planning process* and *changes in the organisation of this project happen a lot*. Here a negative correlation of -0.402 was found. It is assumed that involving team members in the planning process creates commitment and commitment with the project leads to the fact that team members will less often abandon the project. Therefore organizational changes will happen less often. Thus it is assumed that an increased involvement of team members in the planning process will lead to a decrease in the amount of organizational changes.

Merged element 11

Merged element eleven was represented in the second part of the questionnaire by statements ten and eleven. In table 33 the significant correlations between these merged statements and the complexity statements are shown.

table 33: significant correlations merged element 11

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
a detailed planning was not made at the beginning of the process, but a one week/month planning is made on a weekly/monthly basis (S2_10)	the project management has much experience (S1_4)	0.357	medium	0.003	⇐ +
	the stakeholders involved in this project have many different interests, perceptions and interpretations (S1_14)	0.255	weak	0.037	⇐ +
	the political influence is considerable (S1_15)	0.305	medium	0.012	⇐ +
in the planning only tasks with high priority (according to the customer) and for which all prerequisites are met are included (S2_11)	the duration of the project is high (S1_9)	0.251	weak	0.041	?

For merged element 11 four significant correlations were found. The first one being between *weekly/monthly plannings* and *the project management has much experience*. Here a positive correlation of 0.357 was found. An opposite direction is assumed. It seems unlikely that adopting weekly or monthly plannings leads to a more experienced project management. Yet, the other way around could be possible. A more experienced project management makes use of weekly or monthly plannings. Thus it is assumed that in case the experience of the project management increases by one unit the usage of weekly or monthly plannings increases by 0.357 units.

Second significant correlation found is between *weekly/monthly plannings* and *the stakeholders have many different interests*. Here a positive correlation of 0.255 was found. It is assumed that the involvement of stakeholders with differentiating interests, perceptions and interpretations could be seen as increasing the uncertainty of the project. In order to cope with this uncertainty it might be decided to not plan that far into the future and only make a detailed planning for the coming week or month. Therefore here an opposite direction is assumed.

The third significant relation found is between *weekly/monthly plannings* and *the political influence is considerable*. Here a positive correlation is found of 0.305. An opposite relation is assumed. It is assumed that an increased political influence could lead to the fact that it is decided to not plan that far into the future and only make a detailed planning for the coming week or month. This because of the uncertainties the political influence might entail.

For the fourth and last significant correlation a positive correlation of 0.251 was found. This correlation is between *priority tasks in planning* and *the duration of the project is high*. For this correlation no clear direction could be thought of. Looking at the significance of this correlation this does not seem very unlikely.

Merged element 12

Merged element twelve was represented in the second part of the questionnaire by statement fifteen. For this element no significant correlations with one of the complexity statements was found. As already explained two reasons for the non-existence of these correlations could be thought of. Looking at the dataset the second reasoning seems to be applicable here. This means that even though no correlations were found, it could not be concluded that reporting all sorts of problems does not help managing complexity.

table 34: significant correlations merged element 12

Lean and Agile statement	complexity statement	correlation	strength	significance	direction
Problems, even the smaller ones, are reported when they occur and made insightful to all team members (S2_15)	-	-	-	-	-

8.2.4 CONCLUSION CORRELATION ANALYSIS

In the proceeding each of the significant correlations were discussed. In total 51 significant correlations were discussed. For several correlations no logical reasoning could be thought of, for some an opposite directed correlation was assumed and for some an expected directed correlation was assumed. In this conclusion first the meaning and corresponding conclusion drawn from the opposite directed correlations will be discussed. Next also the meaning and corresponding conclusion drawn from the expected directed correlations will be discussed. Concluding an answer to research question 3.2 will be provided.

Opposite directed correlations

In total 21 correlations were assessed as opposite directed. In table 35 these opposite directed correlations are shown. The grey shaded complexity statements are statements for which an increase leads to a decrease in the complexity. For eight statements this complexity statement is *the project management has much experience*. Thus for these opposite correlations goes that the more experienced the project management, the more Lean and Agile elements are implicitly used. Also for *the project team in general has much experience with the used technologies* this goes, due to a more experienced team more implicit usage is made of Lean and Agile elements. The same goes for projects where the communication level is. One could conclude from this that for complex projects, which are managed and worked on in a proper manner: experienced management, experienced team and high level of communication, more Lean and Agile elements are used.

For all other not grey shaded statements goes that an increase leads to an increase of the complexity. Looking at the complexity statements it can be noted that these statements all imply uncertainty, whether it being uncertainty itself (*the project's environment is very uncertain*) or whether it being statements leading to uncertainty. For increased complexity related to these statements it was found that more Lean and Agile elements were used. Thus the more uncertainty is expected, the more Lean and Agile elements are used. This could mean that Lean and Agile elements to help manage these expected uncertainties.

table 35: opposite directed correlations

Lean and Agile statement	complexity statement	correlation
all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process (S2_3)	the project management has much experience (S1_4)	strong*
	in this project many new technologies are used (S1_6)	medium*
	the political influence is considerable (S1_15)	medium
	the level of impact on the environment is high (S1_16)	medium*
all relevant alternatives are considered and worked out (S2_5)	the project team in general has much experience with the used technologies (S1_7)	weak
the decision making process related to the alternatives is delayed as much as possible (S2_6)	the project management has much experience (S1_4)	weak
	the project's environment is very uncertain (S1_8)	medium*
	the political influence is considerable (S1_15)	medium*
	the level of impact on the environment is high (S1_16)	medium*
the constructability of the project is taken into consideration (S2_2)	the project management has much experience (S1_4)	medium*
	the amount and level of communication in this project is high (S1_12)	medium*
	the political influence is considerable (S1_15)	medium*
	the level of impact on the environment is high (S1_16)	medium*
	information is available to all team members on any given moment of the day (S1_17)	weak
I have selected the tasks I am performing myself (S2_13)	the project management has much experience (S1_4)	medium
	the amount of contracts in this project is high (S1_11)	medium*
amongst the team everyone is aware of who is doing what, since we often align this (S2_14)	the project management has much experience (S1_4)	medium*
I was involved in the planning process (S2_12)	the project management has much experience (S1_4)	medium
a detailed planning was not made at the beginning of the process, but a one week/month planning is made on a weekly/monthly basis (S2_10)	the project management has much experience (S1_4)	medium*
	the stakeholders involved in this project have many different interests, perceptions and interpretations (S1_14)	weak
	the political influence is considerable (S1_15)	medium

* correlation with a significance level of $\rho \leq 0.01$

Expected directed correlations

Also 22 expected directed correlations were found. These are listed in table 36. The grey shaded complexity statements are the statements for which an increase causes the complexity of the project to decrease. For the not grey shaded statements the other way around applies. As can be noted for correlations between Lean and Agile statements and grey shaded complexity statements the correlations are positive, meaning that the Lean and Agile element decreases the complexity of the project. Whilst for the correlations between Lean and Agile statements and not grey shaded complexity statements the correlations are negative, with one exception, meaning that the Lean and Agile element decreases the complexity of the project.

table 36: expected directed correlations

Lean and Agile statement	complexity statement	correlation
all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process (S2_3)	the goals of the project are clear to me (S1_1)	weak
	scope changes happen quite often (S1_2)	(-) weak
	all resources needed for this project are readily available (S1_10)	weak
	the amount and level of communication in this project is high (S1_12)	strong*
	changes in the organisation of this project happen a lot (S1_13)	(-) strong*
	information is available to all team members on any given moment of the day (S1_17)	medium*
the constructability of the project is taken into consideration (S2_2)	the goals of the project are clear to me (S1_1)	medium*
much information, like problems and corresponding action plan and the project's performance, is visualised and insightful to me at any given moment (S2_8)	the amount and level of communication in this project is high (S1_12)	medium*
	information is available to all team members on any given moment of the day (S1_17)	strong*
standardization is used in this project (S2_1)	the project management has much experience (S1_4)	medium*
	all resources needed for this project are readily available (S1_10_)	medium*
	the level of impact on the environment is high (S1_16)	weak
	information is available to all team members on any given moment of the day (S1_17)	weak
amongst the team everyone is aware of who is doing what, since we often align this (S2_14)	all resources needed for this project are readily available (S1_10)	medium*
	the amount and level of communication in this project is high (S1_12)	medium*
	information is available to all team members on any given moment of the day (S1_17)	medium*
the work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback (S2_4)	the goals of the project are clear to me (S1_1)	weak
	the project management has much experience (S1_4)	medium*

	the amount and level of communication in this project is high (S1_12)	weak
	changes in the organisation of this project happen a lot (S1_13)	(-) weak
I was involved in the planning process (S2_12)	the amount and level of communication of this project is high (S1_12)	weak
	changes in the organisation of this project happen a lot (S1_13)	(-) medium*

* correlation with a significance level of $\rho \leq 0.01$

Undefined directed correlations

Also six undefined directed correlations were found. These are listed in table 37. For these correlations no logical underlying reasoning could be thought of. Two reasons are assumed: (1) the correlation does truly not exists, or (2) there is another or multiple other variables that also relate to both variables. For this second reason one could thus speak of a more indirect correlation. As can be seen in table 37 the last four correlations are barely significant, therefore for these correlations the first reason is assumed. For the first two the second reason could be applied, an indirect relation is assumed.

table 37: undefined directed correlations

Lean and Agile statement	complexity statement	correlation
the decision making process related to the alternatives is delayed as much as possible (S2_6)	the goals of the project are clear to me (S1_1)	weak
the constructability of the project is taken into consideration (S2_2)	there are many dependencies between the different disciplines/sub-teams (S1_5)	weak
standardization is used in this project (S2_1)	the political influence is considerable (S1_15)	weak
the work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback (S2_4)	the level of impact on the environment is high (S1_16)	weak
I was involved in the planning process (S2_12)	there are many dependencies between the different disciplines/sub-teams (S1_5)	weak
in the planning only tasks with high priority (according to the customer) and for which all prerequisites are met are included (S2_11)	the duration of the project is high (S1_9)	weak

* correlation with a significance level of $\rho \leq 0.01$

Non correlating elements

There were three statements for which no correlations were found: *performance is tracked on a daily basis, the team or sub-team meets on a daily basis* and *problems, even the smaller ones, are reported when they occur and made insightful to all team members.* For these it was already assessed that the non-existence of correlations was due to the fact that for none of the projects these statements were applicable. Thus for these statements the extent to which they could help coping with complexity is unsure.

Answering the sub research question

> *3.2 Does applying elements of Lean and Agile in practice leads to a better way of coping with complexity and uncertainty?*

In order to answer this research question in table 38 the statements and their corresponding elements are categorized in elements and corresponding statements that can truly reduce the complexity of a project (statements for which an expected directed correlation was found), elements and corresponding statement that can help managing complexity (statements for which an opposite directed correlation was found), and elements and corresponding statements for which the extent to which they could help dealing with complexity is unsure.

table 38: conclusion correlation analysis

element	statement	reduces complexity	manages complexity	unsure
Lean element 1	all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process	X	X	
Lean element 2	all relevant alternatives are considered and worked out		X	
	the decision making process related to the alternatives is delayed as much as possible		X	
Lean element 3	the constructability of the project is taken into consideration	X	X	
Lean element 4	much information, like problems and corresponding action plan and the project's performance, is visualised and insightful to me at any given moment	X		
Lean element 5	standardization is used in this project	X		
Agile element 6	I have selected the tasks I am performing myself		X	
Agile element 7	performance is tracked on a daily basis			X
Agile element 8	the team or sub-team meets on a daily basis			X
	amongst the team everyone is aware of who is doing what, since we often align this	X	X	
Agile element 9	the work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback	X		
merged element 10	I was involved in the planning process	X	X	
merged element 11	a detailed planning was not made at the beginning of the process, but a one week/month planning is made on a weekly/monthly basis		X	
	in the planning only tasks with high priority (according to the customer) and for which all prerequisites are met are included			X
merged element 12	Problems, even the smaller ones, are reported when they occur and made insightful to all team members			X

FOUR//

THE ADVICE

9 DISCUSSION

In this chapter the research will be discussed. What were the limitations of the study and how did they influence the outcomes. This discussion thus also provides in constraints for the conclusions and recommendations. In paragraph one the findings will be discussed and in paragraph two the limitations of the research will be discussed.

9.1 DISCUSSING THE FINDINGS

This thesis aimed to find an answer to the following research question: *How could a combination of Lean and Agile help coping with complexity and uncertainty in the front-end development of an infrastructure project?* For answering this question several literature studies were conducted as well as two analyses. In this thesis the research question was thus answered by studying 'the past'. This research made use of existing literature and people's existing expertise and experience. Yet, most respondents have little to no experience with both Lean and Agile. This may cause that the answer to the research question as formulated based on the results of the research conducted for this thesis might differentiate from reality. In order to study reality, tests should be performed, Lean and Agile should be tested out in real existing projects. Due to time constraints and other practical limitations it was not possible to conduct those tests for this thesis. This also makes that not the whole concept of Lean and Agile could be tested. Going back to the research question, did this research provide a sufficient answer? No, not completely. It provided an answer on how some elements of Lean and Agile could help coping with complexity and uncertainty in the front-end development of an infrastructure project and it provided in a profound assumption related to the complete answer, yet this answer, as it is based on assumptions, is not hundred per cent certain. What this research did do was provide a thorough basis for future research in this field.

Looking at the problem as formulated in the introduction it can be concluded that this research has extended existing knowledge on the problem of the inadequacy of conventional project management. Existing knowledge in this flied mostly focuses on identifying the inadequacies of conventional project management and exploring what needs to be changed. Yet little knowledge is available on how existing methods, like Lean and Agile, could help with complementing for these inadequacies. Since little knowledge is available on what can practically be done in order to overcome the inadequacies of conventional project management, this research extends the existing knowledge in this field.

9.2 DISCUSSING THE LIMITATIONS

This paragraph discusses the limitations of the studies and researches conducted for this thesis. In sub-paragraph one the limitations of the theoretical framework will be discussed and in sub-paragraph two the limitations of the actual research will be discussed.

9.2.1 LIMITATIONS OF THE THEORETICAL FRAMEWORK

For the literature study on complexity, uncertainty and conventional project management plenty of literature was available. Yet, due to time limitations the literature studies on complexity, uncertainty and conventional project management as conducted for this thesis should not be considered as complete. Due to the extensive amount of literature, it was found impossible to take knowledge of all literature available. This makes that the answer to sub-question one, the list of characteristics as provided on page 25 is most probably not a complete list. The literature study on Lean and Agile shows some limitations due to a lack in available literature. Applying Lean to infrastructure projects is less done compared to applying Lean to building projects. This is mostly due to the fact that there are no tools for applying it to infrastructure project, and also the need is smaller compared to building projects (Kemppainen, Mäkinen, Seppänen, & Kankainen, 2004). Also the literature study on Lean applied to the front-end development phases entails some limitations. When looking at Lean, a lot of literature is available on Lean applied to the execution phase and little to the FED phases of a construction project (Marzouk, Bakry, & El-Said, 2011). Agile methodologies, like Scrum, applied to the construction sector, and thus also to the infrastructural sector, is done even less often. Most sources describe the possible applicability of Agile methods to the construction sector (Demir et al., 2012; Owen R. , Koskela, Henrich, & Codinhoto, 2006; Owen & Koskela, 2006), but hardly any sources can be found on the practical application of Agile methods to the construction industry. Reasons for the non-existence of literature on the practical application of Agile methods to the construction industry are also hard to find (Maylor, 2010). It is assumed that it can be traced back to the fact that Agile methods originate from a completely different sector, the IT sector, and that the term Agile was founded recently (2001) (Highsmith, 2001). These limitations on the available literature on Lean and Agile made that some assumptions needed to be made. Due to these assumptions the answer to sub-question two is also bound to some constraints.

9.2.2 LIMITATIONS OF THE RESEARCH

Regarding the research also several limitations should be kept in mind. Both analyses show limitations related to their internal validity and their external validity. First the limitations of the Q sorting will be discussed and next the limitations of the correlation analysis.

Limitations of the Q sorting research

Regarding the internal validity of the Q sorting research two main limitations are distinguished:

- The statements included in the questionnaire were based on the distinguished helpful elements of Lean and Agile. Since the helpfulness of these elements were based on assumptions, also the statements included in the questionnaire were based on assumptions. This makes the internal validity of this research limited.
- Also the way the statements were explained led to a limited internal validity. Respondents might have misinterpreted some statements. This is called a measurement error: the bias that originates from the respondents' own interpretation and assessment of the survey (Visser, Krosnick, & Lavrakas, 2000), and occurs in most studies using a written or electronic questionnaire.

Regarding the external validity also two main limitations are distinguished:

- The respondents of the Q sorting were all employees of Antea Group. This has led to a coverage error: the bias that may result from the fact that the total amount of potential participants from which the respondents are chosen, does not reflect the true population of interest (Visser, Krosnick, & Lavrakas, 2000). The fact that all respondents are employees of Antea Group influences the generalizability of the results, since the aim of this research was to create and advice for civil engineering firms in general.
- A P set of 53 possible respondents was defined. Of these 53 possible respondents 28 actually responded. This is called a non-response error: in most cases not all selected respondents will actually participate in the survey (Visser, Krosnick, & Lavrakas, 2000). The respondents responding to the survey, and thus participating in the survey, might have different characters and personalities compared to the respondents not responding to the survey (Wyse, 2012). This might have led to some bias in the results.

Limitations of the correlation analysis

Regarding the internal validity of the correlation analysis the two main limitations as distinguished for the Q sorting research also apply here, yet the correlation analysis shows more limitations regarding the internal validity:

- It was decided to perform a Pearson's correlation. For a Pearson's correlation the assumption is made that the variables are measured at interval or ratio level. A Likert scale lies somewhere between a categorical scale and an interval scale. Conducting a Pearson's correlation could therefore lead to correlations assessed to be significant whilst in reality they are not. This thus leads to some limitations.

- Since the correlation matrix did not provide in assessing the direction of the correlation at hand, assumptions were made to define these directions. These assumptions also makes that the internal validity of this research is limited.

Regarding the external validity three main limitations are distinguished:

- Also for the correlation analysis the coverage error is present. Here not only because respondents are all employees of Antea Group, but also because the respondents are working on just six different projects. This makes that the generalizability of the research is limited.
- For the correlation analysis also the sampling error applies: the amount of respondents is mostly limited. This makes that the sample of respondents always differentiates from the population they were selected from (Visser, Krosnick, & Lavrakas, 2000). The total amount of respondents for the correlation analysis was 67. Mostly a minimal amount of 80 respondents is advised in order the get reliable results. Yet, due to time limitations and the fact that the pool of people out of which possible respondents could be selected was limited (the amount of complexity projects Antea Group performs is limited), getting a minimal responds of 80 was not achievable. In total 119 questionnaires were sent to possible respondents, which means that a response rate of 56.3 per cent was achieved, which is reasonable.
- Sending out 119 questionnaires and getting 67 responses means that there were 52 possible respondents not responding. For the correlation analysis the non-response error should thus also be considered.

10 CONCLUSIONS

In this chapter the conclusions will be discussed. In the first paragraph a conclusion for each Lean, Agile or merged element will be drawn up. Leading to a categorization of the elements which provides insight in the usefulness of the elements (10.2). This categorization provides an answer to research question three. Finally, in paragraph 10.3, the answer to the main research question will be composed.

10.1 COMBINING THE CONCLUSIONS

Below for each element the helpfulness for coping with complexity and uncertainty in the front-end development of an infrastructure project will be discussed based on the intermediate conclusions of sub-questions one, two and three.

Lean element 1

Lean element one implied that all stakeholders should be involved in the decision making process, that also incomplete information should be shared and that information should be visible to all stakeholders. It was linked to the criteria of *trust* and *close cooperation between the stakeholders*. Thus this element should in theory increase the level of trust and cooperation in the project and by increasing trust and cooperation should help coping with a project's overall complexity. In the Q sorting research this element was represented by the statement: *involving the contractor in the designing process would help coping with complexity.* This statement was not assessed highly by the respondents of the Q sorting research. The overall assessment was more neutral. Resulting from the correlation analysis, where Lean element one was represented by the statement: *all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process*, this element appeared to be both helpful for reducing complexity and for managing complexity.

Even though the results from the Q sorting research are not convincing, based on the results from the correlation analysis it is concluded that this element helps coping with complexity and uncertainty in the front-end development of an infrastructure project.

Lean element 2

Lean element two was related to the set based decision making strategy. Thus creating many alternatives and working all relevant alternatives out in detail, combined with making a decision for one of the alternatives at the last responsible moment. This element was linked to the criterion of *redundancy: considering all possible alternatives and making a decision at the last responsible moment.* In the Q sorting research this element was represented by two statements: one based on the development of all relevant alternatives, and one based on the delayed decision making. Both were assessed as little helpful for coping with complexity. In the correlation analysis questionnaire this element was represented by two similar statements. Resulting from the correlation analysis it appeared that both were applied to complex project, and thus were used to manage complexity. Yet it is assumed that considering more alternatives and delaying the decision is mostly applied to complex projects since this is almost inevitable. For complex projects decisions are often delayed not as the result of proactive thinking, but mostly as the result of reactive thinking.

Based on the theoretical usefulness of this element and the results of the analyses, it is concluded that this element in theory could be useful, but the industry is not yet ready to apply them proactively in order to cope with complexity.

Lean element 3

Lean element three implied that the Lean ideal should be present in the design work. The design should be practicable, follow-up phases should be taken into account and work should be conducted in smaller batches. This element was linked to two criteria: *close cooperation between the stakeholders* and *recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats (resilience)*. The last one linked to conducting the work in smaller batches. In the Q sorting analysis this element was represented by two statements: one based on the practicability of the design, and one based on including prefabricatable parts in the design. Practicability was averagely assessed as most useful for coping with complexity, whilst prefabrication was only assessed as most helpful element by perspective two. In the correlation analysis merely a statement on the practicability, or in this case the constructability, was included. This statement appeared to both be able to reduce complexity, as well as help manage complexity.

Based on the results from both the Q sorting analysis and the correlation analysis it is concluded that this element, and in specific keeping the practicability of the design in mind, helps coping with complexity and uncertainty in the front-end development of an infrastructure project.

Lean element 4

This element implied that technologies which facilitate Lean Design should be used. This element was linked to the criteria: *open information exchange* and *trust*. Due to this link merely the 'technology' of *Visual Management* was included in this research. In the Q sorting analysis this element was represented by two statements. Both statements focused on *Visual Management*, the one on visualizing action plans and the other on visualizing the administrative steps. The overall assessment on visual action plans was considerable high, whilst the overall assessment on visual administrative steps was only considered helpful according to perspective one. In the correlation analysis this element was represented by one statement on visualization of all kinds of information. This element appeared to help reduce a project's complexity.

Based on the results of both analyses it is concluded that *Visual Management* helps coping with complexity and uncertainty in the front-end development of an infrastructure project.

Lean element 5

This element implied continuous learning through standardization of the product and the process. This element was linked to criterion: *using standardization to an extent that fits with the project's context in order to achieve reflective learning*. In the Q analysis this element was represented by two statements, one on the standardization of the design itself, thus product standardization, and one on the standardization of the process, process standardization. Process standardization was averagely assessed as very helpful for coping with complexity, whilst design standardization was less positively assessed and only as very helpful by perspective two. In the correlation analysis both were merged into one general statement on standardization. Resulting from the correlation analysis it appeared that standardization could help reducing a project's complexity. Yet, it could also add to the complexity, as the project's impact on the environment could increase.

Based on the results of both analyses it is concluded that standardization helps coping with complexity and uncertainty in the front-end development of an infrastructure project. Yet, it should be noted that design standardization should only be applied to an extent that fits with the project's context.

Agile element 6

This element, a Scrum element, implied self-organizing teams. The cross-functional teams characteristic is included in merged element 10. It was linked to the criteria of *trust* and *self-steering of the complete project team* (self-organizing teams). In the Q sorting analysis this element was translated into a statement on the self-assignment of tasks. This statement on self-assignment of tasks was averagely assessed very poorly. In the correlation analysis this element was also represented by one statement on self-assignment. Also the results of the correlation analysis related to this statement are not convincing. It appear to be helpful for managing complexity, yet not for reducing complexity.

Based on the results from both analyses it can be concluded that the self-steering aspect of this element in theory could help coping with complexity and uncertainty, yet not so much in practice. Most mentioned concern is that with self-assignment of tasks merely the 'fun' tasks will be performed. It is assumed that the industry is just not ready to adopt self-steering teams.

Agile element 7

Agile element 7 implied the Scrum process as well as the theory behind Agile project management that change should be seen as something positive. This element was linked to the criterion of *resilience: recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats* but also to the criterion that the scope in fact only needs to be functionally described, thus not all details have to be included in the scope description. In the Q sorting analysis this elements was translated into two statements. One about the daily progress tracking and one about including merely tasks with high priorities, according to the client, in the planning. Regarding the daily progress tracking statement no consensus amongst the total set of respondents was found. Regarding merely including tasks with high priorities in the planning a majority of the respondents were negative. In the correlation analysis this element was represented by only one statement. This statement was based on tracking performance on a daily basis. For this element no clear correlation with the project's complexity could be defined.

Based on the results from both analyses it can be concluded that it is not clear whether this element helps coping with a project's complexity and uncertainty or not. Based on theory it would be helpful, yet the practical translation does not tell us the same.

Agile element 8

In this element the daily meetings part of the Scrum process were captured. It was linked to the criterion on *open information exchange*. In the Q sorting analysis this element was represented by two statements. One on daily communication and one on the fact that team members should be encouraged to make insightful to all other team members what they have done the previous day and what they expect to do the coming day. Both statements were only assessed as most helpful by respondents related to perspective one. All other respondents were more neutral to more negative about this element. In the correlation analysis this element was translated into two statements similar to the Q sorting statements. Here the correlation between daily communication and complexity was unsure, whilst the correlation between: *amongst the team everyone is aware of who is doing what, since we often align this* and complexity pointed out that this element would both help reducing complexity and managing complexity.

Based on the results of both analyses it is concluded that it is unsure whether this element helps coping with a project's complexity and uncertainty or not. Alignment amongst team members appears to be helpful, yet whether this should be done on a daily basis is questionable.

Agile element 9

This element implies the delivery of intermediate products, and by doing so also receive intermediate feedback. This element was linked to the criterion of *resilience: recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats.* In the Q sorting analysis this element was translated in the following statement: *dividing the assignment in several partial assignments which will also incrementally be delivered to the client would help coping with complexity.* The perspectives on this element were very diverse. Merely according to perspective three this element would considerably help coping with a project's complexity. The other perspectives took a more neutral or negative position. In the correlation analysis this element was translated in a similar statement as the statement used in the Q sorting analysis. From this analysis it was concluded that this element does help reducing a project's complexity.

Based on the results of both the Q sorting analysis and the correlation analysis it is concluded that this element does help coping with a project's complexity and uncertainty. Yet, only people who can identify themselves with perspective three will react positive to this element. For other people there needs to be more convincing evidence.

Merged element 10

Lean element one and Agile element six were merged together into this tenth element. They showed overlaps related to cross-functional teams, therefore this merged element implies the usage of cross-functional teams. This element was linked to both the criteria of *trust* and *close cooperation between the stakeholders*. In the Q sorting analysis this element was translated in a statement on involving team members in the planning process. Perspective one was quite positive, whilst the other perspectives were more neutral regarding this element. In the correlation analysis this element was translated into a similar statement as the Q sorting analysis statement on this element. From this analysis the element appeared to both be able to reduce complexity, as well as help manage complexity.

Based on the results of both analyses it is concluded that involving team members in the planning process helps coping with complexity and uncertainty in the front-end development of an infrastructure project. Yet, not everyone is truly convinced of its impact.

Merged element 11

Merged element eleven related to the way the project is managed. This element refers to the Last Planner System of Lean Design and the Scrum process as part of Agile. This element can mostly be linked to the criterion of *resilience: recognizing that change is inevitable and dealing with change, by seizing opportunities and coping with threats.* In the Q sorting analysis this element is represented by two statements: *visualizing the progress and making this insightful for all team members would help coping with complexity* and *creating the planning on a weekly basis including merely the coming week, instead of creating one planning at the beginning of the process, would help coping with complexity.* Where visualising the progress is assessed as quite helpful for coping with complexity, regarding weekly plannings no consensus was found amongst the total set of respondents. In the correlation analysis this element was also translated in two statements: one similar to the statement about weekly plannings of the Q sorting research and one about including merely tasks with high priority in the planning. It should be noted here that this last statement was part of the Q sorting yet related to element 7. It was concluded that regarding this element a majority of the Q sorting respondents were negative. In the correlation analysis this statement on prioritising tasks showed a correlation which could not be logically interpreted. This is most probably caused by the fact that what this statement implies is not applied in existing projects. Regarding the statement on weekly plannings three opposite directed correlations were distinguished and thus weekly plannings are used to manage complexity.

Based on the results of both analyses it is concluded that it is unsure whether this element helps coping with a project's complexity and uncertainty or not. Based on theory it would be helpful, yet the practical translation does not tell us the same.

Merged element 12

Merged element 12 relates to the reporting of problems. Problems should be reported as soon as possible and also the smaller problems should be reported. This element was linked to the criterion: of open information exchange. In the Q sorting analysis this element was translated into three statements. One about reporting problems immediately when they occur, one about reporting all sorts of problems thus also the smaller once, and one about making problems insightful to all other team members. This last aspect was averagely assessed as quite helpful, reporting problems immediately was assessed positive by all respondents, yet more neutral by the respondents related to perspective three. Reporting small problems was neutrally assessed by perspectives two and three, and negatively by perspective one. In the correlation analysis this element was captured in one statement, entailing the content of all three Q sorting statements. Resulting from the correlation analysis was that for this element no clear correlation with the project's complexity could be defined.

Due to the made assumption that in the correlation analysis no correlation was found, due to the fact that for non or a only a small minority of the projects problems were reported as asked, and due to the positive results of the Q sorting analysis it is concluded that this element will most likely help coping with complexity and uncertainty in the front-end development of an infrastructure project.

10.2 SUMMARY OF THE CONCLUSION

Q3	*Does the combined approach of Lean and Agile work in practice?*

figure 32 provides a summary of the conclusion as discussed in the previous paragraph. In this figure the elements are categorised in elements that showed to be convincing for helping coping with complexity and uncertainty in the front-end development of an infrastructure project. These are the elements for which most Q sorting respondents were positive, and which showed to have a correlation with one or more complexity elements translated as helpful for reducing or useful for managing complexity and uncertainty. Second category are elements that were not entirely convincing, not every respondent agreed and the correlation was only translated in manages complexity or, in case of standardisation, could, next to considerable decrease, also increase complexity. Last category are the elements that showed not to be convincing at all. In the Q sorting the majority of respondents disagreed and also the results of the correlation analysis were assessed as not convincing.

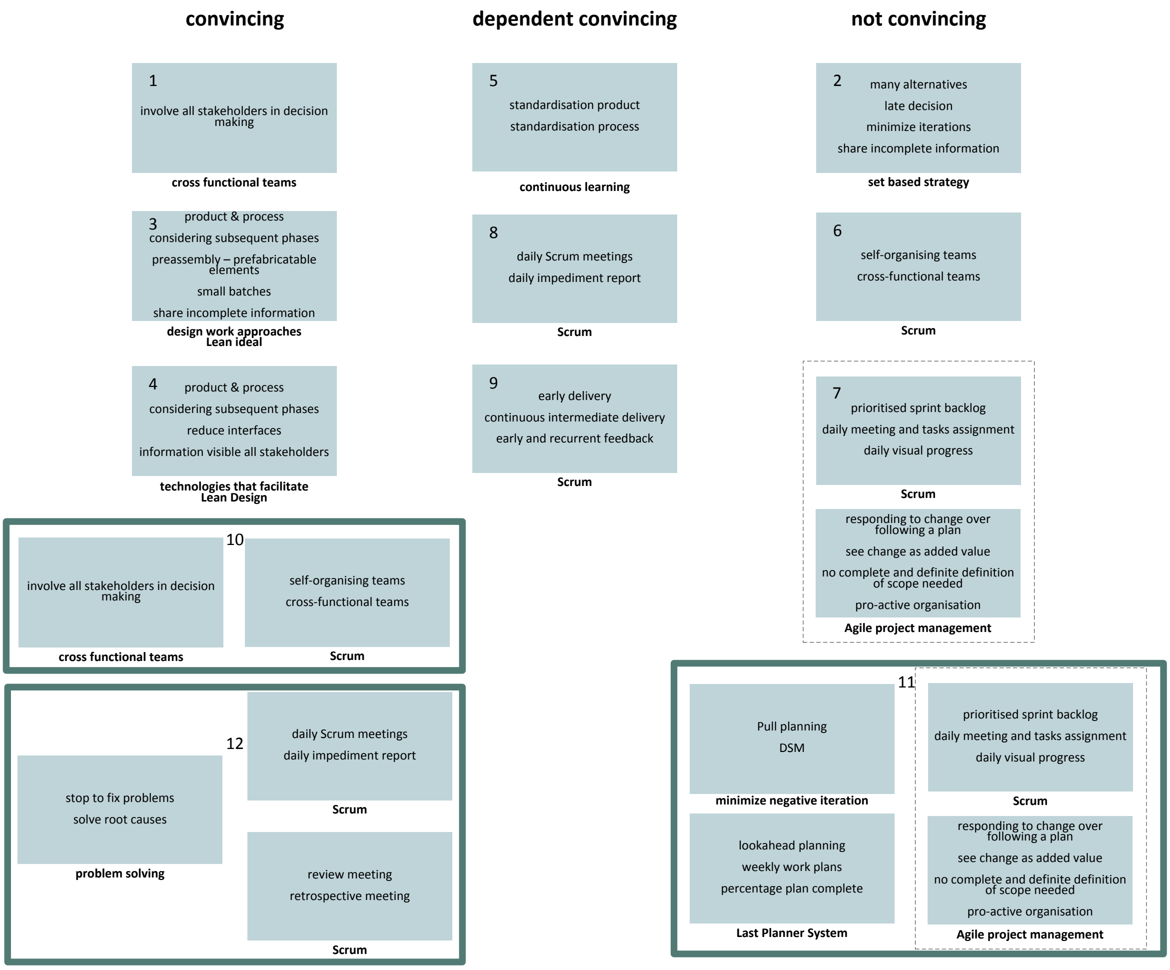


figure 32: conclusion summary

10.3 ANSWERING THE MAIN RESEARCH QUESTION

Could, and how could, a combination of Lean and Agile help coping with complexity and uncertainty in the front-end development of an infrastructure project?

In this research several elements of Lean and Agile were identified as helpful for coping with complexity and uncertainty. First a selection was made based on available theory and next the elements were examined on their true applicability. Resulting in the conclusion as presented in the preceding section. Based on this conclusion, keeping the scope and limitations of this research in mind, it can be concluded that the answer to the research question is yes: a combination of Lean and Agile could help coping with complexity and uncertainty in the front-end development of an infrastructure project. How the combination helps managing complexity is related to their shared underlying ideal. The ideal behind both Lean and Agile is value maximization for the client. Conventional project management is also aimed at value maximization, but does this for the value as defined by the client at the beginning of the process. For projects not subjected to complexity and uncertainty, this may be sufficient. Yet, for complex and uncertain projects conventional project management is not adequate. For these projects the client's definition of value at the beginning of the process differentiates for the client's definition of value at the end of the process. For these projects value maximization means maximization of the client's definition of value at the end of the project. This requires a project that is more flexible and adaptive to changes instead of a project that rebels against changes, complexity and uncertainty require a project that *embraces change*. Both Lean and Agile *embrace change* instead of rebel against it. Thus implementing the Lean and Agile ideal in project management would help coping with complexity and uncertainty in the front-end development of an infrastructure project as they *embrace change*.

11 RECOMMENDATIONS

This chapter will provide in some recommendations. In the first paragraph recommendations for implementation and use of Lean and Agile will be discussed. In the second paragraph some recommendations for further research will be provided.

11.1 RECOMMENDATIONS FOR IMPLEMENTATION AND USE

These recommendations are based on the objective as formulated in chapter two: *composing a grounded advice for civil engineering firms on whether Lean and Agile could help them to cope with complexity and uncertainty in a project's front-end development.* Three deliverables were pointed out. These deliverables were:

1. A framework of useful elements of Lean and Agile.
2. An advice on how to use the proposed elements of Lean and Agile.
3. An advice on how to implement the Lean and Agile ideal.

In the proceeding a framework with useful elements of Lean and Agile, and thus deliverable one, was already provided. In these recommendations an advice on how to use the proposed elements of Lean and Agile, deliverable two, and an advice on how to implement the Lean and Agile ideal, deliverable three, will be provided. This advice will be based on the gained knowledge from the research. The advice based on deliverable two and three will be merged and one advice on how to use and implement the elements will be provided.

The categorization as made in the conclusions is used as basis for the recommendations on how the implement and use Lean and Agile in the project management of a front-end development infrastructure project. It is advised to divide the implementation and use into three stages or phases. In figure 33 the implementation scheme is illustrated. In this figure the elements are included (light blue rectangles) as well as the practical application of the elements (green ovals), as they were tested in this research. Below an explanation on how to proceed in each phase will be provided.

1. **Phase one:** looking at the categorization it is advised to first start with implementing and using the elements which were categorized as convincing elements. These were the elements which were positively assessed by the majority of the respondents as well as they showed to be helpful for reducing and/or managing complexity and uncertainty. Taking the practical application of the elements into account (green ovals) it is advised to start with implementing the more easy to implement applications: visual management, involving team members in the planning process, reporting all sorts of problems (…) and process standardization. This last practical application is part of element five, yet design standardization is harder to implement and is therefore not part of this phase. It is advised to implement these practical applications first in a few appropriate 'test' projects and thereafter they can be implemented in all projects. Yet, it should be noted that they all need to be adapted to the project's needs, so if a project does not require to visualise for example the administrative steps. Regarding the remaining elements it is advised to encourage project team members to make use of them, but for these practical applications it is harder to distinguish tools for achieving them. Prefabrication is not part of this phase but part of phase two as it was not pointed out as useful by all respondents.
2. **Phase two:** in the second phase elements which were distinguished as not entirely convincing are included. Regarding these elements it is advised to implement them once the implementation of phase one is completed and the usage has become standard. For implementing these elements first appropriate projects need to be selected. For example regarding *daily communication* select a project with an advisor in the role of project leader. Once these projects are up and running best practices can be distinguished. These best practices can then also be used in other projects.
3. **Phase three:** the last phase includes the elements which were distinguished as not convincing. For these elements more convincing is needed. It is advised to wait a bit more till the rest of the industry is also up to speed and first perform some tests. First in forms of 'games', simulations of reality, and next real life tests in existing projects. Hereafter the tests can be evaluated and it can be assessed whether they are truly useful for helping coping with complexity and uncertainty.

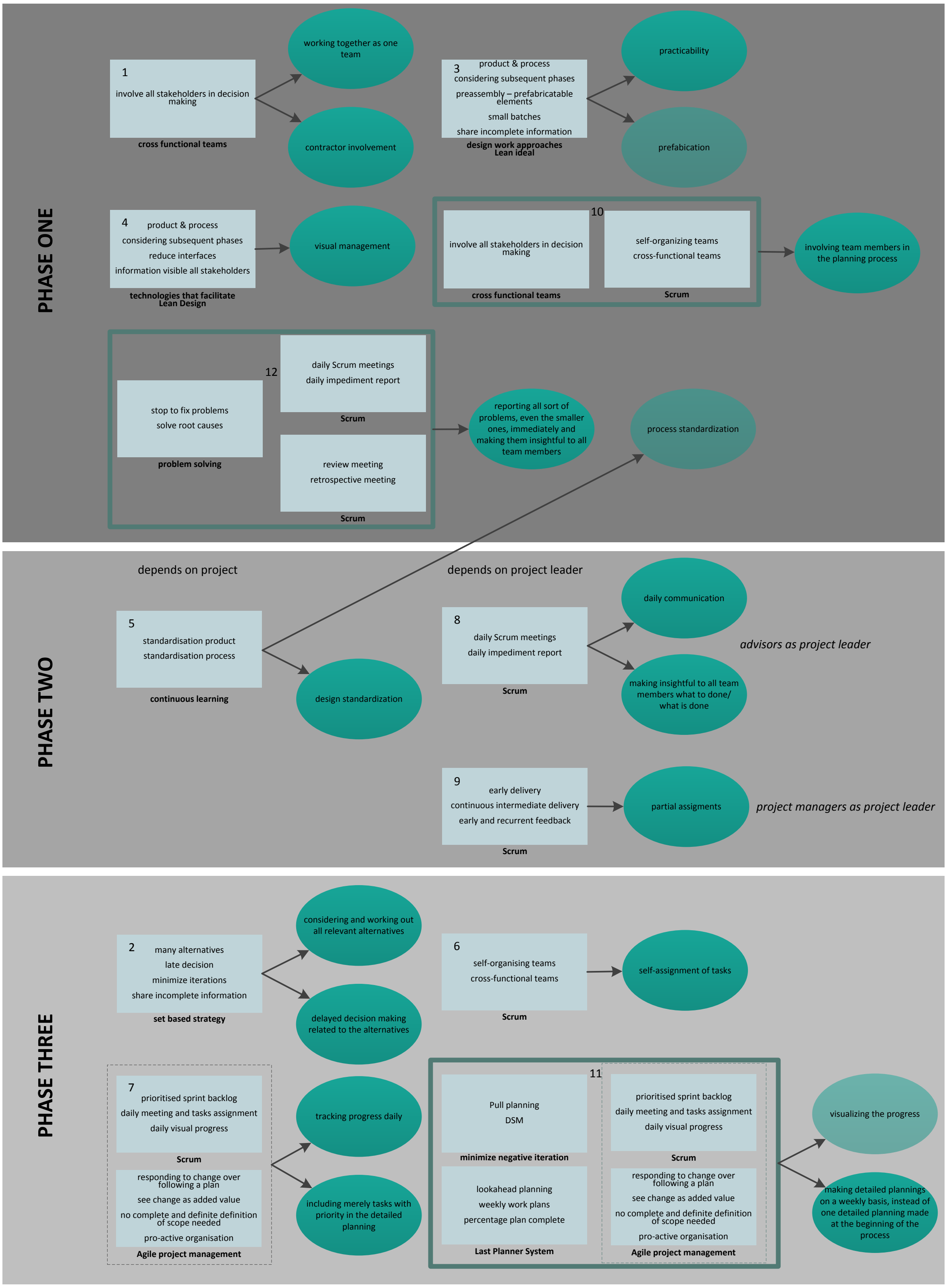


figure 33: implementation scheme

11.2 RECOMMENDATIONS FOR FURTHER RESEARCH

In this paragraph recommendations for further research will be provided. Below a list of recommendations for further research is presented. This list is based on the limitations of the research as discussed in the previous chapter.

- The scope of this research was set at the front-end development of an infrastructure project. The front-end development of a project is vital for ensuring the project will perform up to standard (Paulson, 1976; Josephson, 2009; Bosch-Rekveldt, 2011; Lessard & Miller, 2013). Therefore putting more effort in the front-end development of your project could be very rewarding. Further research could be performed in this field. What is helpful in the front-end development of an infrastructure project and what could be done in these phases to increase the overall performance of an infrastructure project?
- Also related to the scope, this research was conducted for a civil engineering company and thus also focussed on civil engineering companies. It is recommended to also conduct further research in the field of front-end development from the point of view of the client of an infrastructure project or the contractor contracted for an infrastructure project under an integrated contract.
- Another aspect for which it is recommended to perform further research is value definition. Conventional project management, Lean and Agile are all focussed on value maximization. Yet, who for infrastructure projects defines the desired value, who is your actual client and does this client exactly knows what he wants?
- The limitations of this research were discussed and it was established that the list of characteristics needed for coping with complexity and uncertainty was not complete. Further research could thus be performed in this field. A more extensive literature study could be performed as well as new research adding to the existing knowledge in this field.
- In this research readily available solutions provided by Lean and Agile were examined. Further research could be conducted to examine other kinds of solutions for making project management better able to cope with complexity and uncertainty.
- The literature study on Agile showed some limitations as there is barely any research on the possible application of Agile to construction projects in general or infrastructure project. Even though this research added to the existing knowledge in this field, it would still be very interesting to conduct more research in this field.
- The same goes for the application of Lean to infrastructure projects.
- Since this research was more theoretically based and studied the 'past' it would be recommended to conduct also more practical studies. How can Lean and Agile really be implemented and used and what are their effects? This could add to answering the main research question of this research with more certainty.
- This research should be seen as an explorative study into the possible application of Lean and Agile. More in depth research is recommended. For example conducting more in depth research in the possible application and effects of *visual management*, *standardization* or the Scrum process.
- In this research the Scrum process was examined within the boundaries of the front-end development phases. Yet, as was introduced in Agile Project Management (Owen et al., 2006), it would also be interesting to examine the possible application and effect of implementing the Scrum process beyond the project phases. Thus research into the effects of letting the clear boundaries between phases go and (partially) merge them.

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APPENDICES

A ABBREVIATIONS

ADM - Activity Definition Model

DSM - Design Structure Matrix

FED - Front-End Development

GTS - Grasp The Situation

JIT - Just-In-Time

LPDS - Lean Project Delivery System

LPS - Last Planner System

OBC - Operator Balance Chart

OOPSLA - Object-Oriented Programming, Systems, Languages & Applications

PDCA - Plan-Do-Check-Act

PPP - Public Private Partnership

TBC - Time Based Competition

TFV - Transformation, Flow, Value

TOE - Technical, Organizational, External

TPM - Total Productive Maintenance

TQM - Total Quality Management

VBM - Value Based Management

B GLOSSARY

Client/customer - in most cases the person who ordered the project, yet for some projects it is harder to clearly define the end client/customers. In this thesis the former definition of client is employed.

Concourse - the concourse on a topic consists of all possible opinions or points of view existing on that topic.

Conventional Project Management - project management as we know it today. Thus all standard or most applied project management tools and methods.

Coping with - according to the Oxford Dictionaries coping with means: "deal effectively with something difficult". In the context of infrastructure projects effectively dealing with complexity and uncertainty would mean that the complexity and uncertainty of a project is dealt with in such a way that possible cost overruns and delays resulting from this complexity and uncertainty are minimized or eliminated completely.

Correlation - the coherence or relation between two variables. A correlation exists when a change in one of the variables causes a change in the other variable.

Element - in this thesis used for representing a (partial) practical translation of an overarching term.

Perspective - a point of view on a subject, mostly influenced by a person’s frame of reference, context or culture.

P set - the total set of possible respondents for a Q sorting research.

Q sample - the set of statements which are to be ranked by the respondents of the Q sorting research.

Q sort - a, by a Q sorting research participant, filled out score sheet. Thus the individual perspective of the respondent.

Significant - indication of whether or not something can considered to be a coincidence. When something is considered to be significant one cannot speak of a coincidence.

Small batch - producing in small batches is the opposite of mass production. A small batch in the FED on an infrastructure project is considered to be a small part of, for example, the design that is incrementally delivered to the client. This instead of working on a design and delivering it only once it is completed.

Stakeholder - a person who has some sort of interest or is influenced in one way or the other by, in case of this thesis, a project.

Value - mostly defined by the required cost, time and performance of a project. Yet, in some cases other requirements might be important for defining the value of the project.

Work Breakdown Structure - a conventional project management tool that is used to make a hierarchical schematization of all subprojects in which the total project can be divided.

Z-score - represents the distance between the true value of a variable and the expected value for that variable.

C METHODOLOGY

In this appendix the methods used in the research section will be discussed and explained. This to provide some insight in how the analyses were performed and interpreted. In paragraph one the Q method will be explained and in paragraph two the correlation analysis.

C.1 Q METHODOLOGY

Q methodology was introduced in 1935 by psychologist and physicist William Stephenson (1902-1989) (Brown, 1993). It was introduced as a method to analyse human behaviour or in other words the human subjectivity. McKeown and Thomas (1988) explained the latter as: "a person's communication of his or her point of view" (Mckeown & Thomas, 1988). Brown (1986) stipulated that even though subjectivity cannot be proven, in most cases some sort of structure is present which makes it easier to study and observe subjectivity. By means of Q methodology this structure can be uncovered. The structuring is achieved by examining correlations between the different personal subjectivities. A correlation indicates that two or more persons share the same point of view, which indicates a segment of subjectivity. Q methodology makes use of Q sorting, which is the ranking of statements by several respondents. The ranking mostly occurs on a scale of disagree to agree. Each respondent ranks the statements according to his or her own point of view, which gives an indication of the person's subjectivity (Brown, 1993). Q methodology research can be divided into five steps: (1) defining the concourse, (2) developing the Q sample, (3) selecting the P set, (4) Q sorting, and (5) analysing and (6) interpreting (Van Exel & De Graaf, 2005).

C.1.1 DEFINING THE CONCOURSE, DEVELOPING THE Q SAMPLE, AND SELECTING THE P SET

(1) Brown (1993) gives the following definition of a concourse: "the flow of communicability surrounding any topic is referred to as a 'concourse' " (Brown, 1993). Thus the concourse consists of all the opinions or personal views which exists on a specific topic. (2) The Q sample is the set of statements chosen for the Q sorting. These statements are selected from the concourse, which was defined in the first step. With selecting the Q sample it is important to keep the representativeness in mind, the Q sample should give a realistic reflection of the concourse. In general two types of Q samples can be distinguished: naturalistic and ready-made Q samples. Where naturalistic Q samples are based on communicated statements from the participants of the Q sorting or external communicated statements. Ready-made Q samples are not compiled from communicated statements, mostly these statements are obtained from literature. Also sub-types exist, for example a hybrid Q sample which combines naturalistic and ready-made. Another example are standardized Q samples. Also strategies on how to select statements from the concourse, which will form the Q sample, are defined. Two ways are possible: the structured way and the unstructured way (McKeown & Thomas, 1988). By adopting a structured strategy the Q samples are defined in a systematic way. Statements are selected from the concourse on the basis of a predetermined hypothesis of the researcher on the amount of factors which are to be defined (Brown, 1980). For this mostly a deductive way of reasoning is applied, but also an inductive way of reasoning can be applied, which implies that statements are chosen on the basis of discovered patterns in literature. Unstructured selection of statements is based on the presumed relevance of the statements to the topic according to the researcher. Not only the relevance is considered but the researcher also needs to keep in mind that the Q sample needs to reflect all possible points of view on the topic. This because applying the unstructured strategy might cause bias in the Q sample, since some aspects might become over/under-sampled (McKeown & Thomas, 1988). (3) The P set represents the selected respondents. For Q sorting only a limited amount of respondents is needed.

C.1.2 THE Q SORTING

(4) The Q sorting implies the respondents, the P set, ranking the statements, the Q sample. The respondents are asked to place the statements in a predefined score sheet, which represents the presumed quasi-normal distribution, see figure 34. The scale mostly ranges from most disagree to most agree. The steepness of the score sheet depends on the level of knowledge of the respondents on the topic. When the respondents have little knowledge about the topic a steeper distribution can be chosen, to give some room for ambiguity or indecisiveness. When respondents have much knowledge about the topic or have strong opinions about the topic it is advised to use a less stepper distribution. In that way room for strong (dis)agreement is created (Van Exel & De Graaf, 2005). The distribution can thus differ, but in most cases it comes down to a quasi-normal distribution which is symmetrical around the middle. The chosen range and distribution shape have no influence on the final outcome and can therefore be altered according to the situation at hand. The first step of the Q sorting is to inform the respondent about the background of the study, the topic of the Q sorting and on how to perform the Q sorting. Next the respondent is instructed to read through all the statements of the Q sample so he or she can form some sort of first impression. The respondent is then asked to make a first categorization of

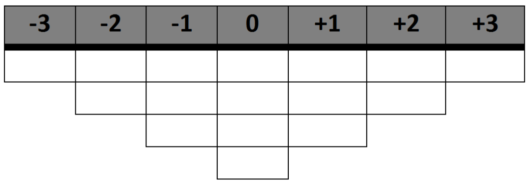


figure 34: Q sorting score sheet example

the statements into three categories: disagree, neutral and agree. Next the respondent is asked to place the statements in the predefined score sheet. When the score sheet is filled out the respondent has the opportunity to comment on his ranking (Brown, 1993). "Obviously those statements scored +3 and -3 should be addressed first since they are demonstrably the most salient, but those scored 0 can be revelatory by virtue of their lack of salience" (Brown, 1993).

C.1.3 ANALYSING

(5) The analysis comprises two parts. The first one being composing a correlation matrix and the second one being the factor analysis. The correlation matrix shows the correlations between the different points of view. A correlation of +1, a perfect positive correlation, between two points of view means that the points of view are identical. A correlation of -1 gives a perfect negative correlation, thus no statement was assessed equally. In order to calculate the correlation between two points of view the following formula can be used:

$$r = 1 - \frac{\sum D^2}{\sum S_{r1}{}^2 + \sum S_{r2}{}^2} \qquad \text{(A.1)}$$

where D is the difference between the scoring of the first respondent on one statements and the scoring of the second respondent on that same statement. D^2 is the root square of this difference and $\sum D^2$ is the summation of all the square root differences over all the statements assessed. S_{r1} is the scoring of respondent one on one of the statements and $S_{r1}{}^2$ is the square root of this scoring. $\sum S_{r1}{}^2$ is thus the summation of all the scoring's square roots. For $\sum S_{r2}{}^2$ the same applies. These calculated correlations can then be put into a matrix, the correlation matrix. The amount of correlations in this matrix is then n^2. Where n is the number of conducted Q sorts, thus the amount of respondents (Brown, 1993).

In order to assess whether a correlation can considered to be substantial the standard error can be calculated. In order to do so the following formula can be used:

$$SE = \frac{1}{\sqrt{n}} \tag{A.2}$$

where n is the amount of statements assessed by the respondents. Correlations are then considered to be significant when their absolute value is at least 2 to 2.5 times bigger than the standard error (Brown, 1993).

Next step in the analysis is conducting a factor analysis. "A factor analysis examines a correlation matrix and determines how many basically different Q sorts are evidence" (Brown, 1993). High correlations between a set of Q sorts and low correlations of those Q sorts with other Q sorts may indicate a factor. With factor analysis one tries to define these factors. To do so, first an initial amount of factors needs to be estimated. Next factor loadings can be calculated. Factor loadings are the correlations of individual Q sorts with the factor, which in fact is the average of the set of highly correlated Q sorts. Factor loadings which are bigger than the absolute value 0.5 are considered to be significant. In the first graph of figure 35 two factors are set out and four Q sorts are considered. The factor loading of one of the Q sorts is also shown. In order to highlight the connections between the Q sorts one could use rotation. The factors are rotated, as is shown in the second graph of figure 35. As can be seen the factor loadings of the two upper Q sorts become more alike in comparison with the unrotated situation. Another benefit of rotation is that factor loadings might increase which is beneficial for the significance of the factor loading. For the example Q sort one can see that the factor loading on factor one increases from 0.55 to 0.8, whereas the factor loading on factor two decreases from 0.6 to 0.2. Factor rotation can be performed as many times as needed to result in a final set of factors (Brown, 1993).

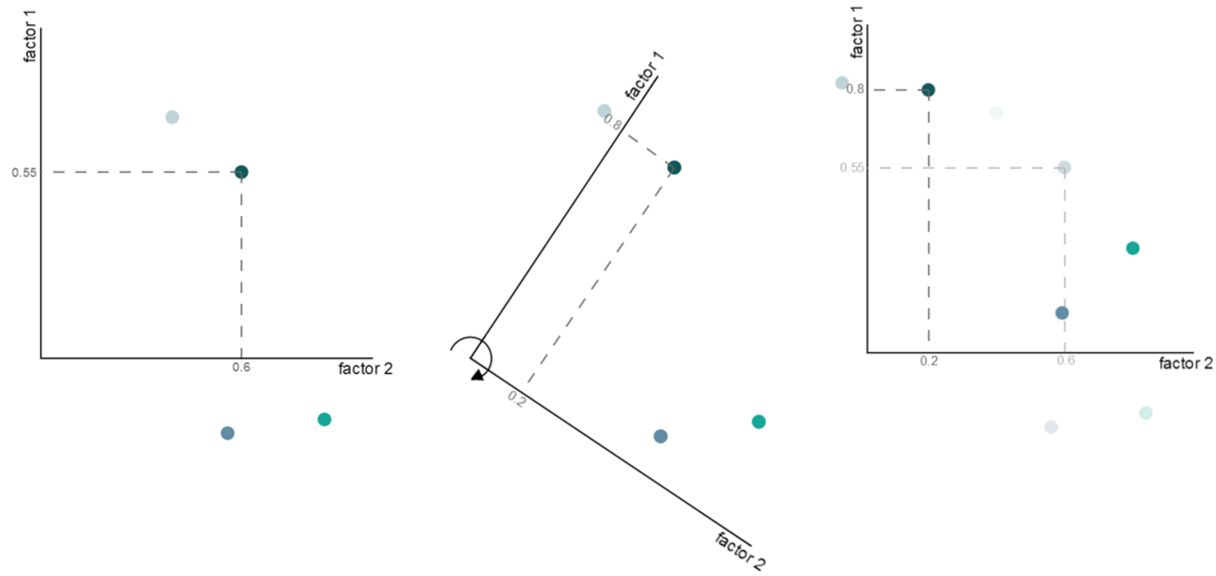


figure 35: unrotated to rotated factors

C.1.4 INTERPRETING

(6) For interpreting the final factors not so much the factor loadings are interesting but more the factor scores. The factor score of a statement is the weighted average score of a statement, based on the scorings on that statement of each of the Q sorts corresponding with the factor. The weighted average needs to be calculated since not all Q sorts have the same correlation with the factor. A Q sort correlating higher with the factor should

also have more weight in defining the factor. The Q sorts are assigned weights according to the following formula:

$$w = \frac{f}{(1 - f^2)} \tag{A.3}$$

where w is the Q sort's weight and f is the factor loading of the Q sort.

By multiplying the weights with the scoring of the Q sort on the specific statement and doing so for all the Q sorts associated with the factor, the final factor score of the statement can be calculated. Thus applying the following formula:

$$FS_x = \sum (w_{ri} * S_{x,ri}) \tag{A.4}$$

where FS_x is the factor score of statement x, w_{ri} is the weight of the Q sort as filled out by respondent i, and $S_{x,ri}$ is the scoring assigned to statement x by respondent i.

The statements can then be put into the standard Q sorting score sheet based on their factor scores. Thus the statement with the highest factor score will be assigned +3, and the statements with the lowest factor score -3, and so on. This results in the 'average' Q sort of a factor (Brown, 1993). Based on this 'average' Q sort the researcher can interpret the factor and can also assign a name to the factor (Brown, 1980). By examining the statements that distinguishes the factor from the other factors, the researcher may gain more insight in the factors and these distinguishing statements may be used for interpreting the factor (Brown, 1993).

C.2 CORRELATION ANALYSIS

Correlation analysis can be used to assess the relation between two variables. Two most commonly used types of correlation tests are Pearson product-moment correlation and Spearman’s rho. Pearson product-moment correlation is mostly applied to variables which can be measured on an interval or ratio scale and Spearman’s rho is mostly applied to variables which can be measured on a categorical or ordinal scale (Pallant, 2007). Below for both the formula for calculating the correlation between two variables is presented.

Pearson product-moment correlation:

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x^2)][n \sum y^2 - (\sum y^2)]}} \tag{A.5}$$

Spearman’s rho:

$$r = \frac{6 \sum (x - y)^2}{n(n^2 - 1)} \tag{A.6}$$

Where r represents the correlation, n the sample size, x variable one and y variable two (Baarda & De Goede, 1999).

A correlation of +1 of -1 can be seen as a 'perfect' correlation, since this means that one is able to exactly determine the value of a variable just by knowing the value of the other correlated variable. A correlation of 0 means that there is no relationship between both variables. A positive correlation can be interpreted as follows: in case variable one increases, variable two also increases. A negative correlation can be interpreted as follows: in case variable one increases, variable two decreases (Pallant, 2007).

The strength of the correlation can be assessed by using the following guidelines as set up by Cohen (1988).

- Weak: $0.10 \leq r \leq 0.29$
- Medium: $0.30 \leq r \leq 0.49$
- Strong: $0.50 \leq r \leq 1.00$

D STARTING POINT INTERVIEWS

In this appendix the format for the starting point interviews is presented. It should be noted that these questions were only used as guide line for the interviews and were, during the interviews, translated in Dutch. The guide line questions are divided into seven categories: projects, the process, communication, scope, flexibility, problems and Lean and Agile.

General information

Interviewee:
Interviewer: Rianne Blom
Date:
Time:
Location:

Introduction

- Thank them for participating in interview
- Ask for permission to record the interview
- Explaining why the interview takes place and why the interviewee was selected
- Explaining the research and the stage the research is at
- Asking the interviewee to introduce him-/herself

Goals of the interview

- Provide context for sharpening the problem statement and the main research question
- Assess the current situation
- Assess the different perspectives regarding project management
- Map out opinions and perspectives regarding Lean and Agile

Interview questions

<u>Projects</u>

1. What kind of projects do you mostly perform?
2. Using what kind of contracts? Also for example integrated contracts?
3. What is the normal duration of the projects you perform?
4. In this company the phase: back in the days we mostly performed smaller public projects, yet these days we perform more and more bigger public projects, is much heard.
    a. What does this mean?
    b. What has changed in the procedures because of this?
    c. What kind of problems does this result in?

<u>The process</u>

1. What does the beginning of a project look like?
    a. Acquisition?
    b. Who is involved in the team?
    c. How many people are involved in the team?
    d. Does the team work at one office of multiple?
2. Roles: who does what?
    a. In general: which tasks are there to divide?
    b. With which tasks does the project commences, and what is done when?
    c. How are the tasks assigned? Looking at who can do what the best? Or what someone finds most interesting?
3. Who makes the planning? And how is the planning made?

Communication

1. What is discussed during the first consultation?
2. How often are consultations arranged during the project?
    a. How long are those consultations?
    b. What is discussed during those consultations?
    c. During these consultations, do the team members indicate if they have encountered problems?
3. Besides the consultations, is there much intermediate communication amongst the team members?
4. How do you maintain contact with the client?
5. Do team members also perform different project simultaneously?
    a. What kind of consequences does this has for the planning?
    b. How is it assessed which project takes priority?

Scope

1. How specified are most assignments?
2. And how do you react?
    a. Do you immediately work it out in detail and make an offer?
    b. Or do you first ask what the real wishes are? Do you start a dialogue with the client?

Flexibility

1. How often do changes happen?
    a. In the assignment as formulated by the client?
    b. In the team formation?
2. How do you cope with these changes?

Problems

1. Are there any problems you frequently encounter?
2. How were those problems solved?

Lean and Agile

1. Have you ever heard of Lean and Agile?
2. Did you ever make usage of the ideas behind Lean and Agile?
    a. What did you exactly do?
    b. For what kind of project did you make use of it?
    c. How did that go?
3. *In case the above question is negatively answered a short explanation of Lean and Agile will be provided.*
    a. Do you think this could be helpful?
    b. What could be helpful and what not?
    c. Which problems do you predict?

Closure

- Ask interviewee if he/she has any questions, comments or tips
- Make agreements
    - Anonymity
    - Use of information from interview
    - Informing interviewee of results research
- Thank interviewee

E COMPLEXITY FRAMEWORKS

In this appendix several complexity frameworks will be reviewed. In the first paragraph the frameworks as defined by Gidado, Wood and Ashton (1996; 2004; 2008; 2009) will be discussed, next the framework as set up by Hertogh and Westerveld (2009) will be reviewed. Paragraph three will elaborate on the framework formed by Bosch-Rekveldt (2011) and paragraph four will elaborate on the framework as set up by Ahmadi and Golabchi (2013). In paragraph five the frameworks will be combined in order to form the final framework used in this research.

E.1 COMPLEXITY ACCORDING TO GIDADO, WOOD AND ASHTON (1996; 2004; 2008; 2009)

In 1996 Kassim Gidado studied complexity in the construction industry. He studied the way different experts in the field of construction projects perceived complexity. By conducting several interviews he came up with a list of six different perceptions of complexity (see table 39). He also made a distinction between managerial complexity and operative and technological complexity. Managerial complexity relates to creating a fluent work flow by planning how to combine the various elements of the system, or project. The operative and technological complexity relates to the level of difficulty of the execution of the different elements, which can be caused by either the used resources or the project's environment.

table 39: complexity according to Gidado (1996)

perception of complexity
that having a large number of different systems that need to be put together and/or that with a large number of interfaces between elements
when a project involves construction work on a confined site with access difficulty and requiring many trades to work in close proximity and at the same time
that with a great deal of intricacy which is difficult to specify clearly how to achieve a desired goal or how long it would take
that which requires a lot of details about how it should be executed
that which requires efficient coordinating, control and monitoring from start to finish
that which requires a logical link because a complex project usually encounters a series of revisions during construction and without interrelationships between activities it becomes very difficult to successfully update the programme in the most efficient manner

Gidado (2004) also saw that there are six different categories under which the factors influencing the complexity of a project can be scaled. These six categories can be found in table 40.

table 40: complexity according to Gidado (2004)

factor category
inherent complexity
uncertainty
number of technologies
rigidity of sequence
overlap of phases or concurrency
organisational complexity

Also Wood and Gidado (2008) studied complexity in construction projects. This they have done by conducting several interviews with experts in the field of complex projects. From these interviews they have obtained factors that make a project complex. Interesting is that they also ranked the factors based on degree of influence on the complexity. They also noted that the occurrence of only one or two factors in most cases does not make a project complex, solely in cases where multiple factors are present complexity exists. They first listed all different definitions of complexity, obtained from the interviews (table 41). This lists entails a ranking of the definitions.

The first definition was mentioned most and the last definition least. Therefore they were able to conclude that, since most top ranking definitions are related to the amount of parts and the dependencies between those parts, the construction industry defines a complex project as a project with many interrelated parts.

table 41: complexity according to Wood and Gidado (2008)

definition of complexity
projects with a high interdependency between the parts
projects with a high degree of interaction between the parts
projects that are continuously changing/evolving
projects made up of many interconnecting parts
projects that are surrounded by an intricate environmental envelope
projects comprising of entities with a high level of interface
projects that have a high degree of non-linear interaction with their environment
projects that have a high level of non-linear interaction
projects having a number of complicated individual parts
projects involving a high degree of diverse tasks
projects that have high interaction with their environment
projects that have a high dependency on their environment
difficulty of executing individual tasks that make up a process
projects with a great deal of intricacy
projects with a large number of parts

Next, they found that for each component sub-components existed. These sub-components are factors which can be found in complex projects. Together with Ashton, Wood (2009) studied these components some more and scaled them under six categories, as defined by Gidado (2004) (table 42).

table 42: complexity according to Wood and Ashton (2009)

category	sub component
organisational complexity	poor channels of communication
organisational complexity	poor generation and use of information
uncertainty	lack of working drawings
uncertainty	high degree of overlap of design and construction
overlap of phases or concurrency	high degree of interrelationship between activities in the different overlapping parts
number of technologies	high interdependencies between the roles of various trades in a task
uncertainty	technical core environmental layer (e.g. underwater construction, chemical)
overlap of phases or concurrency	high degree of overlap of construction phases
inherent complexity	role that has no known procedure
inherent complexity	technically complex role the requires special skill, knowledge and equipment
uncertainty	environmental influence – cultural/social/legal environmental layer
uncertainty	lack of uniformity due to continuous change in material or other resource
uncertainty	unpredictable sub-surface
uncertainty	lack of experienced local workforce
uncertainty	conducting or managing a role for the first time
rigidity of sequence	rigidity of sequence between the various packages within a phase
rigidity of sequence	rigidity of sequence between the various operations within a package

rigidity of sequence/ number of technologies	unpredictable work in a defined new structure (e.g. as in new work added to old buildings without record drawings)
rigidity of sequence	rigidity of sequence between the various tasks within an operation
inherent complexity	physically difficult role that requires the use of complex equipment
uncertainty	lack of uniformity due to lack of working space and or access
inherent complexity	technically complex role that requires locally available special skills
uncertainty	undefined structure or poor buildability assessment (e.g. refurbishment works of old buildings)
inherent complexity	technically complex role due to the sophistication of the equipment or method
uncertainty	the effect of weather or climatic conditions
uncertainty	lack or uniformity due to mechanical or other resource breakdown
inherent complexity	physically difficult role that requires simple or no equipment

E.2 COMPLEXITY ACCORDING TO HERTOGH AND WESTERVEL (2009)

Hertogh and Westerveld (2009) studied complexity in construction projects by conducting a series of case studies. They concluded that six types of complexity can be distinguished: technical, social, financial, legal, organisational and time complexity (Hertogh & Westerveld, 2009). Within each of these types of complexity they found several factors causing the specific type of complexity. In table 43 these factors and the type of complexity they cause, as defined by Hertogh and Westerveld (2009) can be found.

table 43: complexity according to Hertogh and Westerveld (Hertogh & Westerveld, 2009)

type of complexity	factor
technical	unproven technology
	technical uncertainty (geological uncertainty)
social	conflicting interests
	different meanings and perceptions
	big impact on the environment
financial	costs and benefits are difficult to calculate and are not always equally divided
	perception of cost developments can differ from calculations
	different perceptions about definitions and agreements
	strategic misinterpretation, optimism, bias and pessimism bias
	cascade of distortion
legal	changing, non-existent and conflicting laws
	extensive legislation and rules, have an important influence on content and processes
	people involved need space to operate
organisational	to find and to keep motivated people appropriate to the challenge
	many decisions with no clear 'best solution'
	the project organisation has numerous work processes that interfere with each other
	consultants, contractors and suppliers requiring numerous contracts to be arranged
time	long time frame with continuous developments
	no sequential process of implementation

E.3 COMPLEXITY ACCORDING TO BOSCH-REKVELDT (2011)

In her dissertation Bosch-Rekveldt paid attention to complexity in projects and the impact of the front-end development phase on the complexity of a project. By conducting an elaborate literature study on complexity she constructed the TOE framework (Technology, Organizational, Environmental) for assessing and capturing the project's complexity. Her literature study consisted of seventeen different sources (Bosch-Rekveldt, 2011). It can thus be concluded that this framework is one of the most elaborate frameworks found in literature.

table 44: complexity according to Bosch-Rekveldt (2011)

TOE	sub ordering	elements defined	explanation
T	goals	number of goals	What is the number of strategic project goals?
T	goals	goal alignment	Are the project goals aligned?
T	goals	clarity of goals	Are the project goals clear amongst the project team?
T	scope	scope largeness	What is the largeness of the scope, e.g. the number of official deliverables involved in the project?
T	scope	uncertainties in scope	Are there uncertainties in the scope?
T	scope	quality requirements	Are there strict quality requirements regarding the project deliverables?
T	task	number of tasks	What is the number of tasks involved?
T	task	variety of tasks	Does the project have a variety of tasks (e.g. different types of tasks)?
T	task	dependencies between tasks	What is the number and nature of dependencies between the tasks?
T	task	uncertainty in methods	Are there uncertainties in the technical methods to be applied?
T	task	interrelations between technical processes	To what extent do technical processes in this project have interrelations with existing processes?
T	task	conflicting norms and standards	Are there conflicting design standards and country specific norms involved in the project?
T	experience	newness of technology (world-wide)	Did the project make use of new technology, e.g. non-proven technology (technology which is new in the world, not only new to the company!)?
T	experience	experience with technology	Do the involved parties have experience with the technology involved?
T	risk	technical risks	Do you consider the project being high risk (number, probability and/or impact of) in terms of technical risks?
O	size	project duration	What is the planned duration of the project?
O	size	compatibility of different PM methods and tools	Do you expect compatibility issues regarding project management methodology or project management tools?
O	size	size in CAPEX	What is the estimated CAPEX of the project?
O	size	size in engineering hours	What is the (expected) amount of engineering hours in the project?
O	size	size of project team	How many persons are within the project team?
O	size	size of site area	What is the size of the site area in square meters?
O	size	number of locations	How many site locations are involved in the project, including contractor sites?
O	resources	project drive	Is there strong project drive (cost, quality, schedule)?
O	resources	resource & skills availability	Are the resources (materials, personnel) and skills required in the project, available?
O	resources	experience with parties involved	Do you have experience with the parties involved in the project (JV partners, contractor, supplier, etc.)?
O	resources	HSSE awareness	Are involved parties aware of health, safety, security and

			environment (HSSE) importance?
O	resources	interfaces between different disciplines	Are there interfaces between different disciplines involved in the project (mechanical, electrical, chemical, civil finance, legal, communication, accounting, etc.) that could lead to interface problem?
O	resources	number of financial resources	How many financial resources does the project have (e.g. own investment, bank investment, JV-parties, subsidies…)?
O	resources	contract types	Are there different main contract types involved?
O	project team	number of different nationalities	What is the number of different nationalities involved in the project team?
O	project team	number of different languages	How many different languages were used in the project for work or work related communication?
O	project team	co-operation JV partner	Do you cooperate with a JV partner in the project?
O	project team	overlapping office hours	How many overlapping office hours does the project have because of different time zones involved?
O	trust	trust in project team	Do you trust the project team members (incl. JV partner if applicable)?
O	trust	trust in contractor	Do you trust the contractor(s)?
O	risk	organizational risks	Do you consider the project being high risk (number, probability and/or impact of) in terms of organizational risks?
E	stakeholders	number of stakeholders	What is the number of stakeholders (all parties (internal and external) around the table, pm=1, project team=1, NGOs, suppliers, contractors, governments)?
E	stakeholders	variety of stakeholders' perspectives	Do different stakeholders have different perspectives?
E	stakeholders	dependencies on other stakeholders	What is the number and nature of dependencies in other stakeholders?
E	stakeholders	political influence	Does the political situation influence the project?
E	stakeholders	company internal support	Is there internal support (management support) for the project?
E	stakeholders	required local content	What is the required local content?
E	location	interference with existing site	Do you expect interference with the current site or the current use of the (foreseen) project location?
E	location	weather conditions	Do you expect unstable and/or extreme weather conditions, influencing the project?
E	location	remoteness of location	How remote is the location?
E	location	experience in the country	Do the involved parties have experience in that country?
E	market conditions	internal strategic pressure	Is there internal strategic pressure from the business?
E	market conditions	stability project environment	Is the project environment stable (e.g. exchange rates, raw material pricing)?
E	market conditions	level of competition	What is the level of competition (e.g. related to market conditions)?
E	risk	risks from environment	Do you consider the project being high risk (number, probability and/or impact of) in terms of risks from the environment?

E.4 COMPLEXITY ACCORDING TO AHMADI AND GOLABCHI (2013)

By conducting a literature review Ahmadi and Golabchi tried to define complexity specifically for project time management. Yet, as they concluded little literature was available. This is why they assessed complexity in the field of project management. This led them to defining the framework shown below.

table 45: complexity according to Ahmadi and Golabchi (2013)

category	aspect
structural complexity	large number of elements
	distinct elements
	interdependent elements
uncertainty	cutting edge technologies or uncommon contractual framework
	experience of an organisation, manager, team or stakeholder with such a project
	availability of information
dynamics	changes in projects - changes in specifications - changes in management team - changes in environment - changes in motivation level - changes in internal politics
social complexity	conflicting interests
	difficult personalities

E.5 COMBINING THE FRAMEWORKS

Due to the fact that the framework as formed by Bosch-Rekveldt (2011) is the most elaborate and also based on a well substantiated literature study, her TOE framework is used as starting point for defining the final framework used in this thesis. All elements mentioned by one, two of three more researchers were included in the final framework. Solely the last element, availability of information, is not mentioned by Bosch-Rekveldt (2011) yet is included in the final framework.

table 46: combining the frameworks

Bosch-Rekveldt	Ahmadi & Golabchi	Hertogh & Westerveld	Gigado, Wood & Ashton	Multiple?
number of goals				
goal alignment				
clarity of goals			poor channels of communication	x
scope largeness				
uncertainties in scope	changes in specification			x
quality requirements				
number of tasks	large number of elements	the project organisation has numerous work processes that interfere with each other		x
variety of tasks	distinct elements	the project organisation has numerous work processes that interfere with each other		x
dependencies between tasks	interdependent elements	the project organisation has numerous work processes that interfere with each other	high interdependencies between the roles of various trades in a task	x
uncertainty in methods			role that has no known	x

			procedure	
interrelations between technical processes		the project organisation has numerous work processes that interfere with each other	high degree of overlap of design and construction, high degree of overlap of construction phases	x
conflicting norms and standards				
newness of technology (world-wide)	cutting edge technologies or uncommon contractual framework	unproven technology		x
experience with technology	experience of an organisation, manager, team or stakeholder wit such a project		technically complex role that requires special skill, knowledge and equipment	x
technical risks		technical uncertainty (geological uncertainty)	technical core environmental layer (e.g. underwater construction, chemical), unpredictable sub-surface	x
project duration		long time frame with continuous developments		x
compatibility of different PM methods and tools				
size in CAPEX				
size in engineering hours				
size of project team				
size of site area				
number of locations				
project drive				
resource and skills availability			lack of experienced local workforce, technically complex role that requires locally available special skills	x
experience with parties involved				
HSSE awareness				
interfaces between different disciplines			high degree of interrelationship between activities in the different overlapping parts	x
number of financial resources		costs and benefits are difficult to calculate and are not always equally divided		x
contract types		consultants, contractors, and suppliers requiring numerous contracts to be arranged		x
number of different nationalities				
number of different languages			poor channels of communication	x
co-operation JV partner				
overlapping office hours				
trust in project team				
trust in contractor				
organizational risks	changes in management team			x

number of stakeholders				
variety of stakeholders' perspectives		conflicting interests, different meanings and perceptions, perceptions of cost developments can differ from calculations, different perceptions about definitions and agreements	lack of uniformity due to continuous change in material or other resource, lack of uniformity due to lack of working space and or access, lack of uniformity due to mechanical or other resource breakdown	x
dependencies on other stakeholders				
political influence		changing, non-existent and conflicting laws, extensive legislation and rules, have an important influene on content and processes, people involved need space to operate	environmental influence - cultural/social/legal environmental layer	x
company internal support				
required local content				
interference with existing site		big impact on the environment	unpredictable work in a defined new structure (e.g. as in new work added to old buildings without record drawings)	x
weather conditions			the effect of weather or climatic conditions	x
remoteness of location				
experience in the country				
internal strategic pressure				
stability project environment	changes in environment			x
level of competition				
risks from environment			environmental influence - cultural/social/legal environmental layer, undefined structure or poor buildability assessment (e.g. refurbishment works of old buildings)	x
	availability of information		poor generation and use of information	x
others				
		strategic misinterpretation, optimism, bias and pessimism bias	lack of working drawings	
		cascade of distortion	conducting or managing a role for the first time	
		to find and to keep motivated people appropriate to the challenge	rigidity of sequence between various packages within a phase	
		many decisions with no clear 'best solution'	rigidity of sequence between the various operations within a package	
		no sequential process of	rigidity of sequence	

		implementation	between the various tasks within an operation	
			physically difficult role that requires the use of complex equipment	
			technically complex role due to the sophistication of the equipment or method	
			physically difficult role that requires simple or no equipment	

F INTRODUCTION TO LEAN

In this appendix Lean will be introduced. The first paragraph will elaborate on the origins of Lean, the Toyota Production System. Next, in paragraph F.2, Lean Thinking will be introduced and in the third paragraph Lean supply and Lean assembly, as part of the Lean Project Delivery System, will be discussed.

F.1 TOYOTA PRODUCTION SYSTEM

In his book *The Toyota Way—14 Management Principles from the World's Greatest Manufacturer* Jeffrey Liker (2004) elaborately describes the Toyota Production System, as developed by the owners of Toyota in those days: Ohno and Toyoda. This sub-paragraph will briefly discuss the fourteen principles of the Toyota Production System as described by Liker (2004).

In the early 1900's Toyota, based in Japan, started to gain interest in the production process of two large American automotive companies. These two American automotive companies were very successful by using mass production. In order to be able to compete globally Toyota also tried to implement mass production, yet it encountered some problems and mass production turned out to be no option for them. Toyota was thus forced to create their own production process philosophy. By combining different philosophies and ideas from other sectors and by trial-and-error Toyota came up with their own production system. To make their production system more insightful they used a house as metaphor. The house has a foundation on which the pillars find support, two pillars to support the roof, and a roof used as a metaphor for the objective (Liker, 2004). Below each part of the house will be discussed.

- **The foundation:** at the foundation of the house we find first of all levelled production or *heijunka*. Meaning that production variation should be reduced as much as possible. Next layer is stable and standardised processes. By stabilising and standardising the processes problems will more easy rise to the surface. By using visual management the processes become insightful to all employees. At the true basis stands the Toyota philosophy.
- **The pillars:** the two pillars of the house consist of Just-in-Time and *Jidoka*. Just-in-Time is based on the minimization of inventories. This is achieved by using *takt* times, a cycle time short enough to prevent underproduction and long enough to prevent overproduction, by creating continuous flow, by producing what the client asks for, pull, by creating quick changeovers and integrating logistics. This is how Just-in-Time creates a one-piece-flow. *Jidoka* is used to ensure quality by making problems visible. For this several tools within the production process are used. Automatic stops can be built in, thus in case a problem occurs the complete process can be stopped by 'the push of a button', also an *Andon* can be used, a signboard indicating at which workstation a problem occurs. Person-machine separation implies that one person can operate several machines. Error proving can also be used for *Jidoka*. Error proofing focuses on reducing human errors. In-station quality control and using the 5 why's (iteratively asking *why* to come to the root cause of a problem) to solve the root cause of problems are the two last tools of *Jidoka*.
- **The roof:** the roof of the house shows the objective of Lean. A production system which produces against the best quality, the lowest cost, the shortest lead time, the best safety and with the highest morale. This is done by eliminating waste, which shortens the production flow.
- **The middle:** in the middle of the house we find continuous improvement. This is achieved by first of all focussing on people and teamwork. By selection, setting common goals, *Ringi* decision making, giving everyone the opportunity to participate in the decision making process, and cross-training your employees, training your employees in other fields which they do not normally work in. And second, by reducing waste. Helped by *Genchi Genbutsu*, which means that as a manager you go to the workplace to see it yourself, using the 5 why's, teaching your employees to have eyes for waste and last by problem solving.
  (Liker, 2004)

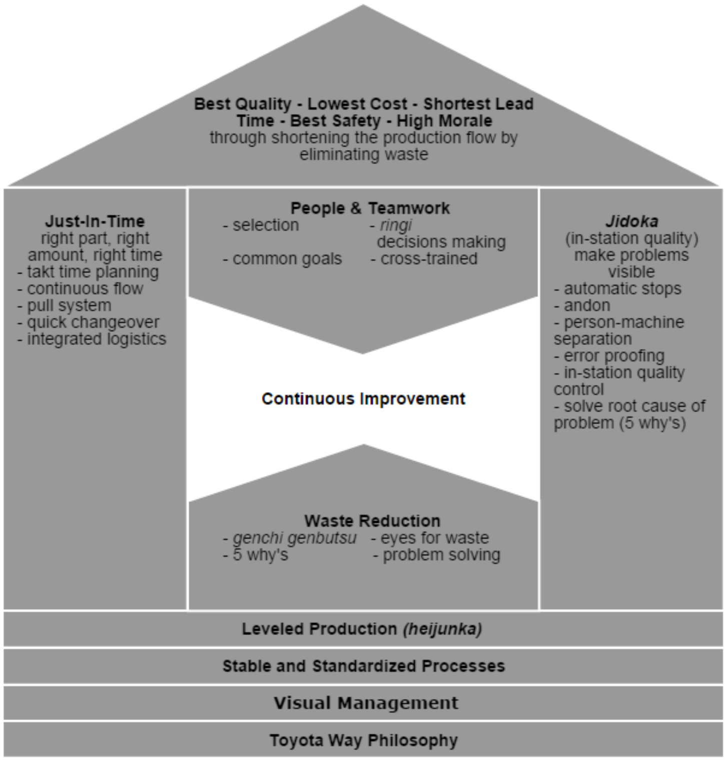


figure 36: the 'house' (Liker, 2004)

The house shows the tools and the techniques, yet what is needed is a culture shift. The philosophy behind this culture is captured by Liker (2004) in fourteen principles, which he distributed among four broad categories. These principles are briefly listed in table 47.

table 47: principles of the Toyota Production System (Liker, 2004)

category	principle
1: long-term philosophy	1: base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
2: the right process will produce the right results	2: create a continuous process flow to bring problems to the surface
	3: use 'pull' systems to avoid overproduction
	4: level out the workload (*heijunka*) (work like the tortoise, not the hare)
	5: build a culture of stopping to fix problems, to get quality right the first time
	6: standardized tasks and processes are the foundation for continuous improvement and employee empowerment
	7: use visual control so no problems are hidden
	8: use only reliable, thoroughly tested technologies that serves your people and processes
3: add value to the organization by developing your people	9: grow leaders who thoroughly understand the work, live the philosophy, and teach it to others
	10: develop exceptional people and teams who follow your company's philosophy
	11: respect your extended network of partners and suppliers by challenging them and helping them improve
4: continuously solving root problems drives organizational learning	12: go and see for yourself to thoroughly understand the situation (*genchi genbutsu)*
	13: make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (*nemawashi*).
	14: become a learning organization through relentless reflection (*hansei*) and continuous improvement (*kaizen*)

F.2 LEAN THINKING

Based on the Toyota Production System Womack and Jones (2003) described Lean Thinking, in which the principles of the Toyota Production System were captured, but were translated into a more general applicable theory. By doing so, they made the philosophy behind the Toyota Production System applicable also outside the field of production processes. Lean Thinking is a method to achieve more with less. It is based on five principles: value, value stream, flow, pull and perfection. Each of these principles will shortly be discussed.

- **Value:** it is important to start with creating a clear definition of the value of your product. It should be attempted to create a precise definition of the value. This value definition should represent the value that the end consumer requests. It should therefore meet the demands of the end consumer, at the time and budget he wants it.
- **Value stream:** this stream represents all the steps that have to be taken by a producer in order to launch a product onto the market. Three types of management tasks have to be taken. First of all the problem-solving task, which includes all the tasks involved with designing a new product. Second the information management task, which includes all the tasks involved with selling the product and last the physical task, which includes all the tasks involved with creating the final product out of raw materials.
- **Flow:** this is the opposite of batch thinking, which is the standard in a lot of companies. Flow implies that a product should be worked on continuously from the raw materials to the finished end product. This will lead to more efficiency and accuracy. A continuous flow throughout the whole value stream as described above will create a shift from focussing on the organization to focussing on the product
- **Pull:** is the opposite of pushing products. Instead of forecasting what the customer wants, the costumers will tell you themselves. This will lead to a stabilization in the demands of the costumers, since they know they can get what they want, when they want it.
- **Perfection:** every company needs a picture of perfection. Not to make sure it achieves perfection, since this is impossible, but in order to keep trying to achieve perfection. By creating a picture of perfection the company will stay motivated to continuously improve its processes. It will keep on reducing cost, time, space, effort and mistakes while still giving the costumer what he wants.
  (Womack & Jones, 2003)

By trying to get value to flow faster, the waste or *muda* in the process will become visible (Womack & Jones, 2003). In general waste are the activities which do not add value to your product. Two types of waste are defined: waste which is needed in the process and waste which is not needed in the process. Seven sorts of waste can be defined: overproduction, inventory, waiting, motion (movement within process), transportation (movement between processes), rework and over processing (Marchwinski, Shook, & Schroeder, 2009).

Under the umbrella of Lean Thinking several tools and methods were coined. Bellow the most commonly used tools and methods will be described.

Just-In-Time: In the preceding sub-paragraph JIT was already discussed, since it is one of the pillars in the 'house'. In short JIT aims at reducing inventories to zero, not only in the single organization but in the entire supply chain. The process should be able to respond to demands immediately, while it does not have an inventory (Hutchins, 1999).

Total Quality Management: TQM entails continuous improvement in an organization. It should be seen as not only a set of tools and principles, but also as a philosophy (Mansir & Schacht, 1989). The most important concepts of TQM include that the customer defines the quality by setting the requirements, the top management is responsible for continuous improvement, continuous improvement emerges from recurrent analysis and improvement of processes, and it is a continuous effort embraced by the entire organization (Houston & Dockstader, 1988). Most models to achieve TQM are based on the Plan-Do-Check-Act (PDCA) cycle, as developed by William Edwards Deming. Also Grasping The Situation (GTS) is a common used tool in Lean to achieve TQM. GTS is based on asking four questions sequentially: (1) what exactly is happening, (2) what should be happening, (3) what needs to happen, and (4) what does the ideal situation looks like (Dennis, 2007).

Time Based Competition: TBC is competing on the basis of reaction time. Thus the speed to which a company is able to respond to customer demands. This time based competitive advantage, in forms of shorter delivery times and lower costs, can be achieved by reducing the time spend in each phase of the process. Reducing time can be achieved by elimination of non-value adding activities or by reducing the time spend on, or more efficient coordination of, value adding activities. For this a time-based management approach is needed. Since the TBC philosophy needs to be present at each level of the company, time-based management consists of various different methods and tools focussed on time management (Sapkauskiene & Leitoniene, 2010).

Concurrent engineering: concurrent engineering is based on the principle of concurrently designing the product and the processes of producing the product. The aim of concurrent engineering is to shorten the production process, to create more value, and to reduce costs. Likewise for TBC, concurrent engineering is achieved by eliminating or reducing time spend on non-value adding activities and by value maximisation of the value adding activities. One of the most important features of concurrent engineering is that it reduces uncertainty by implementing iterations throughout the whole process. These iterations do not include the iterations caused by avoidable errors, those kind of iterations are not desirable and should be avoided (Huovila, Koskela, & Lautanala, 1994).

Process redesign: process redesign is focussed on radically redesigning processes in order to achieve higher performance. The old rules related to the business processes should be replaced by innovative new ones. This is a change entailing high uncertainties, but every now and then necessary to match the changing and new environment. Process Redesign is needed company-wide, which requires high efforts (Hammer, 1990).

Value Based Management: VBM focuses on the maximization of the shareholders' value. Thus, maximizing the value of the company. In order to measure the created value, and thus to assess the level of value maximization, metrics can be used. Metrics based on calculating the discounted cash flow are mostly used for assessing the value. Yet, making use of metrics alone does not necessarily leads to successfully applying VBM. For this a complete system for supporting the value creation processes is needed. Thus, metrics can be used to measure value creation or success, but not for value creation or success itself (Martin, Petty, & Wallace, 2009).

Visual management: visual management means that visual signs are used to communicate information, instead of oral or written communication. Even though the message of both oral or written and visual communication is the same, perceptions are mostly different. By making information visible to all employees of the company, thus by adopting visual communication, perceptions of reality become more accurate (Greif, 1991). Lean offers many tools for Visual Management. The most common ones are listed and explained below:

- A3-report: on a sheet of A3 size a problem and its corresponding analysis, repair actions and action plan are visualized.
- *Andon*: already mentioned in sub-paragraph 6.1.1, a signboard indicating at which workstation a problem occurs.
- Dashboard: again a visualization on one sheet of paper, this time of the current situation according to the performance of important Key Performance Indicators.
- Automatic stops: already mentioned in sub-paragraph 6.1.1, in case a problem occurs the complete process can be stopped by a 'push of a button'.
- *Kanban*: little cards, or something similar, triggering an action. For example a *Kanban* card can be used as a messaging signal that the inventory should be replenished. The *Kanban* card is thus a tool for JIT or a pull-system.

- Operator Balance Chart: when a process entail several different steps, carried out by different operators, the Operator Balance Chart can provide insight. In an OBC the steps an operator has to take are set out against the *takt time*.
- Value-Stream Mapping: a diagram in which the complete process is visualized, thus a representation of all the steps needed to transform the raw materials into a delivered end product.
  (Marchwinski et al., 2009)

Total Productive Maintenance: TPM is based on the idea that investing in maintenance leads to improvements in the production process and thus higher quality of end products. The maintenance is focussed on the optimization of equipment. TPM implies making improvements based on the needs of all equipment, thus it relies on input from the equipment users which are the process engineers, the operators and also the production itself (Borris, 2006).

Employee involvement: employee involvement implies that the employees should be involved in the decision making within a company. Employees should also be involved in the problem solving processes and in the processes related to the continuous improvement of the production system (Vidal, 2006).

F.3 LEAN SUPPLY AND LEAN ASSEMBLY

Lean Supply: implies the supply of materials and services to the construction site. By applying Lean principles to the process of supply, Lean Supply is achieved. To achieve Lean Supply already in the design phase supply needs to be taken into account. This can be done by creating cross functional teams. It is important to not only include the more 'traditional' members, the architects and engineers, but also the stakeholders responsible for downstream phases in the whole construction process, thus fabricators and suppliers etcetera. Also long-term relationships with suppliers can help to achieve Lean Supply. Due to long-term relationships parties involved are familiar with each other, which makes that they are better able to align their processes. Also shifting detailed design to the suppliers can help with achieving Lean Supply. By doing so, standardization of products and processes can be used, which will be advantageous for the whole process. Also implementing the pull principle in supply will create Lean Supply. Implementing the pull principle means that materials and services are only delivered when they are actually needed. For this a short-term planning, which is more accurate, is needed. Next, a close interaction with the supplier is needed, as he needs to respond quickly to the demand of materials or services. Transportation can be seen as another pillar of Lean Supply. By reducing transportation times, for example by selecting suppliers who are located near the construction site, Lean Supply can be achieved. Synchronisation of the different supply chains, the supply chains of the different materials and services needed, is another key factor for achieving Lean Supply (Ballard et al., 2002).

Lean Assembly is the last step of the LPDS. To achieve Lean Assembly first run studies can be used. These first run studies model the operation of the product in a realistic manner in order to estimate the best way to conduct the work. Since these first run studies define the best way to perform the work, they can be seen as a standard against which the actual performance of carrying out the work can be tested. Also continuous flow can help achieving Lean Assembly. A continuous flow can be created by reducing the batch sizes and by applying a first-in-first-out strategy. By doing so the work-in-process will be reduced, which leads to a reduced amount of waste. The team responsible for the assembly should preferably be a multi-skilled team. In those cases each team member is able to assemble a variety of systems, which reduces the fragmentation of the process. Other tools and techniques which can be used for achieving Lean Assembly are: preassembly, standardised and interchangeable parts, Just-In-Time deliveries, one-touch handling, and distributed planning. Just-In-Time delivery means that all materials and services should be delivered at the desired time, which in a lot of cases is just before they are needed. One-touch handling eliminates the need for re-handling and distributed planning implies that it is not necessary to reveal a detailed planning at once. The planning can be revealed in steps, whereby the level of detail which is revealed depends on the circumstances at hand (Ballard et al., 2002).

G Q SORTING QUESTIONNAIRE

The Q sorting questionnaire was made in Excel and emailed as an attachment to all possible respondents. The Excel file consists of five sheets. The first one provides the introduction and the second to fourth guides the respondent through the Q sorting process. The five sheets of the Excel file are presented in this appendix.

G.1 INTRODUCTION

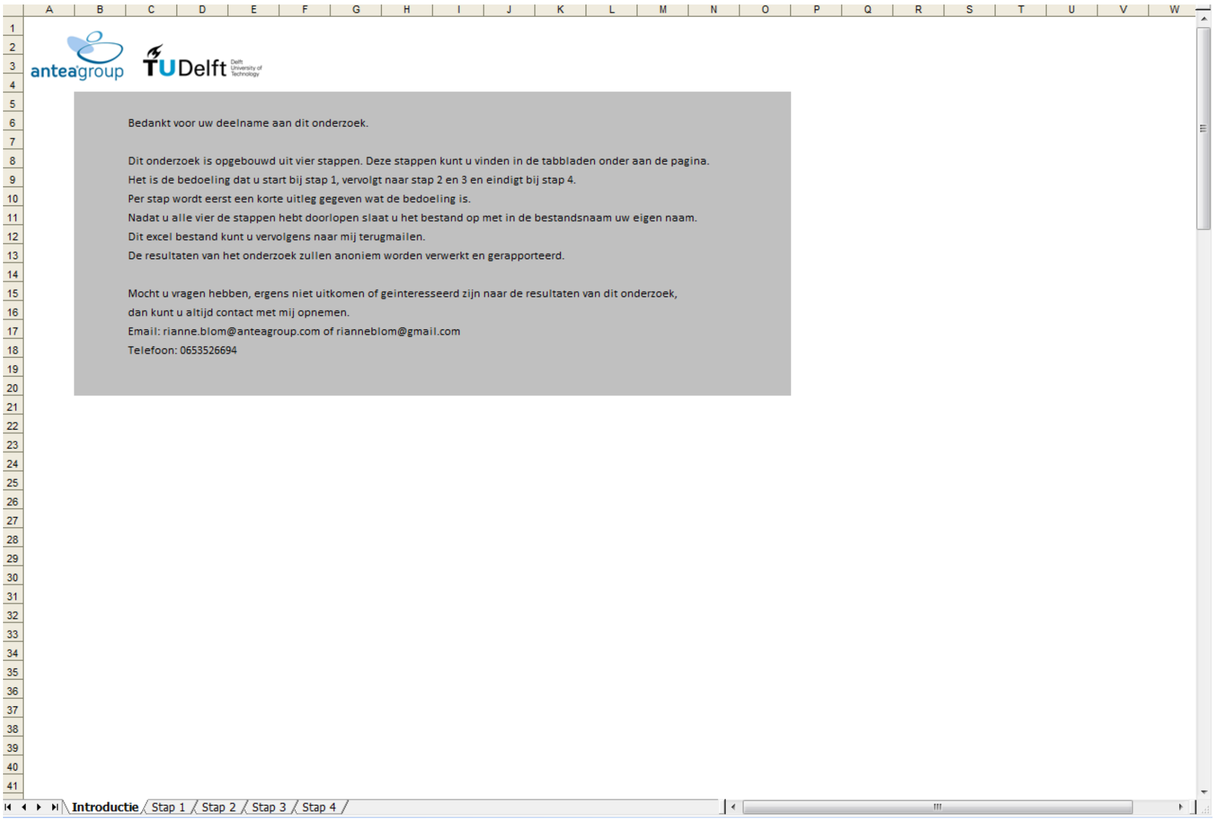
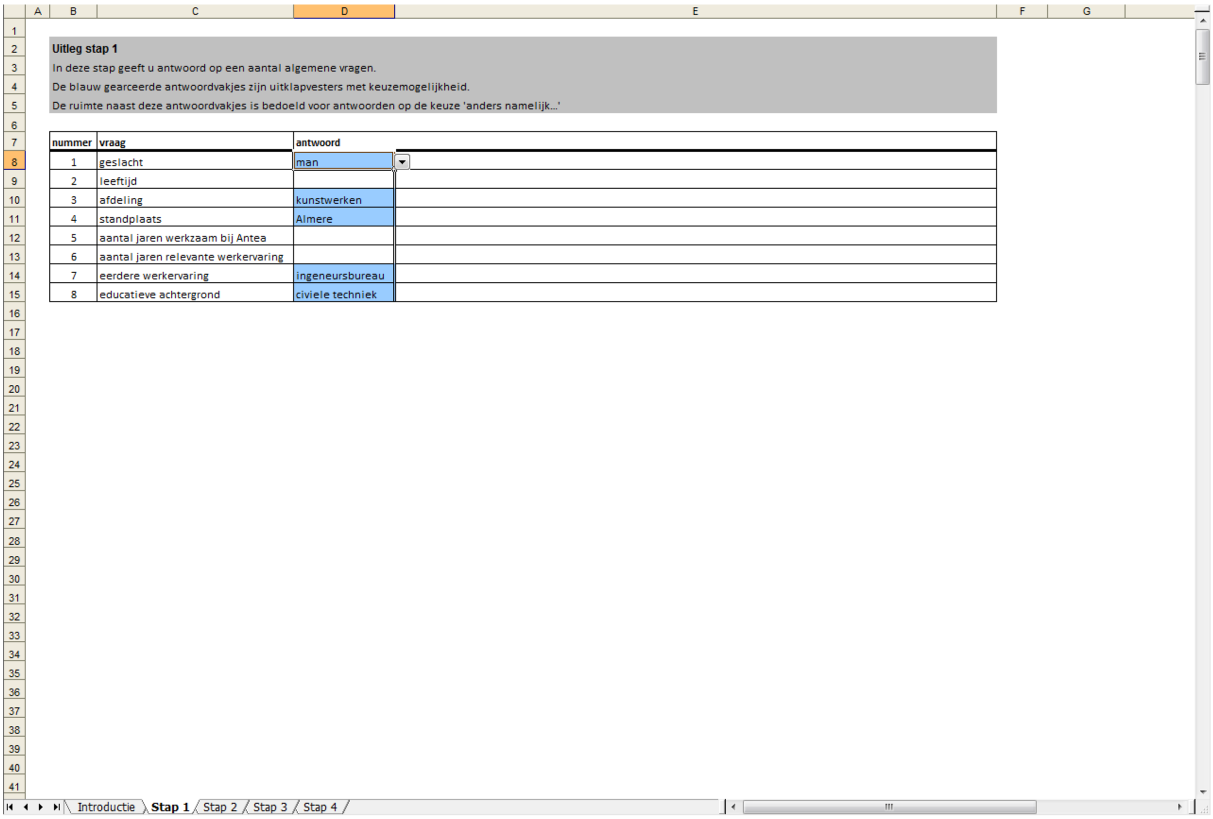


figure 37: Q sorting questionnaire introduction

G.2 STEP ONE



Uitleg stap 1

In deze stap geeft u antwoord op een aantal algemene vragen.

De blauw gearceerde antwoordvakjes zijn uitklapvesters met keuzemogelijkheid.

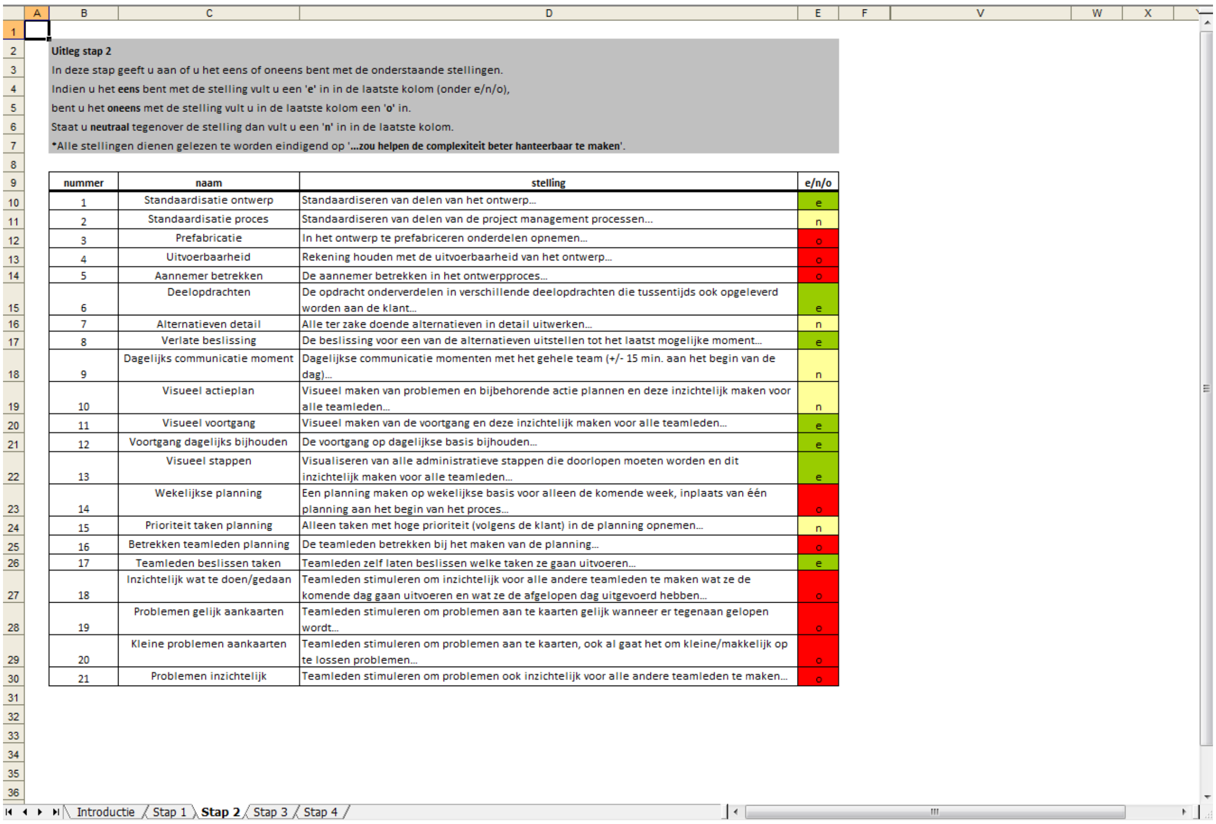
De ruimte naast deze antwoordvakjes is bedoeld voor antwoorden op de keuze 'anders namelijk...'

nummer	vraag	antwoord	
1	geslacht	man	
2	leeftijd		
3	afdeling	kunstwerken	
4	standplaats	Almere	
5	aantal jaren werkzaam bij Antea		
6	aantal jaren relevante werkervaring		
7	eerdere werkervaring	ingeneursbureau	
8	educatieve achtergrond	civiele techniek	

Introductie | Stap 1 | Stap 2 | Stap 3 | Stap 4

figure 38: Q sorting questionnaire step one

G.3 STEP TWO



Uitleg stap 2

In deze stap geeft u aan of u het eens of oneens bent met de onderstaande stellingen.

Indien u het **eens** bent met de stelling vult u een '**e**' in in de laatste kolom (onder e/n/o),

bent u het **oneens** met de stelling vult u in de laatste kolom een '**o**' in.

Staat u **neutraal** tegenover de stelling dan vult u een '**n**' in in de laatste kolom.

*Alle stellingen dienen gelezen te worden eindigend op '**...zou helpen de complexiteit beter hanteerbaar te maken**'.

nummer	naam	stelling	e/n/o
1	Standaardisatie ontwerp	Standaardiseren van delen van het ontwerp...	e
2	Standaardisatie proces	Standaardiseren van delen van de project management processen...	n
3	Prefabricatie	In het ontwerp te prefabriceren onderdelen opnemen...	o
4	Uitvoerbaarheid	Rekening houden met de uitvoerbaarheid van het ontwerp...	o
5	Aannemer betrekken	De aannemer betrekken in het ontwerpproces...	o
6	Deelopdrachten	De opdracht onderverdelen in verschillende deelopdrachten die tussentijds ook opgeleverd worden aan de klant...	e
7	Alternatieven detail	Alle ter zake doende alternatieven in detail uitwerken...	n
8	Verlate beslissing	De beslissing voor een van de alternatieven uitstellen tot het laatst mogelijke moment...	e
9	Dagelijks communicatie moment	Dagelijkse communicatie momenten met het gehele team (+/- 15 min. aan het begin van de dag)...	n
10	Visueel actieplan	Visueel maken van problemen en bijbehorende actie plannen en deze inzichtelijk maken voor alle teamleden...	n
11	Visueel voortgang	Visueel maken van de voortgang en deze inzichtelijk maken voor alle teamleden...	e
12	Voortgang dagelijks bijhouden	De voortgang op dagelijkse basis bijhouden...	e
13	Visueel stappen	Visualiseren van alle administratieve stappen die doorlopen moeten worden en dit inzichtelijk maken voor alle teamleden...	e
14	Wekelijkse planning	Een planning maken op wekelijkse basis voor alleen de komende week, inplaats van één planning aan het begin van het proces...	o
15	Prioriteit taken planning	Alleen taken met hoge prioriteit (volgens de klant) in de planning opnemen...	n
16	Betrekken teamleden planning	De teamleden betrekken bij het maken van de planning...	o
17	Teamleden beslissen taken	Teamleden zelf laten beslissen welke taken ze gaan uitvoeren...	e
18	Inzichtelijk wat te doen/gedaan	Teamleden stimuleren om inzichtelijk voor alle andere teamleden te maken wat ze de komende dag gaan uitvoeren en wat ze de afgelopen dag uitgevoerd hebben...	o
19	Problemen gelijk aankaarten	Teamleden stimuleren om problemen aan te kaarten gelijk wanneer er tegenaan gelopen wordt...	o
20	Kleine problemen aankaarten	Teamleden stimuleren om problemen aan te kaarten, ook al gaat het om kleine/makkelijk op te lossen problemen...	o
21	Problemen inzichtelijk	Teamleden stimuleren om problemen ook inzichtelijk voor alle andere teamleden te maken...	o

Introductie | Stap 1 | Stap 2 | Stap 3 | Stap 4

figure 39: Q sorting questionnaire step two

G.4 STEP THREE

Uitleg stap 3

Hier gaat u de stellingen 'ranken'.

De stelling waar u het het meest mee eens bent rankt u op plaats 1 en de stelling waar u het het meest mee oneens bent rankt u op plaats 21.

U doet dit door de nummers 1 tot en met 21 in te vullen in de kollom 'ranking'.

Om het u iets makkelijker te maken zijn de stellingen al gesorteerd op basis van de door u ingevulde verdeling, eens-neutraal-oneens, van stap 2.

Uw ranking wordt vervolgens automatisch ingevuld in het onderstaande scoreformulier. Het scoreformulier is gebaseerd op de normaal verdeling.

Ter controle zou het scoreformulier van links naar rechts, van rood naar geel naar groen moeten lopen.

naam	ranking
Standaardisatie ontwerp	1
Deelopdrachten	2
Verlate beslissing	3
Visueel voortgang	4
Voortgang dagelijks bijhouden	5
Visueel stappen	6
Teamleden beslissen taken	7
Standaardisatie proces	8
Alternatieven detail	9
Dagelijks communicatie moment	10
Visueel actieplan	11
Prioriteit taken planning	12
Prefabricatie	13
Uitvoerbaarheid	14
Aannemer betrekken	15
Wekelijkse planning	16
Betrekken teamleden planning	17
Inzichtelijk wat te doen/gedaan	18
Problemen gelijk aankaarten	19
Kleine problemen aankaarten	20
Problemen inzichtelijk	21

Score-formulier

meest mee oneens of minst mee eens						meest mee eens of minst mee oneens
Problemen inzichtelijk	Kleine problemen aankaarten	Betrekken teamleden planning	Prefabricatie	Standaardisatie proces	Visueel voortgang	Standaardisatie ontwerp
	Problemen gelijk aankaarten	Wekelijkse planning	Prioriteit taken planning	Teamleden beslissen taken	Verlate beslissing	
	Inzichtelijk wat te doen/gedaan	Aannemer betrekken	Visueel actieplan	Visueel stappen	Deelopdrachten	
		Uitvoerbaarheid	Dagelijks communicatie	Voortgang dagelijks bijhouden		
			Alternatieven detail			

Introductie / Stap 1 / Stap 2 / **Stap 3** / Stap 4

figure 40: Q sorting questionnaire step three

G.5 STEP FOUR

Uitleg stap 4

Hier heeft u de mogelijkheid om opmerkingen te plaatsen bij de stellingen.

Waarom bent u het sterk oneens met een stelling of waarom juist sterk mee eens.

Ook als u een specifieke reden heeft voor een neutrale positie kunt u dit vermelden.

Het is niet verplicht om bij alle stellingen een opmerking te plaatsen!

naam	opmerking
Standaardisatie ontwerp	
Deelopdrachten	
Verlate beslissing	
Visueel voortgang	
Voortgang dagelijks bijhouden	
Visueel stappen	
Teamleden beslissen taken	
Standaardisatie proces	
Alternatieven detail	
Dagelijks communicatie moment	
Visueel actieplan	
Prioriteit taken planning	
Prefabricatie	
Uitvoerbaarheid	
Aannemer betrekken	
Wekelijkse planning	
Betrekken teamleden planning	
Inzichtelijk wat te doen/gedaan	
Problemen gelijk aankaarten	
Kleine problemen aankaarten	
Problemen inzichtelijk	

Introductie / Stap 1 / Stap 2 / Stap 3 / **Stap 4**

figure 41: Q sorting questionnaire step four

H CORRELATION QUESTIONNAIRE

The correlation questionnaire was made by means of the online survey software SurveyMonkey. All possible respondents were sent an invitation email containing the link to the online survey. The survey is comprised of five separate screens. The first one provides an introduction, the second one consists of some general questions, screen three and four consist of the statements, and the fifth screen entails some last words. Screen three of the statements on the complexity and uncertainty of the project the respondent is currently working on and screen four of the statements of the implicit use of Lean and Agile.

H.1 INTRODUCTION

Enquête Afstuderen Complexe Projecten

Voor mijn afstuderen aan de Technische Universiteit van Delft, richting Construction Management & Engineering, doe ik, in samenwerking met Antea Group, onderzoek naar complexiteit binnen infrastructurele projecten en manieren hoe hiermee omgegaan kan worden.

Deze enquête is in drie delen opgebouwd. In deel 1 zullen een aantal algemene vragen gesteld worden. In deel 2 zal gevraagd worden naar uw mening over 17 stellingen met betrekking tot de complexiteit van het project waarin u op dit moment werkzaam bent. In deel 3 zal er gevraagd worden naar uw mening over 15 stellingen met betrekking tot hoe invulling is gegeven aan het project.

Het invullen van deze enquête zal u ongeveer 10 minuten kosten.

Uw gegevens zullen anoniem behandeld worden en zullen niet voor andere doeleinden gebruikt worden. De resultaten van deze enquête zullen gepubliceerd worden in een rapport. Dit rapport kan, na afronding van het onderzoek, opgevraagd worden.

Alvast hartelijk bedankt voor uw medewerking!

Met vriendelijke groet,
Rianne Blom

Mocht u nog vragen hebben over de enquête of bent u geinteresseerd in de resultaten van dit onderzoek, dan kunt u contact met mij opnemen via onderstaande contactgegevens:
Email: rianne.blom@anteagroup.com of rianneblom@gmail.com
Telefoon: 0653526694.

figure 42: correlation questionnaire introduction

H.2 GENERAL QUESTIONS

Enquête Afstuderen Complexe Projecten

Deel 1

In dit eerste deel worden een aantal algemene vragen gesteld.

1. Geslacht

- man
- vrouw

2. Leeftijd

3. Projectnaam

4. Wat is uw rol binnen het project?

- projectmanager
- projectleider
- adviseur
- ontwerper
- tekenaar
- constructeur
- anders namelijk

(geef toelichting)

5. Aantal jaren relevante werkervaring

6. Hoogst genoten opleiding

- VMBO
- HAVO
- VWO
- MBO
- HBO
- WO

figure 43: correlation questionnaire general questions

H.3 STATEMENTS PART ONE

Enquête Afstuderen Complexe Projecten

Deel 2

In dit deel van het onderzoek zal gevraagd worden naar uw mening over 16 stellingen met betrekking tot de complexiteit van het project waarin u op dit moment werkzaam bent. Alle stellingen kunnen beantwoord worden op een schaal van volledig mee oneens tot volledig mee eens.

1. Stellingen deel 2.

	volledig mee oneens	enigzins mee oneens	neutraal	enigzins mee eens	volledig mee eens
De doelen van het project zijn mij duidelijk.					
Scopeveranderingen gebeuren zeer geregeld.					
Het project bestaat uit veel verschillende onderdelen/taken die onderling afhankelijk zijn.					
Het projectmanagement heeft veel ervaring.					
Er zijn veel afhankelijkheden tussen de verschillende disciplines/sub-teams.					
In dit project worden veel nieuwe technieken gebruikt.					
Het projectteam heeft over het algemeen veel ervaring met de gebruikte technieken.					
De omgeving van het project is zeer onzeker.					
Het project heeft een lange duur.					

Alle middelen die nodig zijn voor dit project zijn beschikbaar.					
Het aantal contracten verbonden aan dit project is hoog.					
De mate en kwaliteit van communicatie binnen dit project is goed.					
Veranderingen in de organisatie van dit project komen vaak voor.					
De stakeholders betrokken bij dit project hebben allemaal verschillende belangen, percepties en meningen.					
De politiek heeft een grote invloed op dit project.					
Het project heeft een grote impact op de omgeving.					
Informatie is voor alle teamleden beschikbaar op ieder moment van de dag.					

figure 44: correlation questionnaire statements part one

H.4 STATEMENTS PART TWO

Enquête Afstuderen Complexe Projecten

Deel 3

In dit deel van het onderzoek zal gevraagd worden naar uw mening over 16 stellingen met betrekking tot hoe er invulling is gegeven aan het project waarin u op dit moment werkzaam bent. Alle stellingen kunnen beantwoord worden op een schaal van volledig mee oneens tot volledig mee eens.

1. Stellingen deel 3

	volledig mee oneens	enigzins mee oneens	neutraal	enigzins mee eens	volledig mee eens
Binnen het project wordt gebruik gemaakt van standaardisatie.	○	○	○	○	○
Er wordt rekening gehouden met de uitvoerbaarheid van het project.	○	○	○	○	○
Er wordt als één team samengewerkt, in plaats van in verschillende sub-teams waarvan de resultaten aan het einde worden samengevoegd.	○	○	○	○	○
Het werk is verdeeld in delen, die nadat ze zijn afgerond aan de klant opgeleverd worden zodat die het kan voorzien van feedback.	○	○	○	○	○
Alle ter zake doende alternatieven worden in detail uitgewerkt.	○	○	○	○	○
De keuze voor een van de alternatieven wordt genomen op het laatst mogelijke moment.	○	○	○	○	○
Het team of het sub-team komt op een dagelijkse basis bij elkaar.	○	○	○	○	○

Veel informatie (bv. actieplannen of de voortgang van het project) is visueel gemaakt en is voor mij elk moment van de dag in te zien.					
De voortgang wordt elke dag bijgehouden.					
Er wordt op wekelijkse/maandelijkse basis een gedetailleerde planning gemaakt, in plaats van dat er een grote planning aan het begin van het project is gemaakt.					
In de planning zijn alleen taken opgenomen met een hoge prioriteit voor de klant en waarvoor aan alle voorwaarde is voldaan om de taak uit te kunnen voeren.					
Ik ben betrokken geweest bij het maken van de planning.					
De taken die ik uitvoer heb ik zelf gekozen.					
Binnen het team weet iedereen van elkaar waar hij/zij mee bezig is, doordat wij dit vaak met elkaar afstemmen.					
Problemen, hoe klein ook, worden gelijk gemeld en worden inzichtelijk gemaakt voor het gehele team.					

figure 45: correlation questionnaire statements part two

H.5 LAST WORDS

Enquête Afstuderen Complexe Projecten

Hartelijk dank voor uw medewerking aan dit onderzoek!

figure 46: correlation questionnaire statements last words

I THE Q SORT FACTOR ANALYSIS

The factor analysis was performed by means of the PQMethod software. For extracting the preliminary factors a centroid analysis was performed resulting in the formation of seven unrotated preliminary factors. The unrotated factor matrix can be found in table 48.

table 48: unrotated factor matrix

			factor						
			1	2	3	4	5	6	7
Q sort	1	R1	0.7072	-0.1705	-0.4345	0.0885	-0.2603	0.0536	-0.1048
	2	R2	0.4632	0.3704	-0.3401	0.1331	-0.1262	0.0105	-0.2898
	3	R3	0.2491	0.0136	-0.0627	0.0006	0.1906	0.0367	0.3921
	4	R4	0.7512	-0.0733	0.3757	0.0816	0.1638	0.0274	0.2249
	5	R5	0.6115	0.2072	-0.1908	0.0408	0.3131	0.0994	-0.3356
	6	R6	0.7409	-0.1868	0.3277	0.0733	0.1989	0.0398	-0.2057
	7	R7	0.4787	-0.0682	-0.2840	0.0302	-0.3323	0.0930	0.4698
	8	R8	0.3832	0.0126	0.1813	0.0218	-0.2571	0.0522	-0.0644
	9	R9	0.6824	0.2581	0.0367	0.0442	-0.1335	0.0120	0.1872
	10	R10	0.4618	0.1057	0.2608	0.0507	-0.2278	0.0399	0.1548
	11	R11	0.5770	0.5880	0.3864	0.3180	0.0545	0.0046	-0.0854
	12	R13	0.6143	0.0586	0.2502	0.0420	-0.1892	0.0263	0.0689
	13	R15	0.8340	0.2676	-0.0014	0.0454	-0.1970	0.0288	0.2712
	14	R16	0.5213	-0.4243	-0.1190	0.0759	-0.0692	0.0024	-0.3067
	15	R17	0.8326	0.1278	0.2271	0.0451	0.1858	0.0349	0.0005
	16	R18	0.7527	0.0669	-0.1650	0.0129	0.2743	0.0755	0.1532
	17	R19	0.6403	0.1309	0.2000	0.0389	0.3512	0.1271	-0.3477
	18	R20	0.8058	-0.0705	-0.2273	0.0179	0.0302	0.0015	-0.1528
	19	R21	0.7043	0.2248	-0.2429	0.0551	0.1299	0.0178	0.1898
	20	R22	0.6985	0.0560	-0.5006	0.1148	0.1716	0.0300	0.0739
	21	R23	0.4329	-0.7825	-0.0175	0.3073	0.0954	0.0108	0.0255
	22	R24	0.4238	-0.2882	0.5455	0.2077	-0.2290	0.0403	0.0809
	23	R25	0.5014	0.3115	-0.0906	0.0611	-0.4937	0.2455	-0.4838
	24	R26	0.7072	-0.5322	0.0942	0.1304	0.0846	0.0082	-0.0386
	25	R27	0.5198	-0.2823	-0.2713	0.0560	0.2426	0.0589	0.1037
eigenvalues			9.6937	2.1850	1.8711	0.3376	1.2646	0.1221	1.3805
% expl. var.			39	9	7	1	5	0	6

For rotation the Varimax method was used. With the Varimax method the researcher defines the amount of factors to be rotated. In order to assess that best suitable amount of factor the Varimax rotation was performed five times. Two, three, four, five and six factors were extracted by performing individual Varimax rotations. Deciding upon the appropriate amount of factors was done based on a comparison between the amount of factors based on their number of non-loaders, their number of confounders and a even distribution of the amount of significant loading sorts per factor. Non-loaders are sorts which do not load significant on any of the factors. The amount of non-loaders is therefore preferably low. Confounders are sorts which load significant on two or more factors. The amount of confounders is therefore also preferably low, yet less disturbing compared to the amount of non-loaders, since confounders can be assigned to the factor on which they load the highest. Thus summarising the used criteria for selecting the appropriate amount of factors in order of assigned importance:

1. A low amount of non-loaders.
2. An even distribution of significant loading sorts per factor.
3. A low amount of confounders.

Whether or not a sort loads significant on a factor can be assessed by using the standard error. The formula for calculating the standard error can be found in appendix C. For this research the amount of sorts is 25.

$$SE = \frac{1}{\sqrt{25}} = 0.2$$

Sorts loading more than +/- 1.96 times the standard error are considered to be significant at the 0.05 level and sorts loading more than +/- 2.58 times the standard error are considered to be significant at the 0.01 level (Brown, 1980).

$$|1.96| * 0.2 = |0.392| \text{ and } |2.58| * 0.2 = |0.516|$$

Thus for this research a sort loads significant at the 0.05 level when it exceeds a loading of +/- 0.392 and a sort loads significant at the 0.01 level when it exceeds a loading of +/- 0.516.

Comparing the amount of extracted factor based on these criteria led to the decision for defining three factors. Below the factor loadings of each sort on each of the three factors is shown. Loadings significant at the 0.05 level are highlighted dark blue and loadings significant at the 0.01 level are highlighted light green.

table 49: factor analysis

sort	factor 1	factor 2	factor 3	non-loader	confounder
Respondent_1	0.6726	0.5056	0.1001		x
Respondent_2	0.6674	-0.0951	0.1139		
Respondent_3	0.2068	0.0997	0.1161	x	
Respondent_4	0.2081	0.3276	0.7485		
Respondent_5	0.6004	0.0932	0.2899		
Respondent_6	0.1881	0.4318	0.6851		x
Respondent_7	0.4673	0.2984	0.0840		
Respondent_8	0.1327	0.1235	0.3835	x	
Respondent_9	0.5171	0.0464	0.5140		x
Respondent_10	0.1680	0.0617	0.5103		
Respondent_11	0.3503	-0.3412	0.7674		
Respondent_13	0.2544	0.1689	0.5918		
Respondent_15	0.6434	0.1060	0.5849		x
Respondent_16	0.2458	0.6142	0.1678		
Respondent_17	0.4374	0.2004	0.7278		x
Respondent_18	0.6190	0.2747	0.3737		
Respondent_19	0.3327	0.1214	0.5846		
Respondent_20	0.6397	0.4287	0.3361		x
Respondent_21	0.7013	0.1230	0.3141		
Respondent_22	0.7998	0.3071	0.0875		
Respondent_23	-0.0150	0.8888	0.1239		
Respondent_24	-0.1988	0.3620	0.6242		
Respondent_25	0.5051	-0.0598	0.3129		
Respondent_26	0.1831	0.7600	0.4257		
Respondent_27	0.4008	0.5064	0.0802		x

As can be seen in total there are two non-loaders and seven confounders. It was decided to exclude the non-loaders from the analysis. These sort will thus not be taken into account when analysing and interpreting the factors. For the confounders it was decided to take them into account for analysing and interpreting the factor on which they load the highest. In table 50 the sorts which will be taken into account for analysing and interpreting of each factor are represented.

table 50: sorts per factor

factor 1	factor 2	factor 3
Respondent_1	Respondent_16	Respondent_4
Respondent_2	Respondent_23	Respondent_6
Respondent_5	Respondent_26	Respondent_10
Respondent_7	Respondent_27	Respondent_11
Respondent_9		Respondent_13
Respondent_15		Respondent_17
Respondent_18		Respondent_19
Respondent_20		Respondent_24
Respondent_21		
Respondent_22		
Respondent_25		

J CORRELATION MATRIX

The correlation matrix made by means of SPSS can be found below. In this matrix the correlations between the complexity statements (S1_x) and the Lean and Agile statements (S2_x) are presented. In each cell first the correlation is presented, next the level of significance and thereafter the amount of respondents attributing to this correlation. The grey shaded cells indicate the significant correlations. A correlation is assessed as significant when $\rho \leq 0.05$.

table 51: correlation matrix

	S1_1	S1_2	S1_3	S1_4	S1_5	S1_6	S1_7	S1_8	S1_9	S1_10	S1_11	S1_12	S1_13	S1_14	S1_15	S1_16	S1_17
S2_1	0.234 0.057 67	0.011 0.932 67	0.128 0.301 67	0.413 0.001 67	0.147 0.237 67	0.163 0.186 67	0.073 0.556 67	-0.261 0.079 67	0.120 0.333 67	0.327 0.007 67	0.214 0.083 67	0.235 0.056 67	-0.080 0.519 67	0.216 0.079 67	0.240 0.050 67	0.265 0.030 67	0.248 0.043 67
S2_2	0.340 0.005 67	0.103 0.405 67	0.181 0.142 67	0.485 0.000 67	0.272 0.026 67	0.217 0.078 67	0.019 0.878 67	-0.112 0.365 67	-0.054 0.662 67	0.136 0.271 67	0.105 0.399 67	0.435 0.000 67	-0.332 0.006 67	0.125 0.312 67	0.379 0.002 67	0.376 0.002 67	0.242 0.048 67
S2_3	0.284 0.020 67	-0.273 0.025 67	0.134 0.280 67	0.540 0.000 67	0.235 0.056 67	0.323 0.008 67	0.161 0.194 67	-0.147 0.234 67	-0.116 0.348 67	0.255 0.037 67	-0.169 0.172 67	0.696 0.000 67	-0.561 0.000 67	-0.124 0.318 67	0.303 0.013 67	0.346 0.004 67	0.385 0.001 67
S2_4	0.276 0.024 67	-0.112 0.365 67	-0.064 0.600 67	0.312 0.010 67	0.087 0.482 67	-0.107 0.387 67	0.108 0.383 67	-0.024 0.845 67	0.192 0.120 67	0.171 0.167 67	-1.104 0.403 67	0.244 0.047 67	-0.289 0.018 67	0.119 0.338 67	0.085 0.496 67	0.250 0.041 67	0.126 0.308 67
S2_5	0.076 0.541 67	0.018 0.886 67	-0.059 0.633 67	0.110 0.373 67	0.109 0.379 67	-0.045 0.720 67	0.275 0.024 67	0.081 0.515 67	0.154 0.214 67	0.085 0.494 67	0.026 0.833 67	0.077 0.537 67	-0.032 0.794 67	0.176 0.153 67	0.091 0.464 67	0.115 0.355 67	0.065 0.601 67
S2_6	0.275 0.024 67	0.165 0.183 67	0.014 0.913 67	0.268 0.028 67	0.155 0.211 67	0.123 0.320 67	0.229 0.063 67	0.337 0.005 67	0.149 0.229 67	0.065 0.599 67	0.121 0.331 67	0.080 0.520 67	0.034 0.786 67	0.158 0.201 67	0.367 0.002 67	0.397 0.001 67	0.152 0.220 67
S2_7	-0.038 0.758 67	0.162 0.191 67	-0.037 0.765 67	0.027 0.826 67	-0.037 0.767 67	-0.056 0.655 67	0.014 0.911 67	-0.047 0.705 67	0.002 0.990 67	0.015 0.906 67	0.025 0.842 67	0.033 0.792 67	-0.054 0.664 67	0.071 0.567 67	0.160 0.195 67	-0.091 0.463 67	0.191 0.122 67
S2_8	0.046 0.711 67	-0.040 0.745 67	0.109 0.381 67	0.202 0.101 67	0.035 0.780 67	0.002 0.987 67	0.297 0.015 67	-0.017 0.889 67	-0.104 0.404 67	0.170 0.169 67	-0.109 0.381 67	0.458 0.000 67	-0.105 0.399 67	-0.017 0.894 67	0.222 0.071 67	0.050 0.687 67	0.541 0.000 67
S2_9	-0.004 0.976 67	0.046 0.711 67	-0.044 0.724 67	0.195 0.114 67	-0.007 0.953 67	-0.082 0.510 67	0.209 0.090 67	-0.143 0.248 67	-0.043 0.729 67	0.121 0.329 67	0.029 0.817 67	0.179 0.148 67	0.089 0.474 67	0.154 0.215 67	0.229 0.062 67	0.026 0.833 67	0.225 0.067 67
S2_10	-0.055 0.656 67	0.127 0.306 67	0.081 0.517 67	0.357 0.003 67	-0.001 0.996 67	0.166 0.179 67	0.029 0.815 67	0.166 0.180 67	0.160 0.195 67	-0.085 0.492 67	0.171 0.167 67	0.203 0.100 67	0.077 0.535 67	0.255 0.037 67	0.305 0.012 67	0.100 0.423 67	0.191 0.121 67
S2_11	-0.100 0.421 67	-0.105 0.396 67	-0.117 0.345 67	-0.067 0.589 67	-0.125 0.318 67	-0.128 0.302 67	0.207 0.092 67	0.109 0.378 67	0.251 0.041 67	0.065 0.603 67	-0.085 0.493 67	-0.032 0.799 67	0.215 0.081 67	0.037 0.765 67	-0.087 0.482 67	-0.232 0.059 67	0.083 0.505 67
S2_12	0.053 0.671 67	0.034 0.784 67	0.218 0.077 67	0.355 0.003 67	0.241 0.049 67	0.146 0.239 67	-0.054 0.664 67	0.159 0.198 67	-0.125 0.314 67	0.029 0.815 67	0.191 0.121 67	0.279 0.022 67	-0.402 0.001 67	-0.098 0.429 67	0.170 0.168 67	0.103 0.409 67	-0.004 0.977 67
S2_13	0.096 0.441 67	0.105 0.399 67	-0.117 0.345 67	0.292 0.016 67	0.128 0.303 67	0.169 0.171 67	-0.182 0.142 67	0.195 0.114 67	0.113 0.364 67	-0.035 0.777 67	0.340 0.005 67	0.157 0.204 67	-0.224 0.069 67	-0.080 0.519 67	0.093 0.452 67	0.209 0.090 67	0.066 0.598 67
S2_14	0.129 0.297 67	-0.036 0.772 67	0.218 0.077 67	0.356 0.003 67	0.227 0.064 67	0.227 0.064 67	0.088 0.480 67	-0.066 0.596 67	-0.124 0.318 67	0.371 0.002 67	0.126 0.308 67	0.438 0.000 67	-0.233 0.058 67	-0.084 0.497 67	0.086 0.490 67	0.026 0.834 67	0.370 0.002 67
S2_15	0.080 0.520 67	-0.091 0.466 67	-0.009 0.941 67	0.210 0.088 67	0.039 0.756 67	0.083 0.504 67	0.182 0.140 67	0.098 0.431 67	-0.225 0.068 67	0.148 0.231 67	0.010 0.939 67	0.199 0.107 67	-0.105 0.398 67	-0.208 0.091 67	0.065 0.601 67	-0.010 0.939 67	0.123 0.322 67