

Lean Philosophy in Large Infrastructure Projects

Creating a Lean Maturity analysis tool for Large Infrastructure Projects

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**A4all**

Combination A4all

(Boskalis BV/Heijmans Projecten BV/

KWS Infra bv/Hattum en Blankevoort BV/Vialis BV)

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EXECUTIVE SUMMARY

In 2011 the construction sector was hit hard by years of economic crisis. The sector experienced numerous layoffs and bankruptcies, declines in sales and profit, and large depreciation, according to Figures released by CBS and large construction companies like BAM, Heijmans, Ballast Nedam, VolkerWessels and Dura Vermeer (König, 2012).

The large players in the construction industry remained calm in times of crisis, but the order books were shrinking. The top 50 lost 2.7 billion euros in revenue in 2009 and another 1.4 billion euros in 2010, amounting to a total revenue loss of over 4 billion euros in just two years (König, 2011). Due to the economic decline, the competition for new construction contracts was growing between construction companies. There was a widely shared belief that the development of large-scale infrastructural projects should be carried out far more efficiently in the Netherlands (Commissie Elverding, 2008). As a result of high failure costs, combined with the growing competition and the introduction of several initiatives aimed at improving efficiency, quality and productivity, construction companies were forced to rethink their production processes.

Miller & Dorée (2008) argued that construction companies were confronted with different ‘rules of the game’ than they had been used to. As a consequence of the use of innovative contracts, Rijkswaterstaat (RWS) was not only concerned with cost. Other factors, such as the quality of the product, sustainability and the logistics plan, were also important considerations in the decision making process. Nevertheless, cost reduction and shortening the lead time of projects would remain one of the main challenges for the project management of Large Infrastructure Projects (LIPs). With these changing market conditions in mind, a closer examination of the complexity of large-scale infrastructure and the possibility of applying new approaches such as Lean Philosophy was needed. Lean Philosophy had gained popularity due to the possibilities it promised to offer to respond efficiently and effectively to changing markets.

The objective of this research was to assess if and how Lean Philosophy could be applied to road construction in general and LIPs in particular. If this research were to demonstrate that, unlike the manufacturing industry, LIPs cannot benefit from Lean Philosophy, then it would be necessary to discover exactly which disruptive elements, or failure factors, were responsible and whether there were components that could add value to LIPs.

The basic theory about Lean is based on analysing sub-processes to determine how the Lean process should be structured. This did not have the expected outcome, due to the fact that it was not a just a matter of sub-processes, but rather of the organisation as a whole. The organisation as a whole needed to be mature enough in order to implement the individual Lean processes.

As a result, the main research question had to be re-formulated.

Main research question and sub-questions:

To what extent can Lean Philosophy be applied within a LIP and is it possible to create a research model as a management tool that can have added value for LIPs?

- a. Based on the literature, what could be the added value of Lean for LIPs?*
- b. What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?*
- c. What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?*
- d. To what extent can the Lean Maturity of A4all be characterised?*
- e. Is it possible to convert the lessons learned into a set of recommendations for future LIPs?*

This thesis investigated how Lean Philosophy may be applicable to LIPs, and whether the Lean Philosophy theory could be applied to LIPs in general, and the A4all project in particular. The Lean Philosophy theory, methods and techniques were assessed in practice. The starting point was a Lean Maturity assessment of the A4all organisation.

The literature review revealed that Lean has its origin in the manufacturing industry.

Taking the above as a starting point, it was important to take the different characteristics and the main factors into account. The improvement potential of the LIP organisation could be found in particular in the redesign of its own processes, with the emphasis on efficiency.

Lean management in the manufacturing industry, however, could not be copied directly to (LIP) construction, as the two sectors differed too much. Lean Philosophy was born out of best practices and was only later described in scientific theories, which was common in the field of production methods. In addition, Lean was often used in the production sector and there was a lot of information available.

If Lean Philosophy were to be applied directly, and without any adjustments, to LIPs, a problem would arise, because Lean is based on cyclical process steps, while in LIPs, construction is usually one-off and site specific.

For Lean within LIPs, at the time that the literature review was performed (2013), the amount of information available about Lean within LIPs was quite limited. Not only was the amount of available research limited, there was no proven theory distilled out of existing and successful LIPs. This was due to the complexity, variety and uniqueness of each individual LIP. In short, there was no learning curve directly drawn from examples from practical descriptions.

A production process is an internal process that can be analysed, but a LIP is an internal process made up of semi-external processes, namely the processes of each individual organisation that participates in the LIP. This was also observed during the analysis of the A4all case study. In case of the A4all, there were too many external factors and ad hoc problems that affected the (individual) sub processes.

In conclusion, although Lean was not directly applicable, and while most profit can be made in the sub-processes, Lean could be of added value for LIPs.

What does the model look like and how do the component interrelate? Lean is about doing what matters, by stopping processes that do not add value. Processes that do not add value are wasteful. Hence, in any Lean model, it is important to first look at the 5 Key Principles of Lean and only then look at the 8 Types of Waste. Because process optimisation recognises diverse stages of maturity from structuring to customer-oriented innovation, each phase also implies an associated degree of organisational maturity. By taking this in account, the chance of a process optimisation process succeeding is considerably higher because the organisational boundary conditions are sufficiently present. It is therefore important to keep an eye on the organisational implications when you want to take the next step in the process maturity.

In its original state, the model could not be directly applied to LIPs, since each participating organisation within the consortium had its own 5 Key Principles of Lean, 8 Types of Waste and Lean Maturity. That is why it was crucial to first determine the degree of Lean Maturity of the consortium as an independent entity. For example, the core business of one of the participating companies was delivering sand, that meant that delivering large amounts of sand quickly, was an optimised Lean process within this particular company. However, in practice this lead to waste within the consortium.

The A4all was a LIP, because it had all the characteristics described in the literature: Colossal, Captivating, Costly, Controversial and Complex. The specific characteristics are described in Chapter 3.

In order to use the model, we gratefully used the organisation analysis model by McKinsey to look for the value, waste and Lean Maturity of the A4all as a project.

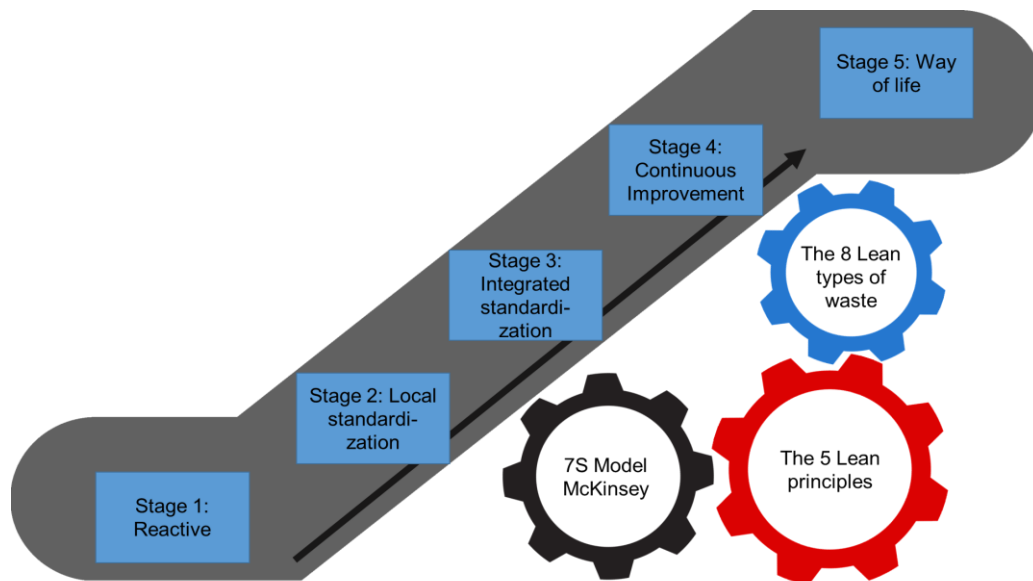


Figure 1: Lean maturity analysis tool for LIPs

In the A4all project, processes were illogically interrupted as a result of a poorly designed workplace, technical malfunctions and poorly designed processes. This led in turn to the re-describing of processes and extra quality inspections, due to the lack of a clear mission, vision and project objective. More attention to the interaction with stakeholders within the project formulation process, more attention to the formulation of the project, and reformulation of the project's objective could add value, thereby removing the problems that frustrate the implementation of Lean Philosophy.

However, it should be noted that, on a sub-process level, the repeating processes are lean and improved noticeably every time they were performed. One example was that of pile driving. As the team became more attuned to one another, the pile driving became noticeably faster. The processes of supplying the piles, setting up the equipment and the collaboration of the team became more optimally attuned. In addition, there were a few problems that occurred during the project that were dealt with quickly, decisively and leanly.

Overall, this research came to the conclusion that Lean as a philosophy was a model that was applicable, but demanding with regard to the participating organisations within the LIP. Based on the theory, it became clear that Lean Philosophy was applicable to all possible projects, but that LIP management required a completely different approach, collaboration and task maturity. A start condition should be that the participants of the consortium were willing to subordinate their own mission, vision and corporate target to a LIP-specific reformulated mission, vision and corporate target. In addition, a redesign of all relevant organisational and procedural structures, including

those of individual participants, as well as a widespread awareness of what Lean Philosophy meant for all echelons within this one-off uniquely constructed project organisation, were needed.

With the Lean Maturity analysis tool, a management tool was developed as part of this research, the A4all was described in terms of the 7S model, and an investigation was launched into the 5 Key Principles of Lean and the 8 Types of Waste that could be found at A4all. This is illustrated in the model in Figure 1. Future users will be able to ascertain which process steps are required to improve Lean Maturity.

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List of Abbreviations

- LIPs – Large-scale Infrastructure Projects
- A4all - Consortium name for the A4 project
- A4DS - A4 Delft Schiedam

List of Keywords

- Lean Philosophy
- Large-scale Infrastructure Projects
- The 7S Model of McKinsey
- The 5 Key Principles of Lean
- The 8 Types of Waste
- Lean Maturity
- Project management processes

1 INTRODUCTION

1.1 Background

Changing Market Conditions for Large Infrastructure Projects

The construction sector hit hard by years of economic crisis. This sector was characterised by numerous layoffs and bankruptcies, declines in sales and profit, and large depreciation, according to Figures released by CBS and large construction companies like BAM, Heijmans, Ballast Nedam, VolkerWessels and Dura Vermeer (König, 2012).

The large players in the construction industry kept calm in times of crisis. This was exemplified by the fact that there was still no heavy competition between the fifty largest construction companies. The Cobouw 50 (2013) – the Quote 500 for construction companies – reported that 46 of the 50 largest builders from the year 2010 were still on the list in 2013. In 2010, the 50 largest companies booked a profit of 774 million euros and increased their market share, but the order books were shrinking. The top 50 lost 2.7 billion euros in revenue in 2009 and another 1.4 billion euros in 2010, amounting to a total revenue loss of over 4 billion euros in just two years (König, 2011).

Despite the efforts of the Dutch government, the Netherlands was officially in recession since the beginning of 2012. The main reason for the decline in the first quarter was the lack of investments. In 2012, construction investments, in particular, decreased compared to other sectors (CBS, 2012). It is important to mention that this research was carried out in 2013-2014 and the Dutch economy over time was growing again at 1.9% (CBS, 2016).

Although the housing industry was hit the hardest, the decline directly impacted on the construction companies and their other operating sectors. Because of this trend, the construction companies relied heavily on their other building competencies, such as the infrastructure sector, to compensate for their losses in the housing and office industries (VolkerWessels, 2012).

Due to the economic decline, the competition for new construction contracts grew between construction companies. There was a widely shared belief that the development of large-scale infrastructural projects should be carried out far more efficiently in the Netherlands.

As a result of the growing competition and the introduction of several initiatives aimed at improving efficiency, quality and productivity, construction companies were forced to rethink their construction processes. The aim was to use technology and re-engineer construction processes to achieve high quality and an optimum price at a minimum lead time (Kärnä, 2005). Bouwkennis, a Dutch knowledge and network partner for the construction industry, raised another issue in 2012. Construction is a complex sector involving many different parties and sub-processes. Failures occur in the coordination of these processes. The preparation process is often underestimated and too little attention is paid to the feasibility of the design. For many projects, the preparation is incomplete,

which often results in technical adjustments at a later stage. This leads to significant failure costs, which are estimated between 10% and 35% (Flyvbjerg, 2007).

Miller & Dorée (2008) argued that construction companies were confronted with different 'rules of the game' than they had been used to. As a consequence of the use of innovative contracts, Rijkswaterstaat (RWS) was primarily concerned with cost. However, other factors, such as the quality of the product, sustainability and the logistics plan were also important considerations in the decision making process.

In addition to these new contractual forms, stronger competition and the necessity to distinguish themselves from the competition compelled construction companies to look into product and process optimisation (Miller, 2008). In other words, apart from price and quality of work, considerations such as the speed of the work became increasingly important in construction. There were many methods to improve the speed of work for a project, such as technological innovations, innovative construction methods, innovative materials and innovative planning methods.

With these changing market conditions in mind, the next section examines the complexity of Large Infrastructure Projects (LIPs) from the viewpoint of the experts.

Complexity of Large Infrastructure Projects

Among the managerial functions in LIPs, the most important function that brings success to any given process is good planning (Gidado, 1996). However, the complexity of the planning phase of LIPs was expanding, both in a technical and an organisational sense. At the time of this research, an increasing number of different standards had to be met, e.g. with respect to safety and environmental protection (Hertogh, 2008). Moreover, political and societal conditions increasingly influenced the planning process. Citizens and the private sector were becoming more critically involved in the planning phase of LIPs, due to the shift towards more communicative-based processes and the increasing role of private parties (Niekerk, 1999).

Another point of complexity was the large number of stakeholders involved in LIPs. Large construction or infrastructure projects have a wide range of connected stakeholders with different concerns and interests. They each try to influence the shape and progress of the project to a greater or lesser extent (Ward, 2008). Neglecting stakeholder values was considered to be a main source of opposition and resistance to new infrastructure in the Netherlands (Commissie Elverding, 2008). A new way of dealing with stakeholders' values was needed. Stakeholders therefore needed to be actively involved (Ensering, 2000).

Another problem for LIPs was the high percentage of cost overruns. Research by Skamris and Flyvbjerg (1997) found an average construction cost overrun for completed projects of 14%, ranging from 10% to 33% (Cantarelli, 2010). Skamris and Flyvbjerg identified three common causes of cost underestimation in projects: price rises, incompleteness of estimations and adjustments to the projects. Comparative research further showed that LIPs in Europe shared a set of characteristics, not only with regard to complexity, scale, number of people, size of budgets, long lead times and the

number of stakeholders, but the major impact on environment and nature was also comparable (Hertogh, 2008).

Uncertainties in LIPs are a common problem. In many projects, particularly large ones, key performance issues are often related to uncertainty introduced by the involvement of multiple parties and the associated project management infrastructure, rather than technology-related issues. An evident uncertainty factor in any project is the estimates of potential variability in relation to performance measures like cost, duration, or quality of particular planned activities. For example, we may not know how much time and effort will be required to complete a particular activity (Atkinson, 2006). “The quality of planning is seldom shielded when projects are bigger and more sophisticated. Work flow is often interrupted by various uncertainties. One of the biggest categories of uncertainties that has been recognised are the discrepancies between anticipated and actual resource/information availability. When certain types of resources (such as manpower, materials, equipment) or information (such as 3d drawing, specifications, change approvals) are missing, current construction work generally cannot proceed until the missing resources or information are available. If such occurrences happen frequently and cannot be effectively controlled, the reliability of the planning would have been severely compromised” (Chua, 2012, p. 2). An additional problem is that LIPs are unique in their kind. Therefore, insufficient evaluation material was available or shared in order to learn from similar international projects (Hertogh, 2008).

To conclude this section, it appeared that there was a large amount of waste in complex LIPs. With this assumption in mind, the question arose what management method could improve the processes and thereby decrease the waste in LIPs. A possible philosophy to help with answering this question was Lean Philosophy, which was introduced in the construction industry in recent years (Ballard, 1994). Its aim was to work more efficiently by tackling the inherent flaws in traditional management practice and reducing waste in the work flow. What experts expected to achieve with Lean Philosophy will be discussed in the next section.

Lean Philosophy

Around the middle of the twentieth century, the Toyota factory in Japan developed a new management philosophy that combined the benefits of handicraft production and mass production. Lean manufacturing made it possible to manufacture cheap and high-quality products that only demanded “half the human effort in the factory, half of the production site, half of the investment tools needed, and half the numbers of hours for the development of a new product” (Womack, 1990).

This philosophy was quickly adopted by other industries that were looking for a more efficient and effective way of working and variations of the Lean Philosophy blossomed over the years (Womack, 2003). However, Lean Philosophy in car production was not easily copied to the construction sector, due to the differences between the sectors. According to Koskela (2000), there were three distinguishing features of the construction industry:

1. The uniqueness of every project and that the conceptual product is also the end-product.
2. Every project has its own location with the associated risks and logistical challenges.

3. Temporary organisation consisting of multiple parts (a so-called multi-organisation). Various companies combine forces for the project and when the project is finished, the companies each go their own way.

However, according to Forbes (2010), it was possible to derive benefits when Lean Philosophy was implemented into construction processes. Possible benefits included lower costs, fewer delays, less uncertainty, less waste, more efficient building/facilities and higher user satisfaction. This approach became known as Lean Construction (Koskela, 2000).

Lean Construction differed from traditional construction on two points. Where traditional construction was aimed primarily at conversion (from input to output), Lean Construction focused on the flow of information and materials, as well as value generation for the customer (Abdelhamid, n.d.; Ballard, 1998; Forbes, 2010).

There was, however, also some critical literature about the blanket implementation of Lean (Construction) Philosophy (Green, 1999). Green stated that implementation of the Japanese methodology, because of cultural differences, might not always be the best solution for a Western organisation. Furthermore, it is important to note that most of the existing literature on Lean Construction was based on the construction of houses. Not much literature was available about the implementation of Lean (Construction) Philosophy in LIPs.

With the aforementioned objections in mind, this research focused on the question whether Lean Philosophy can be applied to LIPs.

1.2 Research Problem

Lean Philosophy proved to be successful in the automotive industry, with many positive results, including increased profitability and a higher level of quality (Womack, 2003). But whether Lean Philosophy might (also) be applicable to road construction in general and LIPs in particular remained to be seen. If it was found that Lean Philosophy was applicable to LIPs, it would be essential to discover the success factors that enabled improvements in performance. However, only limited empirical scientific research had been conducted on the effectiveness and efficiency of Lean Philosophy in road construction. Over the past two decades, however, the theoretical literature regarding expectations on this topic had grown significantly (Arian, 2011; Cantarelli, 2010). If this research were to show that Lean Philosophy was not suitable for LIPs, then it would be prudent to find out precisely what failure factors were responsible, and whether there were any components of Lean Philosophy that could add value for LIPs.

Basic Lean theory deals with structuring the Lean process and analysing sub-processes. The theory did not have the expected outcome. This was due to the fact that the organisation as a whole needed to have sufficient task maturity in order to implement the individual Lean processes.

1.2.1 Problem Analysis

When summarising the main problems mentioned in the previous pages, it became evident that LIPs struggle with finishing a project on time and within budget. Lean Philosophy could be an interesting management tool to improve processes and was proven to have positive effects on manufacturing companies and even on the construction of houses. A review of the existing literature indicated that Lean Philosophy could also contribute to LIPs, but there was no evidence in the literature to validate this statement. In order to apply Lean within a LIP, a tool was needed that could evaluate both the LIP as a whole and the individual sub-processes and projects.

A key objective of this research was to make a positive contribution to science and society by sharing knowledge of what had been learned about the applicability of Lean Philosophy, particularly in terms of management and organisational aspects that could ensure effectiveness and efficiency within LIPs.

For the A4all consortium and any future participants of LIPs, a management analysis tool - that compiled potentially useful components - offered an opportunity to optimise the processes. The following research question was therefore formulated.

Main Research Question:

To what extent can Lean Philosophy be applied within a LIP and is it possible to create a research model as a management tool that can have added value for LIPs?

Firstly, a solid understanding of the basics of Lean Philosophy and what a LIP entails was needed. Once this had been established, it was essential to describe how LIPs compare to organisations/projects to which Lean (Construction) Philosophy had successfully been applied in the past.

Secondly, the question arose as to whether Lean could be used in LIPs and how it would need to be implemented. To answer this second question, this research sought to determine which elements of Lean might be applicable to LIPs.

- a. Based on the literature, what could be the added value of Lean for LIPs?*
- b. What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?*
- c. What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?*
- d. To what extent can the Lean Maturity of A4all be characterised?*
- e. Is it possible to convert the lessons learned into a set of recommendations for future LIPs?*

1.3 Research Objective

The main goal of this research was to develop an analysis model to determine whether and how Lean Philosophy would be a suitable management tool for Large Infrastructure Projects and for A4all in particular.

Social and Scientific Relevance

This research is socially relevant as the costs associated with waste in large-scale projects could potentially be enormous. Moreover, the lead time of major infrastructure projects often is long. Many years tend to pass between inception and realisation; assuming that the need and usefulness for a product was identified several years beforehand, it means that society has to wait many years to benefit. In addition to the high social costs (traffic jams and stagnations on the road), the actual material costs increase with each stagnation that follows.

From a scientific point of view, the added value of this research was a more concrete understanding of the application possibility of Lean in the construction industry. Lean Philosophy was gaining popularity and the literature predicted it could bring about big positive changes in more industries than just the manufacturing industry.

Although the value of Lean production management in the automotive industry had been demonstrated (Koskela, 2000), in many other sectors this had not (yet) been established. These other sectors include road building and the construction sector. In the past few decades prior to this research, there had been many studies into the implementation of Lean production management in the context of construction (Koskela, 2000). When this research commenced, it could only be stated with certainty that Lean Philosophy had had a positive impact on the automotive and manufacturing industries (Koskela, 2000). The starting point in this research was that Lean Philosophy could also make a positive contribution in other sectors. This assumption was put to the test in this research. It was the aim of this thesis to develop a tool that would allow managers to assess added value of Lean Philosophy in LIPs.

1.4 Research Approach

In order to answer the research question, the research was broken down into a few sequential steps. Firstly, a literature research was conducted to answer *sub-question a. Based on the literature, what could be the added value of Lean for LIPs?* Before the A4all interviews were carried out, a desk study was conducted, which focused on three subjects: **a.** LIPs in general, **b.** Lean Philosophy, and **c.** the degrees of Lean Maturity which could be reached. The potential effects of Lean Philosophy on Large Infrastructure Projects were considered, and taking these expected effects into account, the question of how this philosophy could be implemented in LIPs was investigated. To help answer this question, the A4all case was the chosen research object. The A4all case was studied in-depth to examine how Lean Philosophy could be implemented in LIPs.

The research methodology for the A4all case study was both qualitative and quantitative (Creswell, 2014). The initial phase of the research consisted of a desk study. In this phase, relevant information based on literature and existing documents was collected. This phase was followed by a round of interviews with all employees at the locations. To ensure that one methodologically sound system was applied from which valid conclusions could be drawn, the framework of the interviews and the literature review were recorded. The first round of interviews revealed upon evaluation that the

questionnaire yielded insufficient information. Based on this evaluation, the final questionnaire was adjusted.

Sub-question b. *What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?* Drawing on existing theoretical knowledge, the Lean Maturity model by Hines was called upon. This model provided guidance regarding the process of optimisation of processes. The model originated in the field of quality management.

Sub-question c. *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?* This question was answered based on the existing literature at the time of the research. The characteristic features that were associated with LIPs were assessed in practice.

Sub-question d. *To what extent can the Lean Maturity of A4all be characterised?* Based on the 7S model, the A4all project was dissected and compared to the Lean Maturity requirements that an organisation should meet.

Sub-question e. and the main research question were answered by a combination of a literature review, a case study and the application of analytical models derived from The 5 Key Principles of Lean, the 8 Types of Waste and the 7S Model by McKinsey.

Our first assumption was that a survey of employees would give sufficient information about the extent to which Lean Philosophy was applicable within LIPs in general and A4all in particular. The research had an additional research question and later consisted of 2 parts.

The research consisted of two parts; a quantitative and a qualitative part. The quantitative part consisted of a survey with pre-structured closed questions. The qualitative part gave insight into the organisational processes based on the literature review and the analytical questions from the McKinsey 7S model.

From analysing the interviews with all relevant employees and from the literature review, an attempt was made to answer the research questions as outlined in paragraph 1.2. The expectation was that a well-designed survey would provide a solid foundation to build on in order to find answers to the sub-questions. The results were disappointing. The most important information that could be learned from the answers was that there was insufficient knowledge about Lean within the A4all project and that Lean awareness was low. After conducting additional research based on the McKinsey 7S model as an analysis tool, it was possible to ascertain the degree of Lean Maturity, making it possible to extract a crude generalised knowledge from the A4all project. A meaningful generalisation was found, which can be included in future projects, not least because the results were compatible with the results for LIPs as found by NETLIPSE (Hertogh, 2008). As stated before, there were no accepted or standardised methods available to successfully analyse LIPs like the A4all project (Hertogh, 2008; Yin, 1994).

1.4.1 Case Selection

An important research strategy to increase the external validity is selecting relevant cases in which to develop an answer to the research question. In this particular research, the A4all project was selected. Due to the size, uniqueness, complexity and unique character it was impossible to find a similar case. There were several reasons why A4all was chosen. A4all sent a significant number of employees to Lean training. The project organisation did this because it believed that the implementation of Lean Philosophy could help improve various processes, including logistics and coordination between the different participating parties, thereby saving money and resources and avoiding mistakes. Secondly, the A4all project had a great social and political impact and the decision-making process of this project had been very long with conflicting interests on national and regional level. Consequently, the A4all project was a top priority for the government. The project finished at the end of 2015 (RWS, 2015). As it was such a comprehensive and recent project, the lessons learnt could be useful for other major mega structural projects.

1.4.2 Thesis Roadmap and Stratification of the Research

Chapter 2 focuses on Lean Philosophy in general. In Chapter 3, Large Infrastructure Projects in general and the A4all project in particular are discussed. Chapter 4 focuses on the A4all case study. The A4all project is examined in this chapter using the McKinsey 7S model. In Chapter 5, the A4all project is scrutinised using the 5 Key Principles of Lean. It also looks at the 8 Lean Waste typologies. After going through the analysis model, the degree of Lean Maturity of the A4all project is determined. Chapter 6 provides reflection, conclusions and recommendations based on the lessons learned.

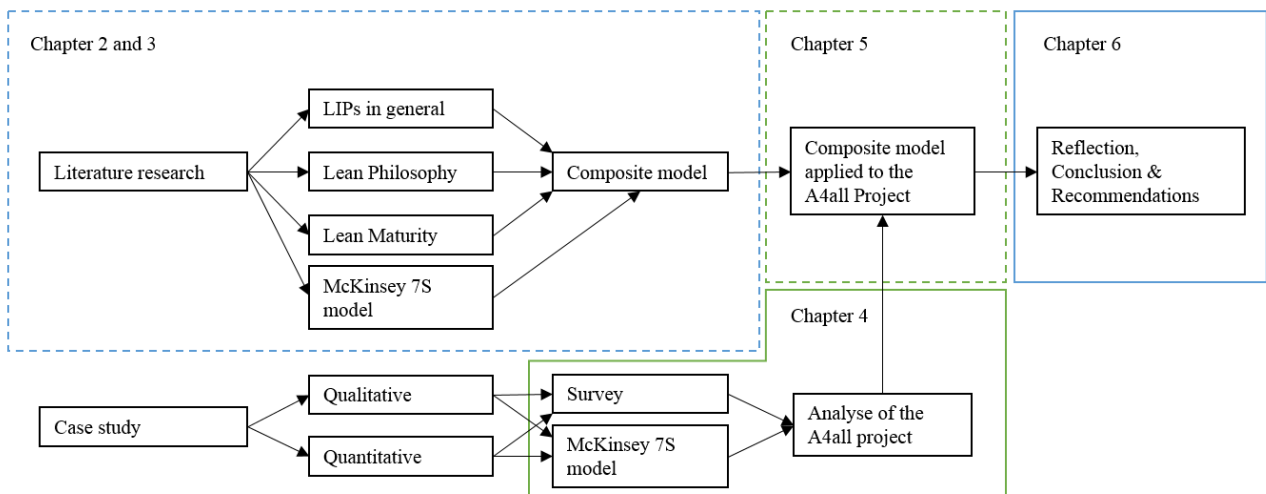


Figure 2: Research approach model

2 LITERATURE REVIEW: LEAN PHILOSOPHY

There is a substantial body of research on Lean Philosophy. Because the roots of Lean Philosophy lie in the mass production sector, most of the literature available at the time of this research focused on manufacturing companies. One variation discussed in the literature on Lean Philosophy was Lean Construction, which was more closely related to LIPs. The literature on Lean Construction focused mainly on the housing industry and the repetitive construction of houses, in which the construction workers learned from each repetition, resulting in a significantly faster building time of the last house compared to the building time of the first house. Unfortunately, the literature on LIPs was scarce. Nevertheless, a framework was provided that allowed for the application of Lean Philosophy to LIPs. Before we could take this step, we first needed to understand Lean Philosophy in more detail.

To create a better understanding, this chapter examines the history and development of Lean Philosophy, followed by an in-depth discussion about Lean Philosophy.

In this chapter, sub-questions a and b will be answered, respectively: *Based on the literature, what could be the added value of Lean for LIPs? and What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?*

2.1 Theoretical Background of the Development of the 'Lean' Production Process

Developments in manufacturing succeeded one another at a rapid pace. While manual production was still the norm at the end of the 19th century, with attention to craftsmanship, this changed in the 20th century to mass production systems with emphasis on high numbers. Halfway through the 20th century, Toyota made the first strides towards the transition to Lean production. Large numbers of manufactured goods were eliminated in this production system. Instead, it created products tailored to customer demand. How was Toyota able to make this transition, and more importantly, safeguard it?

After World War II, the Toyota management visited the Ford plant in Dearborn, Michigan, which at the time was the biggest and most complex manufacturing facility in the world. Back in Japan, they found that Ford's mass production system would not work in Japan. The Japanese automotive industry was too small and diverse, ranging from compact mid-size cars to exclusive luxury vehicles. This was one of the primary reasons underlying Toyota's decision to find an alternative to the successful mass production system. The size of the facilities and necessary equipment were based on the vision of management, as well as negative aspects of the mass production system. Toyota took up the challenge and focused on a completely new mode of production, with attention to development, manufacturing, delivery, assembly and labour. With the start of the development of the Toyota Production System (TPS), the term 'Lean' also originated. Many of the basic principles, however, had been in operation for decades already (Noble, 2017). From the start of the 20th century there had been

attention to increasing efficiency and minimising costs (known as Taylorism/Scientific Management), in which production processes were parsed into small steps (Koskela, 2000).

In the second half of the 20th century people started looking at interpersonal problems within the production lines. The Hawthorne Studies, amongst others, demonstrated that attention to staff increases productivity, but this was not the solution (Wickström, 2000).

The TPS principles were aimed at continuous improvement and respect for the people within the organisation (The Toyota Way). It supported the notion that the right production process would lead to the right products. TPS effectively combined production and logistics within the organisation by taking into account customers and suppliers (both internal and external).

Continuous improvement was often referred to with the term *Kaizen* and was one of the fundamental principles of The Toyota Way. In addition to the small (individual) continuous improvement processes, Kaizen focused mostly on creating a corporate culture, in which continuous improvement was not only accepted, but was also encouraged and propagated by everyone. This could only be achieved by putting people at the heart of the organisation. The word 'people' can be defined as staff or (internal/external) customers and suppliers.

Parallel to this, other theories about flow and value generation gained popularity. According to the flow concept, anything that did not add value should be removed from the process. This included inspections, waiting and/or motion (Holweg, 2017). As a result, according to the theory, deliveries to the customer were faster because there were fewer disruptions in the process. The work should also be simplified (Holweg, 2017).

The main criticism of the flow model was that the model did not take the wishes of the customer into account, but focused only on an internal manufacturing process. The concept of value creation was focused on the customer's wishes and on the production process in the interests of the customer (Koskela, 2000).

2.2 Lean Philosophy

In response to the positive developments at Toyota, the movement that was now called Lean Philosophy received increasing attention (Holweg, 2017). The term Lean Management was used to refer to this interesting production philosophy, in which enormous reduction took place in terms of human effort, space and investment. This was achieved by eliminating waste and adding value (Womack, 1990).

The concept of Lean manufacturing was introduced in 1988 by John F. Krafcik, who was an MBA student at the time at the International Motor Vehicle Program (IMVP) of Massachusetts Institute of Technology (MIT). Shortly thereafter, Womack, Jones, and Roos ensured Lean thinking became widespread through their book *The Machine That Changed the World*.

At the same time, the new philosophy related to creating value for the customer and the company, the need for internal quality assurance within all parts of the production process and increasing effective

cooperation between the subgroups. It attempted to establish a transformation between the output and the wishes of the customer. Finally, the transparency of the process was increased because the intermediate steps were made visible and understandable to all employees (Vargo, 2004).

The importance of the employees had been a topic of discussion from the outset in the scientific literature on Lean production management (Womack, 1990). Employees had a different task description in the Lean production process than in a traditional production process. They had more responsibility, wider knowledge and were expected to work differently (for example, more teamwork, more flexibility and etcetera).

The 'human side' of Lean management in construction work only recently received conceptual attention (Macomber, 2010; Slivon, 2010). There were differences between employees who worked on the basis of Lean Philosophy and traditional employees. There had not yet been an empirical investigation into the exact characteristics that employees needed to possess to function well in an organisation that worked according to the Lean methodology. It was furthermore not known whether these characteristics differed from employees that worked within a traditionally operating organisation. This was notable because it had often been argued in the existing literature on Lean management that, in the end, it was the employees that needed to take on their roles and be involved (Coleman, 1994; Kalleberg, 1989; Keijzer, 2011; Macomber, 2010; Womack, 1990). The existing research focused primarily on the organisations. Ultimately, everything came down to the functioning of people and the work of individuals. The success of an alteration (in this case, Lean Management) stood or fell with the execution by this group (Macomber, 2010; Slivon, 2010).

2.2.1 Lean History

In 2011, Toyota celebrated its 75th anniversary. Toyota was still one of the biggest car manufacturers in the world and even managed to book a 2% profit during the crisis (BNR, 2012). The foundation of this success was laid down in the 1950s. In this period, Toyota implemented a method that rapidly improved its production. Toyota's top manager Ohno was responsible for this success. He reduced, for example, the changing time for dyes from three days to three minutes and eliminated the need for fabric specialists. He also changed the use of enormous lots to the use of small batches. This proved to be another big breakthrough and carried two advantages: problems and errors were quickly exposed and there was no need for an inventory. These two advantages resulted in waste reduction and quality increase (Womack, 1990, p. 53). Another important factor was that Ohno considered the assembly workers responsible for adding value, which is why they were placed high in the ranking. This was completely different in the Western world, where the assembly workers had a lower status (Womack, 1990, p. 57). Toyota had eliminated the inventory and to accomplish this elimination, Toyota's relationship with their suppliers became an essential part of the production process. The logistics needed to be arranged in a highly efficient way, which meant the suppliers had to be integrated into Toyota's organisation (Womack, 1990, p. 57). This approach was called the Toyota Production System. This new way of producing cars was significantly more efficient and became known as Lean. According to Ohno, this was not sufficient - every aspect of the organisation had to become Lean. To

establish this, he wanted to forge a Toyota family where the employees would feel at home, thereby creating a Lean culture. The positive input was palpable; when the dedication of the workers was analysed, it was found that the workers felt they had a higher purpose than working only for their wages (Liker, 2004, p. 73).

“The truly Lean plant has two key organizational features: It transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line, and it has in place a system for detecting defects that quickly traces every problem, once discovered, to its ultimate cause”

(Womack, 1990, p. 99)

This quote by Womack illustrates his vision on Lean and the importance of added value.

2.2.2 The 5 Key Principles of Lean

Lean Philosophy is based on the notion that it is not just the product itself that is being designed, but also the production process around it. In order to produce an excellent product, it is necessary to establish exactly what needs to be made based on the design brief. The production process strongly influences the way a product should be made. Each step in the chain is a prerequisite for the next step, thereby creating a Lean process that strives for optimisation. It is important to pay attention to the entire process chain. It is a management tool that is preceded by a continuously structured analysis, based on which the production process is evaluated and adjusted if needed. Lean management is based on continuously striving for optimum flow in the production chain and maximum added value for the customer, to which everyone in the organisation contributes. This is based on a chain activity that is necessary to develop, produce and/or deliver products or services. If the work in such a chain runs sufficiently smoothly, this will happen with virtually no waste, such as waiting periods or intermediate and final stocks.

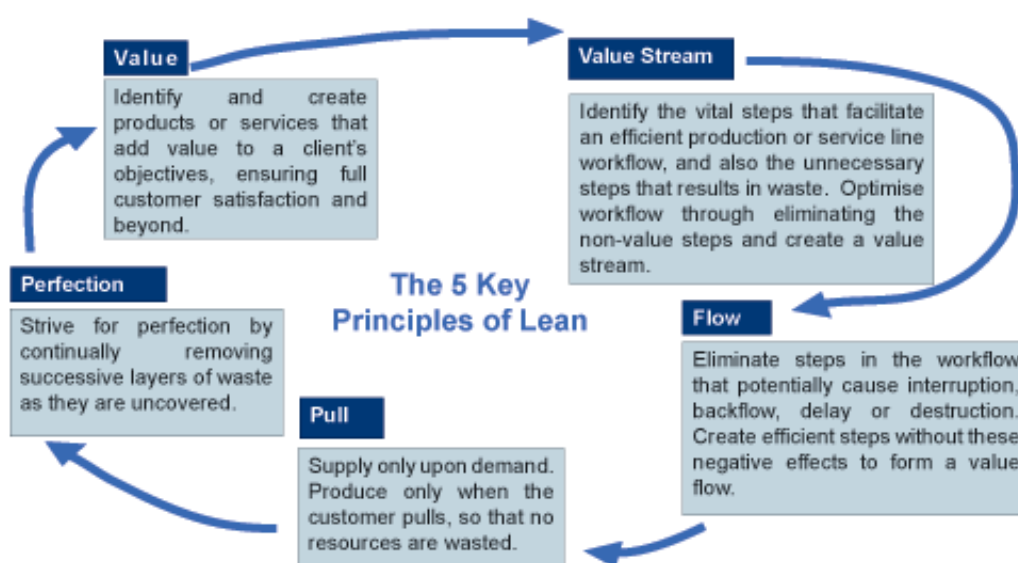


Figure 3: The 5 Lean Principles of Lean (Womack, 2003)

The 5 Key Principles of Lean are explained in more detail in the following sections. It is a continuous improvement process (Kaizen), using the Deming circle (Plan-Do-Check-Act), starting at value and ending in perfection, then restarting the cycle at value. The Deming circle is used in a wide range of quality models (Hamilton, 2014).

2.2.2.1 Value

The book *Lean Thinking* (Womack, 2003) states that value is a key concept. Womack claims that only the ultimate customer can define value and that value is only meaningful when it is expressed in terms of a specific product, which meets the customer's needs at a specific price at a specific time. A product is defined as a good or a service, often both at once. Important factors in specifying value are: consumer, value and product. It is necessary to have a clear overview of what is really needed. Specifying value accurately is the critical first step in Lean thinking (Womack, 2003, p. 19). To create value, the customer has to be treated as part of the organisation. Toyota will be used as an example.

Toyota did not produce cars based on general and global market data and assumptions, but went door-to-door to learn about their own clients. Toyota first sketched a profile of households in different areas. There were frequent visits to various households, where people were asked questions about topics like parking, age, care specification and family size. The collected data was transferred to the development team, where it was used to implement the most appropriate specifications for a new Toyota car model to target a certain client type. When a vehicle was sold, Toyota sold a whole service package with it, from trading in the old car to insuring the new car. Toyota focused on two aspects: the customer was included in the specifications of the car and the customer was seen as an integral part of the organisation. With these services, Toyota created a higher customer commitment (Womack, 2003, p. 182).

The real value added to this car production process came with the face-to-face visits to (potential) customers. The wishes and needs of the customers were presented to the development team, so that the customers' needs could be met as much as possible. This demonstrates that (potential) customers were an integral part of the organisation and were taken seriously by Toyota.

2.2.2.2 Value Stream

To identify the value stream, a set of specific actions is required for a particular product to go through the three critical management tasks of any business. The three tasks are (Womack, 2003, p. 19):

- The problem solving task (e.g. product or service design)
- The information management task (e.g. order processing and other transactional activities)
- The physical transformation task (e.g. converting raw materials into finished products)

For example, a product design that is difficult to build will negatively impact the 'physical transformation' value stream. Furthermore, poor information management from the market will negatively impact the 'problem solving' value stream (Womack, 2003, p. 19).

When the entire value stream for each product or product family is identified, the next step of Lean thinking is established.

2.2.2.3 Flow

When the steps in the process that add value are identified, it is imperative that these valuable steps are selected and aligned without any interruptions or downtime. The only way to smooth out value in a flow is to use valuable activities; in turn, these steps will generate in turn minimal Muda (Womack, 1990, p. 35). In Lean language: actions that add value, including Muda 1 actions, should succeed each other as smoothly and quickly as possible without Muda 2 actions.

“If some problem occurs in one piece flow manufacturing then the whole production line stops. In this sense it is a very bad system of manufacturing. But when production stops everyone is forced to solve the problem immediately.”

Teruyuki Minoura, (Liker, 2004, p. 87).

This statement by the former president of Toyota, Teruyuki Minoura, highlights both the strength and the danger of continuous flow. It is a causal effect. It costs the manufacturers money when the production line stops working, but finding and solving the problems immediately is much more beneficial than encountering bigger problems later in the process (Liker, 2004, p. 87). The steps below need to be followed in order to make value flow (Womack, 2003, p. 52):

- It is essential to focus on the actual object, the specific order, the specific design and the product itself – and to never let it out of sight from beginning to completion.
- Form a Lean enterprise: ignore the traditional boundaries of careers, jobs, roles (often organised according to departments).
- Rethink specific work practices and tools to eliminate backflows, waste, and stoppages of all sorts so that the design, order, and production of the specific product can proceed continuously.

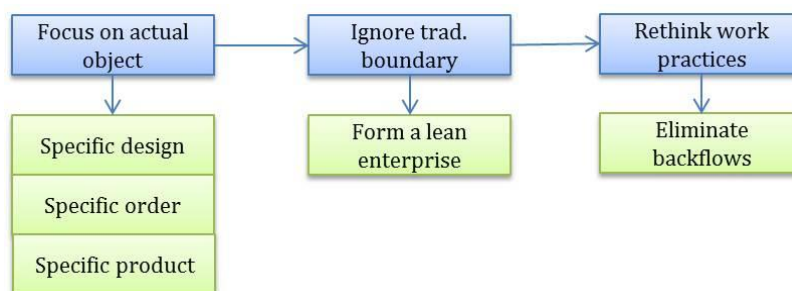


Figure 4: Steps to follow in order to make value flow

In the continuous-flow design, the production steps are arranged in sequence, with *no* buffer of work-in-process in between steps. For this process to work, it is therefore important to establish standardisation of the processes to keep the flow continuous. In addition to the standardisation of processes, it is crucial that the employees, and with them the production team, are cross-skilled.

Should any employee be absent, other employees are able to fill the gap (Womack, 2003, p. 60). When cross-skilled employees are combined with standardisation of processes, optimisation of the value flow steps will occur - see the results in Figure 5: Extended steps flow.

Teamwork is paramount. According to Batt and Doellgast (2010), teams are at the core of Lean management. By using well-trained teams at all levels of the organisation, the natural waste that occurs at a traditional hierarchical organisation can be reduced because team members know each other's tasks and, if necessary, can take over if someone is absent.



Figure 5: Extended steps flow

2.2.2.4 Pull

“Don’t make anything until it is needed; then make it very quickly.”

(Womack, 2003, p. 71)

The next step is to implement a pull system in the organisation to avoid overproduction and to be able to deliver what the customer wants when they want it. Good examples of efficient pull systems are supermarkets. The pull system of supermarkets can be seen as the replenishment of material initiated by consumer needs. One important element of the Toyota Production System (TPS) is *Kanban*. Kanban (literally ‘signboard’ or ‘billboard’) is used as a tool to manage the flow and production of materials in Toyota's pull production system (Liker, 2004, p. 35). Kanban is not an inventory control system; it is a scheduling system that helps determine what to produce, when to produce it, and how much to produce. A useful way to think of pull is that, in the simplest terms, no one upstream should produce a good or service until the customer downstream asks for it (Womack, 2003, p. 67). The process of pull is illustrated in Figure 6, which depicts a Toyota process.

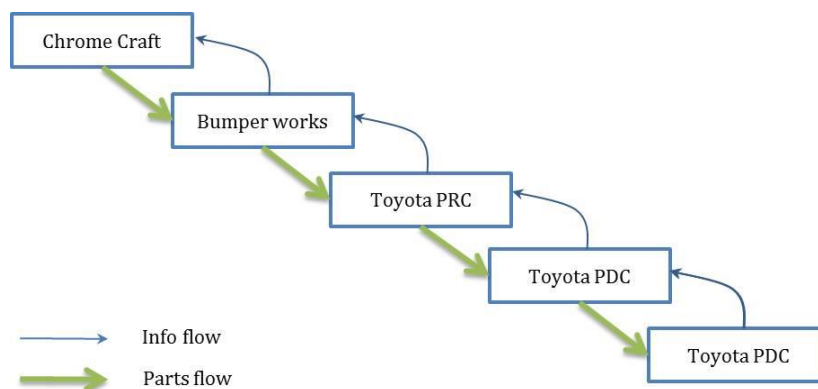


Figure 6: Pull through four loops (Womack, 2003, p. 84)

An important element of this Lean principle is pull planning. As part of this system, the planner starts with the planning of the finished products and then works backwards. Upon analysis of pull planning it is evident that it consists of four stages (Realign, 2012):

- Pre-work: in this phase the conditions and project milestones should be set and a selection of the right people should be in the right place.
- Facilitate the conversation: in this phase interaction between and training of people takes place.
- Follow-up: documentation of the meetings.
- Measuring and evaluating: identification of unplanned work by the planner, planner develops backlog.

2.2.2.5 Perfection

“We view errors as opportunities for learning. Rather than blaming individuals, the organisation takes corrective actions and distributes knowledge about each experience broadly. Learning is a continuous company-wide process as superiors motivate and train subordinates; as predecessors do the same for successors; and as team members at all levels share knowledge with one another.”

The Toyota Way document 2001, Toyota Motor Corporation (chapter 20)

The commitment to perfection is illustrated by the quote above, which highlights the importance of continuous learning in a company. In Japanese this is called *Kaizen*, which refers to continuous improvement and could lead to a Lean organisation optimum. The four steps mentioned in the earlier sections should be in direct contact with each other and hidden waste should be found within the value stream. According to Womack, when the on-going process of perfection is implemented, the Lean aspects can be optimised (Womack, 2003, p. 25). The previous four steps should be analysed by the value stream manager, who is then able to decide where to act first and what waste to eliminate first.

2.2.3 **The 8 Types of Waste**

In addition to the steps to analyse production processes and guidelines, Lean identifies different types of waste. Waste is defined as anything in a company that requires resources but does not add value for the customer. To reduce cost prices this waste needs to be structurally eliminated (ARPA, 2010, p. 28). Traditionally, Lean literature described seven types of waste, but one other type of waste was later added to the list (Emuze, 2016). The eight types of waste are: overproduction, waiting, transport, defects/over performance, inventory, motion/unnecessary actions, corrections/disruptions and unused creativity of employees. For more in-depth information, see Appendix E.

2.2.4 **Lean Methods and Tools**

Section 2.2.2 described the 5 Key Principles of Lean. This section outlines the methods and techniques associated with the processes. Appendix F elaborates on these methods and techniques.

The Lean tools and methods are instruments that support the implementation of the Lean Philosophy and when executed correctly will contribute to a Lean(er) and more efficient organisation (Koskela, 2000). The Lean methods and tools are:

- Value Stream Mapping
- Concurrent Engineering
- Workplace Optimisation – 5S
- Poka Yoke
- Just-In-Time
- Visualisation
- Lean Planning

Koskela (2000) concludes that if just one of these basic components were applied to infrastructural projects, it would yield a positive result and increase profitability.

2.2.5 Lean Construction

The characteristics and history of Lean Philosophy have now been outlined. Lean Philosophy was born out of practice at the same time as several other production methods, and was only later described in scientific theories, which is common in the field of production methods (Buffa, 1961). Most of these 'theories from practice' are only validated in practice and not in academia (Koskela, 2000). To apply the theory of Lean construction for LIPs, the theory needed to be translated in the specific context of large-scale infrastructural construction work. The question is what the characteristics of such construction works are and how these differ from general production. This is essential to consider, because construction is regarded as a specific form of production. Before going into detail about how Lean could be applied to the construction of LIPs, it is first necessary to explore how construction compares to production.

Ballard and Howell argue that construction is a specific form of production (Ballard, 1998; Koskela, 1992). Construction is the design and assembly of objects in a fixed area, and therefore displays certain characteristics. Koskela describes the distinguishing characteristics between construction and production:

- The uniqueness of the product. The uniqueness of the product refers to the fact that, in construction, it is not possible to re-use the output of mass production. This uniqueness is the result of constantly changing wishes from clients, different locations and surroundings, and designers' changing views on the best designs. This shows that production is always related to design (Koskela, 2000).
- Production on location. Site construction is by definition location-based and therefore dependent on local resources and limitations (e.g. quality of the ground, weather and wind effects), which cannot be influenced. The infrastructure of the production process has to be tailor-made for the specific location, and the process moves along the product instead of the product along the process (Koskela, 2000).

- Cooperation of temporary multi-organisations. For one project, different companies and teams, each with their own working methods and (in) experience with cooperation, are forced to cooperate and coordinate work processes and work methods to deliver the final complete product.
- In the construction sector, in contrast to many other manufacturing sectors, the ‘traditional’ craft production prevailed well into the twentieth century (Koskela, 2000, p. 126). Furthermore, some developments were driven by mass-production, e.g. prefabrication and industrialisation. In many ways, these changes have penetrated the nature of construction, but a breakthrough for industrialised construction has not yet occurred (Koskela, 2000, p. 133). Research shows that there is still a large amount of waste and value loss in the construction sector, e.g. delay times, rework, lack of safety, quality costs and unnecessary transportation (Lee, 1999, p. 72).

Combined, these specific characteristics, or peculiarities, of the construction sector are important factors. The uniqueness of the product, the location-based production and the temporary cooperation required between multi-organisations increase the uncertainty, complexity, interdependence, variability, the lack of transparency, the lack of value generation and the lack of quality in the production process (Koskela, 2000, p. 157). The characteristics of the construction sector expose the contra-productive practices that are a greater hindrance than in other sectors. These construction specific characteristics frustrate the process to reach an effective flow and value generation: the flows consist of more variety and complexity (Koskela, 2000, p. 9).

Where Lean Production is focussed on the five continuous principles, Lean Construction is usually one-off, location specific and should eliminate the specific site construction characteristics (Ballard, 1998, p. 7; Koskela, 2000). Products should be more standardised, production should be less location dependent and cooperation between organisations should be better adapted.

Ballard and Howell (2004) suggest that there are four roots of the emergence of Lean Construction as a new approach to construction projects: the success of the TPS, dissatisfaction with project performance, efforts to establish a theoretical background for project management and the failure of traditional thinking and practice to explain facts. The most fundamental difference between Lean and traditional construction is related to scheduling. While Lean Construction is based on a pull work schedule, traditional construction relies on a push work schedule. This is a distinct difference, as a pull system schedule is based on actual downstream demand, while a push system schedule is based on system status (Ballard, 2004).

Production processes can be viewed in three different ways; (1) a process of converting inputs to outputs, (2) a flow of materials and information through time and space, or (3) a process of generating value to the end customer. Until recently, the first view (a production process is a process of converting inputs to outputs) was dominating the construction industry. However, the flow concept is very applicable to the construction industry because production in construction is of an assembly-type, where different material flows are connected to the end product (Koskela, 2000; Ballard, 2004).

The flow principle in particular is important in Lean Construction because it focuses on eliminating non-value adding activities, to ensure a continuous flow of value adding activities (Koskela, 2000).

The more complex the product and the production systems, the more expensive and less reliable they are (Koskela, 2000). According to Koskela, there are four main focus areas within the relationship of construction processes with respect to quality, information available, the organisation itself and finance (Koskela, 2000).

We will now explore the meaning of Lean Construction in relation to *Quality, Information, Organisation* and *Finance* (Aziz, 2013).

Quality: Construction Company

The Lean Construction company could be described as an organisation with a product feature. The construction industry utilises multi-year forecasts to gain insight into the developments regarding the product, the market and the competition. Strategy development is therefore focused on the long term. On the basis of this long-term strategy, the company chooses to aim for a single product market or competency combinations. The construction company is controlled by a marketing oriented management. The emphasis is no longer on the technology, but on the product. The Lean Construction company can be described as an organisation that focuses on the development of new concepts. The proactive hold over the sector stems from the development characteristics of the construction industry. Risks are governed by the specific choice of single product market competency combinations and the repeatability of the developed concepts.

Information: Transparent and Customer Focused

The typical Lean Construction company grows into a responsible company that combines all the different market requirements in business. Efficient in terms of process and quality of the delivered service or products, flexible in creating a specific solution for the end user, innovative in the development of total concepts and responsible in the impact of the construction company on society. The company has a conscious integrity policy and realises that a restoration of confidence in the construction sector is a shared responsibility. Therefore, the company is proactive with regard to social activities. Transparency in business is the foundation for ethical behaviour.

Organisation: Project and Process

The Lean Construction company uses the Lean disciplines to focus on both the customer and the processes. The company operates in the market, using the customer approach strategy, in which the customer is always the main focus, resulting in the best solution for the customer. To provide the best overall solution in the market, it is paramount to improve product properties and remain highly competitive. The Lean Construction company is efficient when it comes to the management and organisation of the internal organisational processes.

The Lean Construction company can be characterised as an organisation that distinguishes itself on the basis of both differentiation and cost characteristics. Cost leadership is related to the control of

the company's own processes, while the idea of differentiation is reflected in the approach to the market. The organisation devotes a great deal of time to the management of suppliers with respect to the execution of a project, having directing and controlling tasks in the process.

With regard to innovation, the Lean Construction company combines process innovation with product innovation based on its role as process monitor. Storage and application of knowledge contribute to optimisation of repeatability of concepts. The Lean Construction company carries the process-based approach to building further, through various forms of cooperation within the chain. To increase the organisational efficacy of the construction process, the best possible solution and a proactive stance with regard to developments in the supply industry are pursued in collaboration with the customer and end users. In consultation with the designer, knowledge of the construction company is introduced at an earlier stage in the process, ensuring quality and efficiency of the entire construction process and increasing the likelihood of decreasing failure costs. In addition, the Lean Construction company seeks alliances to enter new markets.

Lean in Relation to Lead Time

The lead time of the production for the customer is reduced by removing waste from the process using the 5 Key Principles of Lean. The customer will therefore be able to make use of the constructed infrastructure sooner. A short turnaround time also adds value for the company, because the mobilisation of resources is reduced and resources become available for future projects.

Lean and Safety

The second area in which Lean can add value and reduce waste is safety. According to Koskela (2000), safety is an important issue in construction and in other infrastructure projects. The implementation of Lean ensures that there will be fewer useless materials at the site, reducing the risk of falling and related accidents. Standardising and regulating work processes will encourage a better work flow and more careful planning, all of which reduce the risk of accidents, recognising that accidents also lead to waste. In the worst case scenario, an accident will cause a project to be halted. Preventing such a scenario therefore increases profitability (Nahmens, 2009).

Finance: Price and Value

The improvement potential of a company can be found in particular in the redesign of its own processes, with the emphasis on efficiency. The traditional contract is based on quoting the lowest possible price according to customer specification. The improvement potential of the Lean Construction company can be found in the optimisation of both process and product design, with a focus on both efficiency and effectiveness.

2.2.6 Lean Maturity within the Organisation

It is useful to determine the Lean Maturity of an organisation (Maasouman, 2016). Understanding the processes, the interdependencies and the coherence between the processes, could make the difference between successful process optimisations and lagging results. This can be achieved with the model

by Hines (2010). This model consists of five stages at which an organisation can be. Optimising business processes has many dependencies. Insight into these dependencies and how they interrelate can make the difference between successful process optimisations on the one hand and frustration, unhappy customers or divestments on the other. When determining the process improvement strategy, the maturity of the organisation itself as well as the maturity of the processes needs to be considered (McCormack, 2004).

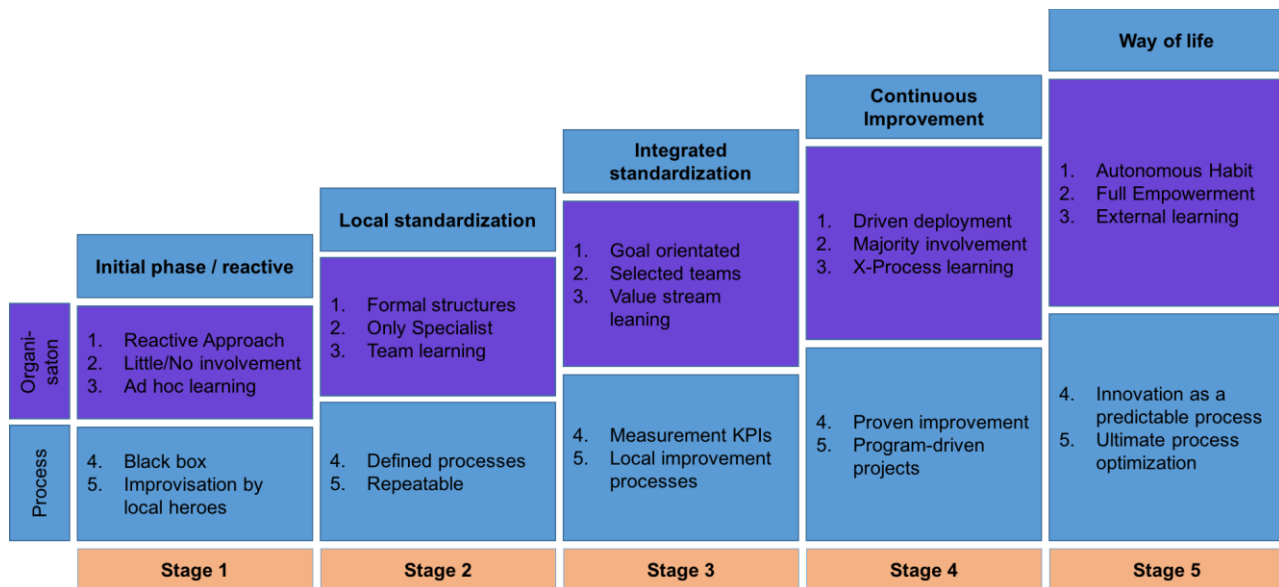


Figure 7: Lean Maturity model (Hines, 2010)

The origin of maturity models is found in the field of quality management. Quality improvements are implemented by means of a five-level maturity grid (Crosby, 1979). Research and surveys have shown that processes have a maturity life cycle and that there is a correlation between improving maturity processes and business performance (McCormack, 2004). In the pioneering phase the work done is mostly ad hoc and unstructured. There are 'local heroes' and the way of working has often grown organically, without standardisation or formalisation. As a result, it is difficult to achieve repeatability and process variation is great. There is no real process optimisation in this phase.

The main goal of this phase is to establish structure and focus within the organisation. Decisions on vision, mission and policy are essential at this stage. Know who your customer is, what they want and what you can bring to the table. Subsequently, it is necessary to identify and evaluate (common sense) processes, thereby enabling repeatability and communicability of the processes. The main issue when making improvements in this phase is recognising the power of the 'local heroes'.

It is likely that they will be resistant when they see their authority dwindle. What is in it for them? Managing resistance is much more important at this stage than mapping current processes.

When recording the processes, it is important to opt for simplicity. It must be communicable and understandable.

In phase 2, processes are described on a local level and repeatability is possible, but there are no company-wide standards yet. To reach a higher degree of maturity, it is first necessary to structure the organisation in such a way that (process) chain control is possible.

In this phase it is possible to start working towards formal structures, starting with recording the existing processes. When implementing chain control, it is essential that the customer's priorities are clear. It is possible to derive from this knowledge which performance indicators the process chain needs. These performance indicators then need to be translated clearly and meaningfully into performance indicators for the sub-processes.

Characteristic of phase 3 is that chain control is possible and that performance indicators are clear and widely respected throughout the process. At this stage, a quality management system such as ISO can be utilised more fully. Key aspects of these quality management systems are: measurement, analysis and demonstrable continuous improvement with a strong customer focus. This also provides a direct link to Lean. In this phase, it is important to establish a 'baseline' for the performance indicators. This will make it possible to identify performance gaps and start targeted improvement projects.

One of the preconditions for the successful implementation of a continuous improvement programme is having the appropriate culture and infrastructure. This has proven to be a stumbling block for many improvement projects as organisational maturity lags behind the process maturity. For example, a company may try to implement the Lean Philosophy without the required organisational structure and commitment from senior management. It is common to see a repeat of the maturity-phasing within a phase. The company may go back to pioneering, to 'dip a toe in the water'. The progression from phase 3 to phase 4 relies heavily on organisational structure and culture. This requires vision, courage, commitment and effort.

There are some organisational considerations when introducing Lean and Kaizen. Lean is strongly project-oriented. To embed Lean firmly in the organisation, the infrastructure needs to be rolled out within the organisation.

Phase 4 continuous improvement programmes have been around for many years. The first improvement programmes started in the 1950s and an increasing number of companies are currently engaged in Lean implementations. All these improvement programmes have a strong customer focus in common. A method that is not commonly mentioned, but fits very well within the continuous improvement principle is *Kaizen*. Kaizen is based on a succession of short-cycle projects, which often take no longer than a week. The act of repetition means the end result is better each time.

The commitment from senior management and the implementation of leadership programmes are essential for the success of this way of working. The aforementioned 'toe in the water' can play a crucial role in the failure of implementing the Lean improvement methodology.

At stage 5, a way of life, there is a strong focus on innovation, which only takes place if the customer wants to pay for it and if the appropriate project can start immediately. In terms of organisational

impact, this means that different departments within the organisation are directly involved in the composition of the project. It is evident that organisational maturity occurs in phases. In other words, the organisation will gradually be formed to enable 'a way of life'. The Lean methodology can be fully utilised to this end.

2.2.7 The McKinsey 7S model

The 7S model is a framework designed by former McKinsey employees Pascale, Athos, Peters and Waterman to measure the quality of a company's performance. The seven 'S' factors are divided into three 'hard' factors (strategy, structure and systems) and four 'soft' factors (style, significant shared values, key skills and staff). In *The Art of Japanese Management*, Pascal utilises this model in case studies that compared American and Japanese companies. Similarly, Peters and Waterman use the model in their book *In Search of Excellence*.

McKinsey developed the 7 factor model. Since all the keywords start with an 'S', it has become known as the 7S model. McKinsey recommends that the interrelationships between organisational factors are maintained (Ragiel, 2001). A successful organisation will review these key factors as if they were compasses that, with a view to effective integration, will all have to point in the same direction. What we see here is a combination of descriptive and normative theory (Bell, 1995).

There is a division between the three hard and four soft factors. The hard factors are strategy, systems and structure. The soft factors are shared values, style, staff and skills.

In an optimally functioning organisation, all aspects of the various factors will correspond to each other. It is therefore important that there is synergy between all aspects and that if the company wants to point to the left, there is not a single factor pointing to the right.

Strategy refers to the analysis of goals set by the company and how they should be reached. In Systems, all conceivable systems are described. These include methods and procedures, as well as communication flows and possibly the deployment of CRM. Structure looks at how the company is organised. It looks at issues like bureaucracy, division of tasks, coordination, accountability levels and overall organisational structure. Placed centrally in the image above are the Shared Values. These refer to a (potential) collective business view. Shared Values are placed in the middle of the model because this is the factor that can provide a direct link between all other factors. The type of corporate culture should be investigated and whether there is a strong team spirit. Is everyone aware of the company's vision and is it being adhered to? Style analyses how management treats employees. Are

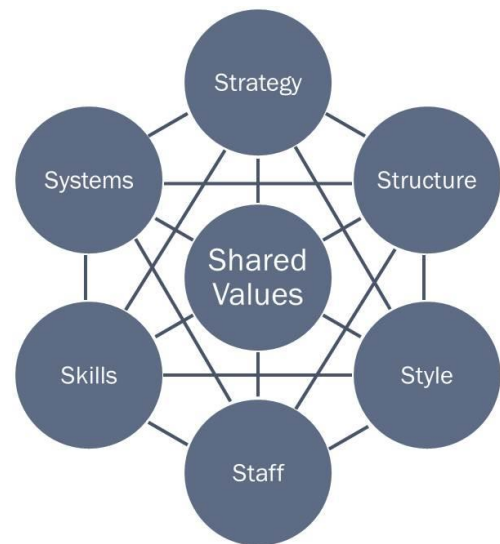


Figure 8: The McKinsey 7S model

there many layers of management or can a staff member from the workshop approach the CEO directly? Is input appreciated, or is everything standardised as much as possible? The method of leadership can significantly affect the working atmosphere. Staff is the beating heart of any organisation. It is therefore important to draw up a profile of all the staff and management. Recruitment and evaluation methods should be reviewed, as well as the reward system and functioning of the staff. Skills are a company's USPs. They are what sets the company apart from the competition. Perhaps the company can offer the fastest delivery, or the best service.

And although there were hundreds of models to organise an organisation, I chose the model of McKinsey, because **a.** It was a widely used analysis model that had proved its worth in practice (Berg, 2015), and **b.** It had a Japanese origin, just like Lean Philosophy.

2.3 Conclusion: Lean maturity analysis tool for LIPs - Answer sub-question a and b

Sub-question a was formulated as: *Based on the literature, what could be the added value of Lean for LIPs?* According to Koskela (2000), Lean Philosophy was gaining ever more attention, particularly in the manufacturing process. By eliminating waste, added value was automatically realised, both for the client and for the company. In terms of manpower, research by Macomber & Howell (2010) demonstrated that only since recently attention was being paid to the importance of employees and which characteristics they possessed in order to work according to Lean within an organisation. This raised the question: Which characteristics were important? However, there was insufficient empirical evidence to answer this question. So what did we know?

Lean consist of 5 principles; from the Value principle we learned that the customer should be treated as part of the organisation. From the Value Stream principle, we knew that every step and sub-process had to be identified and have thorough protocols created for them. A product design that was difficult to build and therefore hard to write down would have a negative impact on the problem solution ability through the Value Stream. Based on the Flow principle, we knew that when a problem arose in the process, the entire production line was frustrated. Well-trained teams were of great importance, because this would reduce hierarchy. The Pull principle taught us what cyclical improvement steps looked like. Based on the Perfection principle, we knew that continual improvement actions were developed from the total number of principles.

The information above taken from the literature was important, because it provided information about the requirements every Lean process needed to meet, including the processes within a LIP. The principles taught us that, if the process steps could be deconstructed, Lean could make a positive contribution. The 8 Types of Waste taught us that waste was defined as anything in a company that required resources but did not add value for the customer.

As construction is a special form of production, as stated in 2.2.5, theory taught us that the 5 Key Principles of Lean and 8 Types of Waste could not be directly applied to the process. The main

difference was that, in a production process, Lean was based on cyclical process steps, while in LIPs, construction was usually one-off and site specific.

Taking the above as a starting point, it was important to take the different characteristics and the main factors into account.

Ballard and Howell outlined the problems a LIP could encounter, but it is worth noting that it would be possible to overcome those problems. Process optimisation recognises diverse stages of maturity from structuring to customer-oriented innovation. Each phase also implies an associated degree of organisational maturity. By taking this in account, the chance of a process optimisation process succeeding was considerably higher because the organisational boundary conditions were sufficiently present. In order to take the next step in the process maturity, the organisational implications would need to be considered.

This would result in attention to eliminating costs from different perspectives, namely: quality, information, organisation, processing time, safety and finance.

In conclusion, Lean was not directly applicable, and most profit could be made in the sub-processes. Knowledge about the 5 Key Principles of Lean, the 8 Types of Waste and Lean Maturity is the foundation for any form of process optimisation.

Sub-question b: *What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?* McCormack (2004) states that Lean Maturity plays an important role, by understanding the dependencies and cohesion of the improvement strategy processes.

The Maturity model was a useful analytical tool in this regard. The model was based on the notion that optimising business processes had many dependencies. Optimisation could be achieved by understanding these dependencies and how they interrelate. In determining the process improvement strategy, the maturity of the organisation itself as well as the maturity of the processes were taken into consideration. To gain insight into Lean Maturity, a tool for analysis was needed. McKinsey provided insight into how coherence between the 7S factors existed. Therefore, the McKinsey 7S model was used to examine the organisation and its processes. The completed keys worked as a compass, a direction indicator for the improvement processes, resulting in a new analytical framework that integrated the models that were discussed.

The outcomes of our theoretical analysis created the model depicted in Figure 9. The three gears set the model in motion. The first step was to analyse the organisation using the 7S Model by McKinsey. Based on the analysis of the organisation the first gear could be filled in. In the second step, the 5 Key Principles of Lean were filled in based on the exercise of the 7S model by McKinsey. The same occurred in the third step, but now the 8 Types of Waste were filled in with information found by using the exercise of the 7S model.

The explanation of the content of the steps can be found in chapters 4 and 5.

Why were these steps necessary? We knew from the theory that an organisation needed to have a degree of maturity to implement Lean. The 1st gear (McKinsey) triggered the 2nd gear of the 5 Key Principles of Lean and the 3rd gear of the 8 Types of Waste. These models combined created an organisational movement that was capable of implementing an optimal workflow, thereby improving Lean Maturity.

What was the relationship between the gears and how did the components relate? Lean was about doing what matters, by stopping processes that did not add value. Processes that did not add value were wasteful. Hence, in any Lean model, it was important to first look at the 5 Key Principles of Lean and only then look at the 8 Types of Waste. Because Process optimisation recognised various stages of maturity from structuring to customer-oriented innovation, each phase implied an associated degree of organisational maturity. By taking this into account, the chance of a process optimisation process succeeding was considerably higher because the organisational boundary conditions were sufficiently present. It was therefore important to keep an eye on the organisational implications in order to take the next step in the process maturity.

In its original state, the model could not be directly applied to LIPs, since each participating organisation within the consortium had its own 5 Key Principles of Lean, 8 Types of Waste and Lean Maturity. That is why it was crucial to first determine the degree of Lean Maturity of the consortium as an independent entity. For example, if the core business of one of the participating companies was delivering sand, that meant that delivering large amounts of sand quickly could be an optimised Lean process within this particular company. However, in practice this could lead to waste within the consortium.

The A4all was a LIP, because it had all the characteristics described in the literature: Colossal, Captivating, Costly, Controversial and Complex. The specific characteristics are described in Chapter 3.

In order to use the model, we gratefully used the organisation analysis model by McKinsey to look for the value, waste and Lean Maturity of the A4all as a project.

In the model in Figure 9 below this integrated process is shown. In this Figure the five stages of Lean Maturity are visualised.

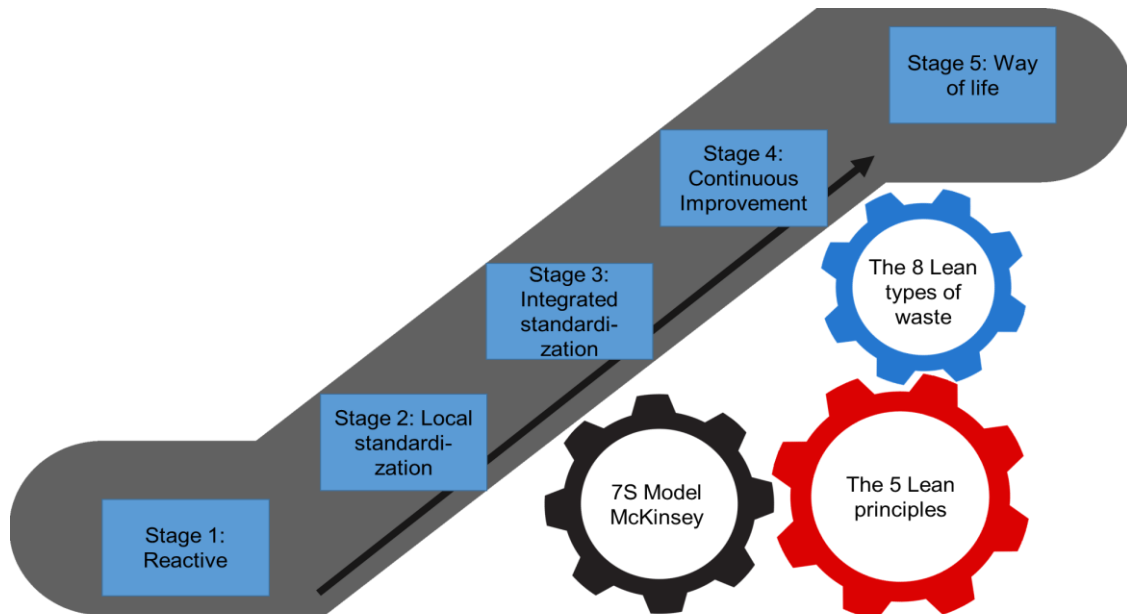


Figure 9: New model that integrates the theories discussed.

With the creation of the model above, it was possible to theoretically answer sub-question b: *What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?* Namely, by applying the new model in the search for improvements, reducing waste, thereby creating value for the LIP as an organisation.

The improvement potential of the LIPs organisation could be found in particular in the redesign of its own processes, with the emphasis on efficiency.

Before the model could be filled in, however, sub-question c needed to be answered first: *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?*

3 LARGE INFRASTRUCTURE PROJECTS

This chapter attempts to answer the sub-question c: *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?* Section 3.2 describes the characteristics and known pitfalls of LIPs. Section 3.3 focuses on A4all as a Large Infrastructure project. The chapter will be completed with a conclusion about Large Infrastructure Projects.

3.1 Large Infrastructure Projects

This section aims to define the term Large Infrastructure Projects and seeks to describe what the common pitfalls are for these LIPs.

As the research focused on implementing Lean Philosophy, it was useful to learn about the common pitfalls related to Large Infrastructure Projects. The existing literature exposed many of the pitfalls that could occur on the difficult journey from the initial conceptualisation to the realisation of large-scale infrastructural projects (Priemus, 2010).

Several characteristics of LIPs were described in the literature (Frick, 2005; Priemus, 2008, p. 3), known as the ‘Six Cs’:

- “**Colossal** in size and scope, whereby there is major facility expansion or reconstruction, which may be a new tunnel, bridge, airport or rail system. These projects are highly visible after construction starts and the public witnesses the monumental endeavours.
- **Captivating** because of the project’s size.
- **Costly**, in that costs are often underestimated and increase over the life of the project.
- **Controversial**, as project participants negotiate funding and mitigation packages, engineering and aesthetic design plans, and pursue construction. Controversy may brew in part because of a project’s potential displacement or impacts to nearby businesses residences and the physical/built environment.
- **Complex**, which breeds risk and uncertainty in terms of design, funding (as project costs are high and often covered by numerous funding sources) and construction.
- Laden with **control** issues related to who the key decision-makers are, what agency/agencies manage/operate the project, and who the main project funders are and what restrictions they put on it” (Priemus, 2008, p. 3-4).

LIPs generally shared the following characteristics (Cantarelli, 2010). The projects are inherently risky because of the long planning horizons and complex interfaces. Technology is often not standard. Decision-making and planning are often multi-actor processes with conflicting interests. Often, the project scope or ambition level will change significantly over time. Statistical evidence shows that unplanned events are often unaccounted for, leaving budget contingencies sorely inadequate. As a consequence, misinformation about costs, benefits, and risks is the norm. The majority of projects suffer from cost overruns and/or benefit shortfalls.

The following section expands on why cost overruns and benefit shortfalls are a problem. Cost overruns and benefit shortfalls of the frequency and size described above are a problem for the following four reasons (Flyvbjerg, 2007, p. 5 - 7):

- They lead to a Pareto-inefficient allocation of resources - that is, waste. Regarding this first point, Flyvbjerg (2007) writes that the following argument is often heard: cost and benefit forecasts at the planning phase could be incorrect. If it is assumed that the forecasts are wrong by the same margin across LIPs, cost-benefit analyses would still be useful for pinpointing the best projects for implementation. According to this argument, the ranking of projects would not be influenced by these forecasting errors. Table 1 shows that this argument is false. The standard deviations demonstrate that the margin of error of the cost-benefit forecasts is not the same across projects, but that the errors vary greatly, which affects the ranking of projects. Policy makers and decision makers are most likely to choose inferior projects because of cost-benefit analyses, which shows that this kind of misinformation about cost-benefits at the beginning of a project increases the likelihood of a Pareto-inefficiency.¹
- This can lead to delays, further cost overruns and benefit shortfalls. Overruns of this magnitude typically lead to delays, as it takes time to secure additional funding. When the overruns are large, it is likely that a project will need to be reapproved or renegotiated.
- This destabilises policy, planning, implementation, and operations of projects. A case in point is the Sydney Opera House. When the Sydney Opera House exceeded several cost overruns, Parliament decided that every increase of 10% cost overrun would need their approval. After this decision, the project became a political football, with increasing debate taking place inside and outside Parliament. The total cost overrun of this project was 1400%.
- The problem is getting bigger, because projects are getting bigger. There have been megaprojects that were so large in relation to the economies of the countries that cost overruns and benefit shortfalls from a single project could destabilise the financial wellbeing of a region or an entire nation. The 2004 Athens Olympics are a case in point. The billion dollar overrun of costs affected Greece's credit rating.

3.2 Common Pitfalls of Large Infrastructure Projects

As described in section 3.1, LIPs shared 7 characteristics. The research below showed that exceeding costs and lead times was a significant problem and that research aimed at curbing the costs or lead times was needed.

One study researched 258 LIPs in twenty countries on five continents to show the inaccuracy of construction-cost estimates measured as the size of cost overrun, see Table 1 (Flyvbjerg, 2007, p. 2).

¹ Pareto efficiency, or Pareto optimality, is a state of allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off (http://en.wikipedia.org/wiki/Pareto_efficiency)

The table showed that the cost overrun for rail projects was 44.7% of the estimated cost. For bridges and tunnels, the average cost overrun was calculated to be 33.8%, and for roads this percentage was 20.4%. A side note to these Figures was that the difference between the three project types was statistically significant and each type should therefore be treated separately.

Type of project	Number of cases (N)	Average cost overrun (%)	Standard deviation
Rail	58	44.7	38.4
Bridges and tunnels	33	33.8	62.4
Road	167	20.4	29.9

Table 1: Inaccuracy of LIP cost estimates by type of project (Flyvbjerg, 2007, p. 2)

The table includes the standard deviations, which is as illuminating as the large average cost overruns. The standard deviations show that uncertainty and risk regarding cost overruns were indeed large. The following observations could be made in relation to cost overruns in LIPs (Flyvbjerg, 2007, p. 2):

- Nine out of ten projects had cost overrun.
- Overrun was found across the twenty nations and five continents covered by this study.
- Overrun was constant for the seventy-year period covered by this study, which meant estimates did not improve over time.

Policy Implications

There were clear policy implications based on the results presented above (Flyvbjerg, 2007, p. 6):

- Lawmakers, investors, and the public cannot trust information about costs, benefits, and risks of LIPs produced by the promoters and planners of such projects.
- Currently, the planning of LIPs is ineffective in conventional economic terms. It leads to Pareto-inefficient investments.
- There is a strong need for reform in policy and planning for LIPs.

3.3 A4all: A Large Infrastructure Project

Was the A4all project a LIP? To find the answer to this question, we checked the A4all case against the literature as described in section 3.1, known as the 'Six Cs' (Frick, 2005).

Since 1960 there were problems with the connectivity between the two Dutch cities The Hague and Rotterdam. It was found that the capacity between the two cities was not high enough for 160,000+ users per day, putting heavy pressure on the existing motorway (A13), making it one of the busiest motorways in the Netherlands. It was also desirable to create an alternative route option in case of emergencies.

Research showed that 96 percent of congestion was caused by structural deficiencies in motorway capacity (RWS, 2011). It was also evident from this study that standards of external safety and road safety were breached increasingly often. The study predicted that continuation of the current situation would increase the problem, which highlighted the urgency of this project.

The project had been delayed for decades, mainly due to the difficult integration of the motorway with the environment/nature and insufficient government funds. Nevertheless, the procedure to actually start building commenced in 1993 and preparations began in 2001. The new infrastructure was to be ready for commissioning at the end of 2015.

*“**Colossal** in size and scope, whereby there is major facility expansion or reconstruction, which may be a new tunnel, bridge, and airport or rail system. These projects are highly visible after construction starts and the public witnesses the monumental endeavours.”*

Rijkswaterstaat would build kilometres of new motorway from Delft to Kethelplein. From Delft, the motorway would be at ground level for approximately 1 kilometre. After that, the road would be semi-sunken for the next 2.6 kilometres. This was followed by 1.4 kilometres of sunken road until it reached the built-up area at Vlaardingen and Schiedam. The motorway would rise up and then go into a land tunnel of 2 kilometres. It would then cross the A4 at the Kethelplein Junction and finally connect to the existing A4 and A20.

The construction of the A4 motorway would improve accessibility between The Hague and Rotterdam. In 2020, 60% more traffic would be able to travel between The Hague and Rotterdam, which would significantly decrease travel time compared to the previous situation. In addition, the network would be more robust, because there would be an alternative route in case of an accident or work on the A13. However, it remained one of the main arteries of the Dutch infrastructure and therefore sensitive to conjuncture. There was no guarantee that there would no longer be any traffic jams. The work started officially in April 2012 and the plan was that the public could use the A4 motorway between Delft and Schiedam in late 2015.

*“**Captivating** because of the project’s size.”*

New connection loops were built at Kethelplein. One existing connection was removed. Approximately halfway through the route an eco/aqueduct of about 100 metres wide was built. An existing tram passage was elevated.

On the A4 motorway between the Kruithuisweg in Delft and the Beatrixlaan in Rijswijk a double layer of porous asphalt was laid and traffic signs were built. Between Kethelplein and the connection to Vijfsluizen, just before the Benelux tunnel, various works were carried out on the existing road.

The A4 could handle approximately 10,000 vehicles per hour (total of both directions). On an average working day, approximately 128,000 motor vehicles per day used the A4.

*“**Costly**, in that costs are often underestimated and increase over the life of the project.”*

The construction of the A4 motorway between Delft and Schiedam cost approximately 600 million euros. That included all associated personnel costs, preparation costs (e.g. land acquisition and diverting cables and pipes) and VAT. At the height of the operations, approximately 1000 employees of both Rijkswaterstaat and the A4all consortium worked on the construction.

Composition	Digging	Replenish/reuse
Soil	960,000	725,000
Sand	1,325,000	950,000
Total	2,285,000	1,675,000

Table 2: Groundwork in m³

The existing top layer had to be replaced, a total of 245,000 m² of asphalt. A completely paved structure on the road bed (incl. land tunnel) of 340,000 m² and (new) engineering constructions of 75,000 m² were built. 125,000 m³ of concrete and 5,000 tonnes of reinforcement was needed for the engineering constructions. The land tunnel was 2000 m and 250,000 m² bentonite cement walls were needed for the sunken construction, with 42,000 m² for the wall structure of the (half) sunken construction. There were three engineering constructions on the A4, plus a 100m ecoduct. There were approximately twenty new engineering constructions at Kethelplein, in addition to widening the six (existing) engineering constructions on the A20 and A4. The noise barriers would have a total surface area of 60,000 m².

*“**Controversial**, as project participants negotiate funding and mitigation packages, engineering and aesthetic design plans, and pursue construction. Controversy may brew in part because of a project’s potential displacement or impacts to nearby businesses residences and the physical/built environment.”*

The A4all project had a long lead time. The first plans dated back to 1953. Actual construction started in 2012 and it was expected that the project would be completed in early 2016. A controversy existed between supporters and opponents over a period of 63 years (IODS, 2012).

*“**Complex**, which breeds risk and uncertainty in terms of design, funding (as project costs are high and often covered by numerous funding sources) and construction.”*

The history of this project spanned many decades. It took many years of negotiation with all the stakeholders. As a result, a complex design was developed that would take the various stakeholders into account as much as possible. High costs, many decision makers and complex operations, combined with a high political sensitivity meant this project could certainly be categorised as complex.

*“Laden with **control** issues related to who the key decision-makers are, what agency/agencies manage/operate the project, and who the main project funders are and what restrictions they put on it” (Priemus, 2008, p. 3-4).*

The A4all general partnership consisted of three large Dutch companies:

1. Boskalis, with a 10% share, had a different specialism than the other two firms and primarily operated internationally. Boskalis focused on groundwork and roads, but to fulfil their 10% share, other aspects were included. These aspects could mainly be found in management, finance and security (A4all, 2011). Boskalis was the official secretary of the consortium.
2. Heijmans, with a share of 45%, was a centralised company and mainly operated nationally. Like Boskalis, the company had several subsidiaries that were involved in the consortium.
3. VolkerWessels, with a share of 45%, was a decentralised company and consisted of more than 130 independent subsidiaries. Each subsidiary had its own specialisation. These companies often worked together on one project. Within this project, Van Hattum and Blankevoort, KWS and Vialis were involved. VolkerWessels was an international company with a focus on the Netherlands, Great Britain and Canada.

In addition, project management had to deal with various stakeholders, including local residents, municipalities, government and environmental organisations.

The aspects that Flyvbjerg ascribed to LIPs and the planning of LIPs, were also applicable to A4all.

The project was risky because of the long planning time, complexity of logistic flows and scale. During the project, problems occurred that could not be solved with standard solutions. Many actors and stakeholders with different viewpoints were involved in this project. The scope of the project changed gradually. After the project started, an amendment meant that the open tunnel had to be regarded as a closed tunnel. This had a substantial impact on the safety standards.

During the project, it became apparent that holes had been drilled in the clay, which was previously assumed to be impermeable to water. The design had to be adjusted and various solutions had to be conceived with different risk and cost scenarios.

- Statistical evidence showed that unplanned events were often unaccounted for, leaving budget contingencies sorely inadequate.
- As a consequence, misinformation about costs, benefits, and risks was the norm.
- The majority of projects suffered from cost overruns and/or benefit shortfalls.

3.4 Conclusion - Answer sub-question c

This chapter answers sub-question c: *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?* The A4all shared all the features as described in the theory (Frick, 2005; Priemus, 2008, p. 3). The A4all tested positive for all 6 Cs: Colossal, Captivating, Costly, Controversial, Complex and Control. According to the literature, 9 out of 10 projects exceeded the cost ceiling, causing major delays. The political context in which the project

was realised also had a big impact. This increased costs and lead time. As a result, the time needed to realise the project was exceeded (3.2). The problems that emerged in the literature also occurred during the project A4all (3.3).

The characteristics from literature theory applied entirely to the A4all project, which showed that this project could indeed be considered a LIP.

4 A4ALL ANALYSED USING THE MCKINSEY 7S MODEL

The second part of the research addressed the sub-question d: *To what extent can the Lean Maturity of A4all be characterised?* The McKinsey 7S model was used to determine to which extent Lean Philosophy might be applicable to A4all, a Large Infrastructure Project. In the sections below, the McKinsey 7S model was applied to the A4all case as an analytical tool in order to prevent relevant aspects of the organisation being overlooked.

The 7S model in this case was filled in based on the way the organisation ended up in the media, its own policy documents, statements in which the consortium informed the outside world about the project, protocols and processes, and own findings.

4.1 Shared Values - The A4all Consortium

'Shared Values' (significant values) - are placed in the centre of the model. They relate to a company's attitudes, beliefs, culture and identity (Mintzberg, 1992). In short: the vision.

The A4all consortium consisted of three major Dutch companies: Boskalis, Heijmans and VolkerWessels (section 3.3).

All three organisations had formulated their own strategy, mission and vision, see Appendix D. This was relevant to know because it meant that the control of the special consortium had three different missions and visions as a starting point.

Conclusion - Shared Values:

A4all was a unique consortium. With all big projects, multiple parties are involved, but every project has its own dynamics. This was the case too, for A4all. The cooperation not only required flexibility, time and space to solve problems ad hoc, but also room for cultural differences. With regard to Shared Values, the conclusion was that there was no common vision, normally formulated in a mission statement. With regard to Lean Maturity, this meant there was no clear direction from mission and vision.

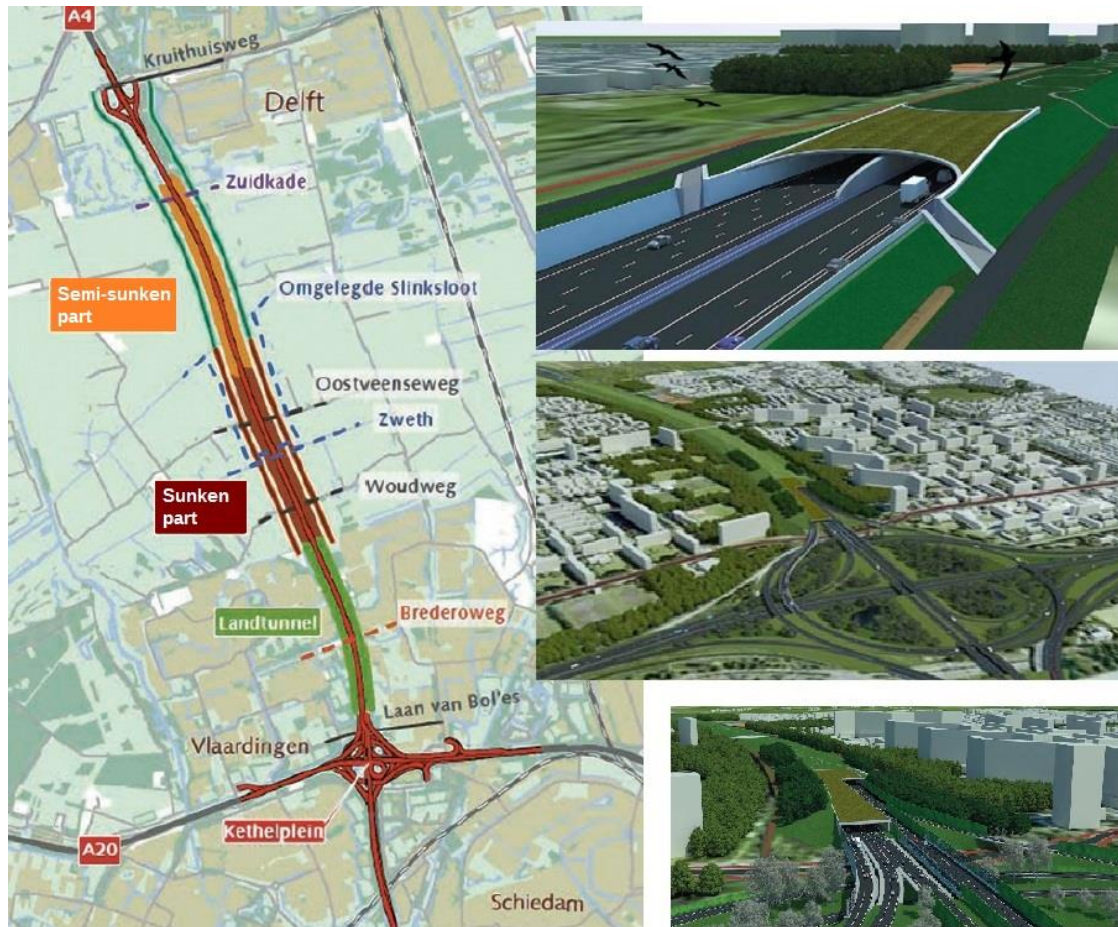


Figure 10: A4 Delft – Schiedam

4.2 Strategy: Project A4all

'Strategy' – indicates the intended actions of the organisation. What explicit targets were set and with what means were they supposed to be achieved? The strategy must be the bridge between the mission statements, that is, the 'raison d'être' of the company, and the hard reality that dictates that with limited resources not all goals can be realised simultaneously. In a strategic plan choices are made and ensures that all parts of the organisation know what is expected of them to contribute to the success of the whole.

The A4all project involved the extension of the A4 motorway. The main objective was to jointly improve the connection between the cities The Hague and Rotterdam and to reduce traffic density on secondary roads (Pols, 2012). The project consisted of a new motorway, 7 kilometres long, consisting of 2.6 kilometres semi-sunken motorway, 1.4 kilometres of sunken motorway, a land tunnel of 2 kilometres, the reconstruction of the Kethelplein junction and maintenance of the connecting sections of motorway (Provincie Zuid Holland, 2000). As part of the integral development with national and local government, nature, recreation and sustainable development of the area were addressed as well.

Rijkswaterstaat assigned this project to the A4all consortium. A4all came up with the most economical and attractive bid, also known as the MEAT method (Most Economically Advantageous Tenders). The project was tendered with a fixed contract price of 300 million euros and had an execution time of 3 years. The completion time was set at the end of 2015 and it was stipulated that, if the term was exceeded, a fine of €250,000 per day would be applied. The contract also provided that the customer had the right to adjust the contract in the interim where necessary (Pols, 2012).

Conclusion - Strategy:

How does strategy translate into Lean terms? Lean theory demands that a clear and unambiguous command joint formulation takes place (2.2.2.1). Strategy turns theoretical goals into hard reality. It is important that all parties know what can be mutually expected from each other. The A4all contract had the provision that the client had the right to adjust the contract in the interim where necessary. If the client decided to exercise this option, changes had to be effected. The fact that the client could add, one sided, specifications and change the contract when wanted/if needed, intervened with the levels of Maturity of the processes. Consequently, in terms of Lean Maturity, level 3 or higher was not feasible with such a practice, see Figure 7.

This meant that no single final unequivocal project assignment was formulated. With regard to Lean Maturity, the consortium had executed a limited goal orientation. As long as the rules of the game could be customised by the client, value stream learning was hard to realise.

4.3 Structure: Organisation of the A4all Consortium

'Structure' – refers to the establishment of the company itself: levels, task division, coordination, as well as line, staff and functional organisation.

The important tender (A4all) was won by the consortium in a so-called 'turnkey' model, in which a private party (or combination of parties) took on the design, financing and construction of the public sector project (Koppenjan, 2005). The consortium partners created the umbrella organisation to undertake the developments, maintenance and/or operationalisation of the infrastructure.

4.3.1 Umbrella Organisation

The umbrella organisation was an alliance of various companies and the project organisation consisting of various disciplines. In addition, the umbrella organisation was responsible for the management of the A4all project, the design, the management of the contract, the supporting activities of the environment and the project. The umbrella organisation maintained contact with the client (RWS). Lean theory was based on the assumption that improvement was formulated based on client demand. A change in the demand changed the scope of the work.

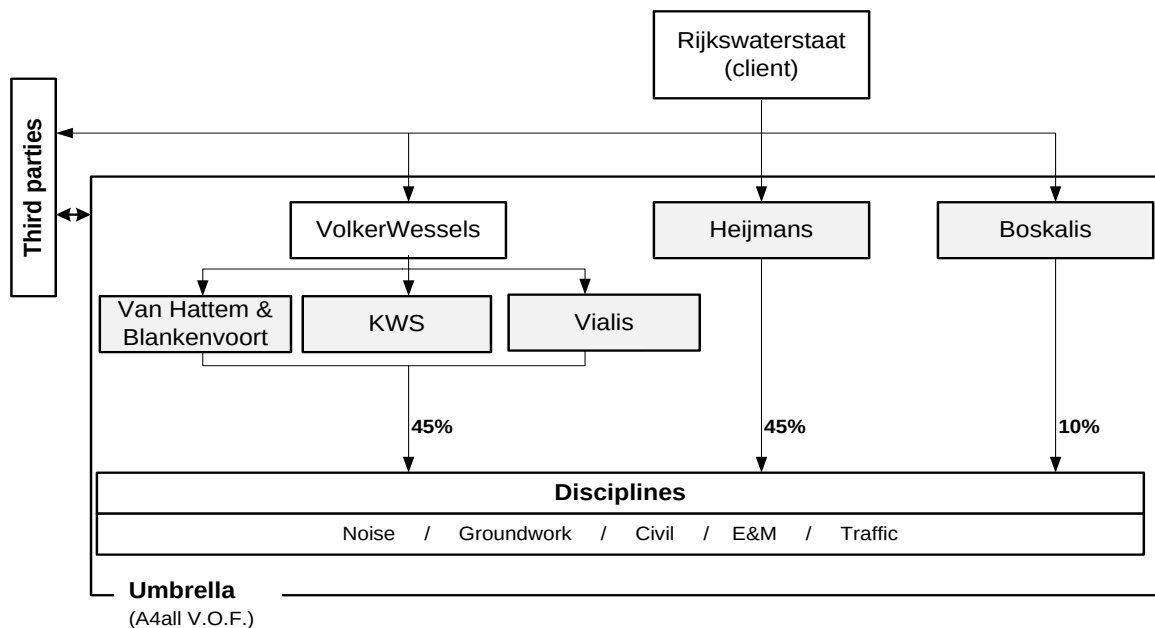


Figure 11: A4all organisation (simple representation)

The individual participating parties were listed and all held leading positions in the Netherlands and abroad. Within the management of the umbrella organisation there was interest in the possibilities of Lean management. This had the attention of the A4all project management, evidenced by the fact that prior to this study, a number (approximately 1/3) of mainly higher educated employees belonging to the umbrella organisation were trained in Lean theories.

4.3.2 Disciplines

The umbrella organisation covered the disciplines. Disciplines operated as separate entities, each with their own goal-oriented activities, which were carried out simultaneously, but with different agendas, interests and needs (Green, 2005).

There was a hierarchical relationship between the umbrella organisation and the disciplines; the disciplines reported to the umbrella organisation and were not in direct contact with the client. Within the disciplines, various subsidiaries of the companies that made up the consortium were active. Each discipline had its task and management, which further complicated the situation (Figure 12: Structure of the disciplines within A4all).

There were five main disciplines within A4all, consisting of (1) noise protection structures, (2) ground and road work, (3) civil, (4) technical installations and (5) traffic. Civil included the sub-discipline foundation, as a considerable amount of work was focused on this.

The umbrella organisation coordinated the extra work and communicated the effects that these changes had with the customer. The discipline estimated the potential effects on the umbrella organisation.

The management team was responsible for the project management plan. The disciplines had to perform according to the plan and were responsible for verification, which included bilateral verification with the other disciplines. The final plan needed to be executed by all disciplines.

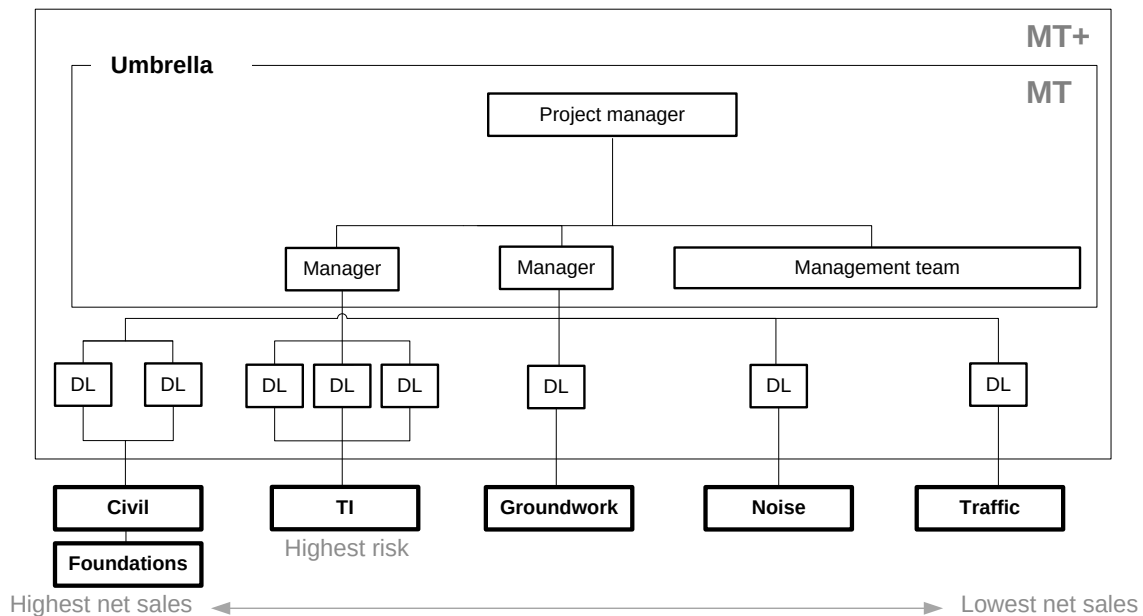


Figure 12: Structure of the disciplines within A4all

The umbrella organisation as well as each discipline should indicate if there was a deficiency and might also – within the given mandate –initiate adjustments.

4.3.3 Third Parties

The umbrella organisation provided its own design with the help of the subsidiaries of the companies involved: Hydronic (part of Boskalis), Volkerinfra Design (part of VolkerWessels) and Breijn (part of Heijmans). Other HR were hired through Fluor B.V., Bosch Slabbers The Hague B.V., IV Infra B.V., Witteveen en Bos Consulting Engineers B.V. and Zwarts & Jansma Architects B.V. (Vos, 2011). It was important to note the number of parties that were involved in the process, because they provided for more possibilities for inter-relational disturbances and could further complicate the project.

Conclusion - Structure:

In Lean theory, the assumption is that the project assignment is uniform and the structure consistent with this. The fact that the disciplines could work autonomously and that third parties were involved, created doublings of structure and bypasses that could thwart the hierarchy. It effectively created a black box and problems were solved improvisationally. This indicated phase one of Lean Maturity because the structure caused a reactive way of working and problems were solved ad hoc by means of improvisation.

4.4 Systems: A4all Processes and Complexity

‘Systems’ – includes all formal and informal working methods, procedures and communication flows, both internally and externally. This refers to all formal and informal procedures, arrangements and agreements. (Mintzberg, 1992, p. 35)

The project A4all could be considered as highly complex, as was already concluded in chapter 3.4 (Hertogh, 2008). It was important to identify the possible problems, because according to Lean Philosophy, mistakes could provide insight into the system to create more effective work processes. The identification of the processes was done by using the Lean Maturity model and the 7S model.

Changes in the scope of the project (made by the client and/or due to unforeseen circumstances) could disrupt the process. These process disturbances involve complications and could cause financial setbacks.

Value stream identifies the important process steps that support an efficient production line or workflow, and aims to find any steps that lead to waste. Value stream assumes that a product design process is an uninterrupted process during its realisation.

The fact that there were problems in the system was discovered when a few of the problems were identified which received media attention. A number of examples shall be elaborated in the following sub-section.

4.4.1 Negative Media Attention for A4all

Groundwater Problem

During an information evening on 17 February 2014, Rijkswaterstaat stated that there was a problem with the groundwater. While Rijkswaterstaat was licensed to pump 450 m³ per day to the Nieuwe Waterweg in Hoogheemraadschap Delfland, it became apparent that more water was rising up at the A4, approximately 1200 m³ of water per day. The biggest leaks occurred in the sunken section near Schiedam. It was not the first time problems occurred during the construction of the A4. For example, a few years before, builders found sand piles, large columns filled with sand that sit vertically in the ground, making the clay layer porous. Partly because of these setbacks in the realisation, the construction of the A4 was some tens of millions euros more expensive than was calculated (Source: Algemeen Dagblad 28 Feb 2015).

The general water board of Delfland called for a structural solution, but it was not found. According to the civil engineers of the A4all crisis team, placing a concrete slab with local anchors could have offered relief. But Rijkswaterstaat found this solution too expensive and was concerned that this would delay construction of the motorway. The A4 had to be ready for the first car in late 2015 (Perreijn, 2015).

RWS's response corresponded to the way decision-making took place as described in section 3.2, Common Pitfalls of Large Infrastructure Projects.

Weather Conditions

During the A4all building process, the project was confronted with weather conditions that caused delays. If the wind chill factor reached -6 degrees Celsius or less, construction site employees were not obliged to work. The project was suspended several times. This was due not only to working conditions, but also other factors, e.g. frozen ground.

Materials

During the construction, a 40 metre crane fell on the tram and bicycle lane of the route (Cobouw, 19 April 2012). This disruption did not halt the project, but caused substantial damage and incurred costs.



Figure 13: Fallen crane at the A4all project, source: Cobouw

Working Conditions

A4all immediately terminated the cooperation with the German secondment service Brugvak. Research showed that the 157 ironworkers that worked on the Delft – Schiedam A4 project did not receive wages in line with the CAO (Collective Labour Agreement) (Cobouw, 2014).

According to A4all, Brugvak paid a number of ironworkers insufficient wages, gave them too few leave days and bonuses were not paid correctly. Lonneke Wijnhoven, spokesperson for the consortium, asserted that the affected employees would be fully compensated. They would furthermore be placed with another company for the duration of the project. The outcome of the

investigation did not motivate the consortium to examine the other companies involved in the project (Cobouw, 2014).

4.4.2 Degree of standardisation of work processes

Another aspect of systems is the extent to which the processes are standardised. Standardisation is a form of coordination that 'pre-programmes' the division of labour (Mintzberg, 1992, p. 69-70). Work processes are standardised when the work content is specified and 'made routine'. In manufacturing companies, standardisation of work processes is largely dependent on the technology that is used within the organisation. Organisations with 'stable', mature technology will have much better knowledge of what needs to be done in advance. That is much easier to standardise than 'uncertain' (new) technologies, where much less is known about what exactly needs to be done when. Possible disadvantages of standardisation of work processes are that adjustments and innovations may be more difficult to implement. Another danger of standardisation lies in the tendency of staff to no longer identify with the goals of the organisation (Mintzberg, 1992).

Standardisation of Work Processes

The A4all project worked according to the ISO 9001 quality system. This system contained a multitude of documents, working methods and protocols. Work was executed according to certain standards, but staff regularly moved away from the set standards (lessons learnt). Due to the high work pressure, reviewers often determined the priority themselves. They did not only derogate from the usual way of working, but they regularly converted to their own way of working. There were also a few observations to be made about the quality of the A4all documents.

Observation of processes concluded that in the provided documents used to coordinate or carry out the project (for whatever reason, client or internal organisation), the number of revisions were high (Moleveld, 2013-2014). In a sample of 200 documents, thirty per cent had more than five revisions.

Standardisation of knowledge and skills

Standardisation of work processes was also shaped by learning processes. An example of a learning process was knowledge of techniques and methods of Lean Philosophy as implemented by the organisation. In practice, it appeared that 32% of respondents had attended the training. It was found that no knowledge was transferred internally by the employees who had attended the training.

Standardisation of Results/Output

Reviews were also useful as indicators for output. When a document or a process description had gone through the entire process in an efficient manner it received the stamp of approval. Unfortunately, in practice it appeared that 30% went through the process five times or more. This meant that the output was not standardised and was not of the desired quality.

Conclusion – Systems:

With regard to Systems, Lean theory argues that there is a uniform flow (2.2.2.3) as a result of the value stream (2.2.2.2). All underlying processes, according to Lean Philosophy, must be adjusted to

this. Considering the range of the disruptions discussed in section 4.4, it could justifiably be argued that there was no overall uniform flow and value stream. This could be translated into phase two of the Lean Maturity model. The informal information structure within the formal structure caused the disruptions that had to be resolved on an ad hoc basis despite the output agreements. Adjusting the reviews could be interpreted as a local improvement project, which indicated that there was no phase 3 value stream learning.

4.5 Style: A4all Management

'Style' - refers to the management style. This concerns the way the manager treats the staff and the way people interact with each other (Mintzberg, 1992).

Mutual Adjustments

With regard to ad hoc processes, the style could be described as management based on mutual coordination (Mintzberg, 1992). This style could be distilled from the following case, an ad hoc problem: the A4all project encountered sand piles, large columns filled with sand that sit vertically in the ground. The sand piles made the clay layer porous. The problem was reported to the client (the customer). The problem was then shared with the project leaders of the separate disciplines in the presence of the client.

Rijkswaterstaat did not initially know what was going on, but later found archive images from the seventies of test drilling on the route. This information had not been disclosed when the project was authorised.

After discovering that the clay layer was not entirely watertight, the consortium was able to put together a specialised team. Within two months the team produced new drawings and process descriptions based on brainstorm sessions, in which subsequent process steps were visualised and decisions were clarified. Whilst calculating, drawing and brainstorming, three possible scenarios were developed and submitted to Rijkswaterstaat, one of which was accepted and successfully executed (not published, internal report). The end-result was described in the report “Aanvullende onderzoek Lekdebiet” (Delfland, 2015).

Direct Supervision

The simplest form of standardisation is direct supervision (Mintzberg, 1992). In the case of A4all, direct supervision took place at the construction site, where many (foreign) employees were at work and staff needed to be instructed on the spot.

Looking at the organisation on a deeper level, the task maturity in the consortium team did not extend to the entire organisation, as evidenced by one of the interviews (the sand piles, section 3.3.), partly because the other employees were particularly task-oriented and standardisation was achieved through direct supervision, due to the fact that many of the workers were foreign contract workers and employed on a temporary basis. It was found that three quarters of the employees did not yet have sufficient knowledge of Lean Philosophy to use it in practice. They had furthermore not been

trained in Lean Philosophy. Moreover, the extent of Lean experience amongst the employees was assessed on average as 5.3 out of 10, which was quite weak. Lean Philosophy only works when the entire organisation is behind it and if the employees are very familiar with Lean methodology and techniques.

As soon as the work processes were uniform, there was a significant increase in effectiveness. The A4all project offered two fine examples in which the process ran more smoothly as time went on. The first example was that of pile driving in the beginning of the A4all project. As the team became more attuned to one another, the pile driving became noticeably faster. The first few kilometres of pile driving went slower than the final few kilometres (internal report). The processes of supplying the piles, setting up the equipment and the collaboration of the team became more optimally attuned. The second example was that of building sheet piling. This was a similar process that could be repeated across seven kilometres. It had the same effect as described in the previous example of pile driving.

Conclusion – Style:

Was Style based on mutual interdependencies? Within two months a suitable plan was accepted by RWS (Value, 2.2.2.1). Three different scenarios were devised by means of brainstorming sessions and concurrent engineering and subsequently presented (Value Stream 2.2.2.2). All steps were taken without delay by utilising the right activities (Flow, 2.2.2.3). The plan was drawn up to meet the client's demand (Pull, 2.2.2.4). The client (RWS) made a choice from the three scenarios and one of the scenarios was performed in accordance with the plan (Perfection, 2.2.2.5). This was in line with phase 5 of Lean Maturity. Lean theory should achieve perfection when all 5 Key Principles of Lean have been successful. When we applied Lean theory to the A4all case, it was evident that all 5 Key Principles of Lean could be analysed and the Lean level be assessed based on information from the case.

Was Style based on direct supervision? According to Lean theory, employees need to be skilled on every level of the organisation (2.2.2.3). Across the breadth of the organisation, perfection must be pursued (2.2.2.5). This philosophy (mission statement) should be carried out top-down. However, in the A4all workplace it appeared that essential knowledge as described in 4.1 and 4.2 was lacking and that only flow (2.2.2.3) was achievable. Thus Phase 3 of Lean Maturity was reached. It only partly reached phase 4, because it required commitment within the umbrella organisation. Phase 5 was out of reach because it required ultimate process chain optimisation instead of sub-process optimisation.

4.6 Staff: Competent Employees

'Staff' - focuses on the question what the profiles of the management and the employees are, now and in the future. How do we recruit, shape, evaluate, reward, motivate and retain them? Without Staff, the other S factors cannot reach their potential (Mintzberg, 1992)

A4all was a consortium? The umbrella employees were well trained and included a large number of specialists. Two thirds received higher education and the example of the ad hoc issue discussed in 4.5 showed that people wanted to learn from each other. People were goal-oriented (Value 2.2.2.1), the teams were organised based on their specialism and were well trained (Flow 2.2.2.3), pursuing perfection (2.2.2.5) using value stream learning (2.2.2.2).

In the workplace, the employees were attached to the individual participating companies and brought their own organisational structures and process methodologies with them. All employees worked based on defined business processes. They were experienced employees at an executive level. In addition, many temporary foreign contract workers were involved.

Conclusion - Staff

The deployment of staff will now be discussed from a Lean perspective. According to Lean theory, employees needed to be skilled on every level of the organisation (2.2.2.3). Across the organisation, perfection had to be pursued (2.2.2.5) and this philosophy (mission statement) had to be carried out top-down. However, in the workplace it appeared that essential knowledge as described in 4.1 and 4.2 was lacking and that only flow (2.2.2.3) was achievable aimed at programme controlled sub-projects. This was phase 2 of Lean Maturity, with a few aspects of phase 3 when it came to the employees of the umbrella organisation.

4.7 Skills: Key Skills

'Skills' (key skills) - focuses on what makes the organisation shine. In which areas does it perform well and/or competitively? (Mintzberg, 1992)

Specialists from the various companies in the consortium participated in the project. The A4all project management organised a course for some of the umbrella employees in preparation for the implementation of Lean project management. Project employees who knew the project in detail were able to apply the training materials immediately (ARPA, 2010).

Based on the description of the process (section 4.4.1), it could be stated that, when an ad hoc problem occurred, the organisation was able to organise a dedicated project team, an informal organisation within a formal structure. Specialists from various disciplines were brought together to reach a solution autonomously. The special team functioned agilely and flexibly, was closely involved with each other and came to a solution through brainstorming (learning). They worked retrospectively from flow, energising the whole team. It could be argued that the highest level (stage 5) of Lean Maturity was reached (see also 3.3 and 4.5 mutual cooperation). Looking at craftsmanship at work, the sub-project - pile driving (4.5.) - showed that, with the right guidance, employees could reach the stage of perfection, provided it concerned a single repeatable process.

Conclusion - Skills

Skills, in Lean terms, can be divided into two levels, namely a. the manner in which an ad hoc problem is addressed, and b. the manner in which the work is completed at the executive level.

Ad a. On the basis of an ad hoc problem, it could be stated that when an ad hoc problem occurred, the A4all organisation was able to organise a dedicated project team tailored to the problem, an informal organisation within a formal structure, which was capable of reaching perfection in Lean terms and thereby achieving the highest level (level 5) (see also 3.3. and 4.5 mutual cooperation).

Ad b. When it came to craftsmanship on the shop floor, the sub-project - pile driving (4.5) - demonstrated that, with the right guidance, employees could also attain the stage of perfection, provided it was a single repeatable process. However, as this was not a way of life, but a continuous improvement process, the highest level that could be reached was level 4.

4.8 Conclusion - Answer sub-question d

After performing a Learn Maturity check based on the organisational analysis of the 7S Model, the following conclusions could be drawn about Lean Maturity and the relative embeddedness in the A4all organisation:

4.1 Shared Values. The conclusion was that there was no common mission and vision, and no mission statement was formulated. When it came to Lean Maturity, mission and vision could not give any direction.

4.2 Strategy. In Lean terminology, the final assignment was determined together with the client (RWS). The contract specifications, a.k.a. the design brief, (2.2.2.1) were defined. It was provided in the contract that the client had the right to adjust the contract in the interim where necessary. If the client decided to exercise this option, changes had to be effected. This meant that no single final unequivocal project assignment was formulated. In terms of task maturity, the consortium had a goal and selected teams were at work. In terms of Lean Maturity, the consortium had a limited goal orientation, executed by selected teams. As long as the 'rules of the game' could be customised by the client, level 3 was not feasible, because value stream learning could not be applied with such a practice.

4.3 Structure. In Lean theory, the assumption was that the project assignment was uniform and the structure had to be consistent with this. The fact that the disciplines could work autonomously and that third parties were involved created doublings of structure that could thwart the hierarchy. It effectively created a black box and problems were solved improvisationally. This was phase one of Lean Maturity. The structure caused a reactive way of working and problems were solved ad hoc by means of improvisation.

4.4 Systems. Lean theory argued that there was a uniform flow (2.2.2.3) as a result of the value stream (2.2.2.2). All underlying processes had to be tailored to this. Considering the diversity of the disruptions outlined in section 4.4, it could justifiably be argued that no clear uniform flow and value stream were possible, despite the processes established by individual participants. This was phase 2 of Lean Maturity. The informal information structure within the formal structure caused the disruptions that had to be resolved on an ad hoc basis despite the output agreements. Adjusting the

reviews could be interpreted as a local improvement project, which indicated that there was no phase 3 value stream learning.

4.5 Style based on mutual interdependencies. Lean theory should achieve perfection when the project has gone through all 5 Key Principles of Lean successfully. In section 4.5, the case study fulfilled the Lean theory requirements: every Lean principle applied. Within two months there was a suitable plan accepted by RWS (Value, 2.2.2.1). Three different scenarios were devised by means of brainstorming sessions and concurrent engineering and subsequently presented (Value Stream 2.2.2.2). All steps were taken without delay by utilising the right activities (Flow, 2.2.2.3). The plan was drawn up to meet the client's demand (Pull, 2.2.2.4). The client (RWS) made a choice from the three scenarios and one of the scenarios was performed in accordance with the plan (Perfection, 2.2.2.5). Phase 3 of Lean Maturity was reached. The project only partly achieved phase 4 because it required commitment within the umbrella organisation, and phase 5 was out of reach, because it required ultimate process chain optimisation instead of sub-process optimisation.

4.5 Style based on direct supervision. According to Lean theory, employees needed to be skilled on every level of the organisation (2.2.2.3). Across the breadth of the organisation perfection had to be pursued (2.2.2.5). This philosophy (mission statement) should be carried out top-down. However, in the workplace it appeared that essential knowledge as described in 4.1 and 4.2 was lacking and that only flow (2.2.2.3) was achievable. In terms of Lean Maturity, phase 4 was attainable. Phase 5 required ultimate process chain optimisation instead of sub-process optimisation.

4.6 Staff. This section discussed the engagement of staff from the Lean perspective. Similar to section 4.5, Lean theory required that employees were trained on every level of the organisation, but at the workplace level it appeared that there was a lack of essential knowledge as described in 4.1 and 4.2. As a result, only flow (2.2.2.3) was possible. This was phase 2 of Lean Maturity, with a few aspects of phase 3 when it came to the employees of the umbrella organisation.

4.7 Skills. In Lean terms, skills could be divided into two levels, namely a. the manner in which an ad hoc problem was addressed, and b. the manner in which the work was completed at the executive level.

- a. On the basis of an ad hoc problem, it could be stated that when an ad hoc problem occurred, the organisation was able to organise a dedicated project team tailored to the problem, an informal organisation within a formal structure, which was capable of reaching perfection in Lean terms and thereby achieving the highest level (level 5) (see also 3.3 and 4.5 mutual cooperation).
- b. When it came to craftsmanship on the shop floor, the sub-project - pile driving (4.5) - demonstrated that, with the right guidance, employees could also attain the stage of perfection, provided it was a single repeatable process. However, as this was not a way of life, but a continuous improvement process, the highest level that could be reached is level 4.

With the findings above, the model of Lean Maturity could be filled in, thereby measuring the Lean Maturity of A4all. The conclusion was that, in terms of Lean Maturity, the A4all project was suboptimal.

Sub-question d. *"How can the Lean Maturity of A4all be characterised in relation to Lean?"* was thus analysed and answered.

5 THE COMPOSITE MODEL APPLIED TO A4ALL

Lean methodology is aimed at avoiding waste. This entails organising processes in such a way that products and projects are realised with as little waste as possible. According to the Lean principle, waste includes anything that adds no value to the customer, such as loss of time, loss of material, cost overrun, idle capacity etc. The degree of Lean Maturity of an organisation can be determined by the amount of Lean Waste.

5.1 Lean Principles Applied to the A4all Project

Having analysed the project with the aid of the 7S McKinsey model, it was then possible to examine the Lean Principles within the A4all project.

Value

From A4all's description - a Large Infrastructure Project, section 3.3- it could be concluded that there was a great deal of political controversy involved with the client, RWS in this case, about what should be built. Several lawsuits preceded the construction. Through years of negotiation processes with stakeholders, a complex design was accomplished, taking into account as much as possible the wide variety of stakeholders, each with their own perception of value.

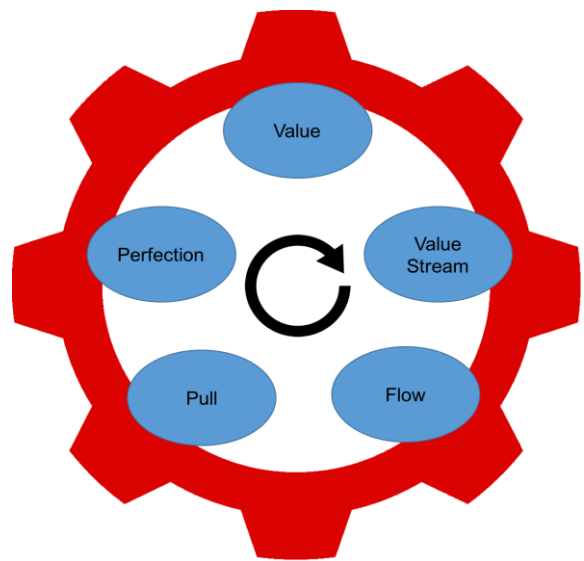


Figure 14: The 5 Lean Principles

Once the process started, the project faced major problems. For example, the open tunnel needed to be viewed as a tunnel from a safety perspective. In 2012, A4all started the implementation and in 2013 the law about additional rules for safety road tunnels was amended (RWS, 2013). This political decision thwarted the initial design, leading to renewed contact with the client to redefine the project assignment (3.3).

It could be argued that according to Lean standards, value was not formulated clearly enough in the contract phase. When it came to assessing Lean Maturity, this would point to phase 1 and 2, as the processes were described on a local level and there were no company-wide standards. To reach a higher level of maturity, it was first necessary that the organisation was organised to enable (process) chain control and that the performance indicators were clear and well-known throughout the process.

Value Stream

Value stream identifies the important process steps that support an efficient production line or workflow. Value stream assumes that a product design process is an uninterrupted process during its realisation.

In the case of A4all, given the complexity and nature of the product or process, the same problems applied as described above for value. The analysis in sections 4.4.1 and 4.4.2 led to the conclusion that the work was compared to WHAT and HOW it should be done, but that did not take into account how it WOULD be done on the basis of all the complicated factors. Examples include: a groundwater problem led to an alignment issue around existing regulations; finding sand piles forced redesign during realisation; processes were halted due to incidents such as falling materials, working conditions and weather conditions; the degree of standardisation of work processes.

Looking at value stream, it could be stated that according to Lean standards, it was not formulated clearly enough in the contract phase. This would point to phase 1 and 2 of Lean Maturity, as the processes were described on a local level and there were no company-wide standards. To reach a higher level of maturity, it was first necessary that the organisation was organised to enable (process) chain control and that the performance indicators were clear and well-known throughout the process.

Flow

Flow assumes a reduction of potential causes of interruptions. Looking at the degree of standardisation and the problems that occurred therein, it could be argued that flow was certainly applicable within the Lean process. This was because the organisational structure of the umbrella organisation was clearly described and the individual participating companies were sequentially taking single process steps, such as the delivery of sand, pile driving and the laying of asphalt etc. (3.3). The sub-processes were characterised by a low level of complexity and a high degree of predictability.

Looking at flow, it could be stated that according to Lean standards, this form of standardisation is unambiguously formulated. This seemed to suggest that phase 3 of Lean Maturity was reached, as the processes were described at a local level and there were company-wide standards. Looking at the degree of maturity, the performance indicators were clear and well-known within the sub-process of the separate business processes.

When analysing the ad hoc processes (4.5), it could be argued that A4all reached phase 5. For example, within two months of encountering the problem of the water-permeable clay layer, three possible scenarios were created in an innovative way, based on mutual cooperation, and submitted to RWS for approval. Phase 5 was a way of life. In phase 5, the focus was on innovation and creativity. The customer was willing to pay and the right project began immediately.

Pull

Pull works on the Just-In-Time principle (JIT), delivery on demand. As was concluded for value and value stream, there were too many disruptive factors, so that supply could not be handled efficiently. At this point, the price was paid for the various operating processes of the individual companies with their own missions and visions. The cohesion between the individual companies was missing and as a result, materials were delivered too early or too late. The materials were waiting until the actors/stakeholders had made decisions about the next steps because there had been too many

deviations from the procedures, as described in the sections on standardisation of work processes (4.4.2), or because of aforementioned major incidents (4.4.1).

According to the Lean standards, it could be claimed that pull was sufficiently unambiguously formulated in the contract phase. This would point to phase 1 and 2 of Lean Maturity, as the processes were described on local level and there were no company-wide standards. To reach a higher degree of maturity, the organisation had to be organised in such a way that (process) chain control was possible and that performance indicators were clear and well-known and respected throughout the process.

Perfection

Perfection is based on optimisation of the four steps described above. The four steps should be in direct contact with each other. Hidden waste can be found within the value stream. When the on-going process of perfection is implemented the Lean aspects can be optimised. The previous four steps show that optimisation had to be pursued before perfection could be reached. Chapter 4 demonstrated that contract conditions were not met or had to be adjusted. From the many disruptions as described in sections 4.1 through 4.7, it became evident that perfection for the entire LIP A4all was not feasible.

When it came to perfection within single sub-processes (e.g. pile driving) then perfection was attainable, but with the maximum maturity level of 4.

5.2 Lean Waste Typologies Applied to the A4all Project

There are 8 Types of Waste: overproduction, waiting, transportation, defects/over performance, inventory, motion/unnecessary actions, corrections/disruptions and unused creativity of employees.

Overproduction

Overproduction, as described in 2.2.3, is considered to be the worst form of waste. As presented in Chapter 3 and the preceding sections in Chapter 4, there were many problems during the construction process. Moreover, construction was regularly halted. The consequence of this was that materials arrive too early or too late. Another form of overproduction was when employees had to wait and were unable to proceed in the process because of the reported disruptions. Furthermore, heavy equipment was idle, because of delays caused by the need to redesign processes and fix errors.



Figure 15: The 8 Types of Waste

Waiting

Employees waited on each other because of difficulties that arose in the production process and that needed to be resolved first (4.4). Waiting was waste because it added nothing to the product but it did incur indirect costs.

Transport

Transport was wasteful because it added nothing to the product, it cost money and loss of quality could occur due to damage. The logistics process of the various documents caused many problems (4.4.2). For example, extra heavy material was needed to get the fallen crane back up and running again (4.4.1).

Defects

As a result of design changes (4.3.2) and a lack of understanding by operating personnel, both overproduction and underproduction could occur. Underperformance or over performance were forms of waste because they cost unnecessary time and money and involved the unnecessary use of manpower, thereby creating unnecessary waste of material and procurement operations and unnecessary storage of raw material.

Inventory

Overproduction resulted in many forms of waste: (misuse of) inventory, unnecessary use of manpower, unnecessary use of material, and unnecessary occupied space. This gave rise to capital loss on the inventory, risk of deterioration due to damage, and unnecessary administration (4.2, 4.3 & 4.4).

Motion/Unnecessary Actions

Production personnel made unnecessary movements, such as searching for tools, information, etc. Movement was wasteful because it added nothing to a product. It was a result of a poorly designed workplace. The TI part was designed at a location in Capelle a/d IJssel, while the work was carried out at the site between Delft and Schiedam; there was unavailability of materials (the fallen crane), tools or information (high frequency of revisions); and many parties were involved in the decision process (4.4.1).

Corrections/Disruptions

The technical malfunctions and poorly designed processes led to re-describing the processes, quality inspections, adjustments, resolving defects (4.4), which were all examples of activities that did not add value to the product and were therefore considered unnecessary. It led to loss of production time and unnecessary inventories.

Unused Creativity of Employees

The large-scale infrastructural project A4all was a consortium which made use of the craftsmanship of the various companies involved. Staff deviated from the standardised work processes (4.4.2) and while Lean was the chosen working method, 68% of employees did not attend training on Lean theory (4.4.2). Most of the employees were deployed for specific tasks (4.6) while the creativity of employees could have improved Lean processes (4.6).

Waste: Conclusion

If measuring waste according to the Lean standards, it would point to phase 1 and 2 of Lean Maturity. The processes were based on a reactive approach at a local level and skilled craftspeople were employed on a local level. The employees were hardly involved in Lean as methodology and there was insufficient structural feedback on work processes (4.6). To reach a higher degree of maturity, it would first be necessary that everyone in the organisation was able to apply the principles of value stream learning.

5.3 Lean Awareness among Employees

The management of the A4all project had hoped that Lean Philosophy could contribute to reaching the production target. As has been argued previously, little was known about the application of Lean to complex infrastructure projects. One of the most important Lean criteria was that the philosophy should be widely supported within the organisation (ARPA, 2010). What did the A4all project employees know about Lean and what was their opinion on it? These were important considerations that helped answer the question whether Lean Philosophy would be fruitful for A4all.

The respective success or failure of implementing Lean Philosophy depended on the participation and acceptance of the project staff of the A4 Delft-Schiedam project. Therefore, when examining the A4all project, it was interesting to investigate the extent to which project employees were already applying certain Lean methodologies, and with what methods they expected to achieve the highest yield. Because Lean Philosophy focuses on eliminating inefficiencies, it was important that the staff recognised this kind of inefficiencies or comes up with a proposal for improvement. It is therefore interesting to find out what their involvement and the degree of participation was. As a result, the role of the employees was so important that this paragraph looks closely at Lean awareness among employees. Two factors reflected the degree of participation: first, the familiarity with Lean Philosophy among the relevant project staff, and secondly - assuming they are familiar with Lean Philosophy - the willingness to participate and apply the learned theory. This was based on the assumption that a higher overall appreciation of Lean would lead to a higher willingness to participate and apply it.

In addition to the literature review of Lean Philosophy and an examination of the A4all project with the help of the McKinsey 7S model, a questionnaire was formulated, containing a number of questions relating to the degree of involvement of the (project) staff. This survey was designed to provide

insight into the willingness of staff to apply and successfully execute Lean Philosophy. A number of conclusions could be drawn from the results of the survey.

Lean Staff: The Findings

The objective of the survey was to examine how the Lean method could be introduced, based on the expectation that (project) employees were familiar with the Lean Philosophy. This expectation proved to be unfounded. The results of the survey showed that three quarters of the employees were not familiar with Lean Philosophy and that they did not receive relevant training. Furthermore, the level of experience with Lean was rated on average as 5.3 on a scale of 10, which was a poor score. In short, it was concluded that Lean Philosophy was not very well-known yet among (project) staff. This conclusion was disappointing, because all subsequent relevant questions and answers left the same impression. The outcome should therefore be scrutinised from this point of view. It could be concluded that those employees who had received training and therefore had a limited understanding of what Lean Philosophy could mean for them, were more positive than those who had no knowledge of it.

The main results of the survey related to:

- The relationship between the education level of the involved project staff and the willingness to engage.
- The relationship between the level of knowledge about Lean and the willingness to engage.
- The relationship between the level of expectation of Lean and the willingness engage.
- The relationship between the positions of the involved project employees and their willingness to engage.

There was no relationship between the attendance of Lean training and the willingness to work with new techniques like those offered by Lean. There was however, a significant relationship between the attendance of training and the expectations of using Lean techniques. After following a training, the expectations someone had of applying the Lean Philosophy did change, but not the willingness to work in accordance with the theory. When looking at this more in-depth, it became clear that employees had moderate expectations of Value Stream Mapping, but slightly higher expectations of the other techniques, which they rated as adequate. Lean planning, visualising and JIT enjoyed the greatest preference among the employees when it came to using Lean tools.

When examining the sociodemographic characteristics, it transpired that different education levels bore no relationship to the willingness to work with new Lean techniques. It was also found that the greater the experience was with Lean, the higher the willingness was to use the techniques. The willingness to engage also increased when expectations about the usefulness of Lean rose, though no strong link was discernible for the last two statements. Finally, it can be said that there was no difference between different positions and the willingness to participate. In short, there was no distinct difference between different education levels or job positions and the degree of interest in working with new, innovative techniques such as Lean Philosophy.

5.4 Conclusion - Answer Main Research Question

This section brings together all the results of the previous sections. With the findings of both the Lean Maturity check and the Lean Principles, the following conclusions could be drawn about Lean Maturity and the relative embeddedness in the Lean Principles in A4all:

The outcome of the analyses of the presence of the Lean Principles and the level of Lean Waste determined the level of Lean Maturity. The Lean Maturity model helped to form a conclusion about the state the project A4all was in. When applying Lean Philosophy to the A4all case, all Lean Principles more or less seemed to apply (Value, Value Stream, Flow, Pull, and Perfection (5.1)). The Lean Waste aspects (i.e. overproduction, waiting, transport, defects/over performance, inventory, motion/unnecessary actions, corrections/disruptions and unused creativity of employees) all seemed capable of significant improvement (5.2).

Analysis of the 5 Key Principles of Lean

It could be argued that according to Lean standards, value was not formulated clearly enough in the contract phase. This did not correspond to any phase of Lean Maturity.

Looking at value stream, it could be stated that according to Lean standards, it was not formulated clearly enough in the contract phase. This would point to phase 1 and 2 of Lean Maturity, as the processes were described on local level and there were no A4all company-wide standards. To reach a higher level of maturity, the organisation would have to be organised to enable (process) chain control and the performance indicators would have to be clear and well-known throughout the process.

Looking at flow, it could be stated that according to the Lean standards, this form of standardisation was unambiguously formulated. In terms of Lean Maturity, this would indicate phase 3, as the processes were described at a local level and there were company-wide standards. Looking at the degree of maturity, the performance indicators were clear and well-known within the sub-process of the individual operational processes.

As previously stated, Phase 5 is a way of life, with the focus is on innovation and creativity. When analysing the ad hoc processes, it could be argued that A4all did reach phase 5 (4.5). For example, within two months of encountering the problem of the water-permeable clay layer, three possible scenarios were created in an innovative way, based on mutual cooperation, and submitted to RWS for approval. The customer was willing to pay and the right project began immediately.

According to the Lean standards, it could be claimed that pull was sufficiently unambiguously formulated in the contract phase. Phase 1 and 2 of Lean Maturity were attained, as the processes were described on a local level, but there were no company-wide standards. To reach a higher degree of maturity, the organisation would have to be organised in such a way that (process) chain control was possible and that performance indicators were clear, known and respected throughout the process.

In terms of perfection, from the many disruptions as described in sections 4.1 through 4.7, it became evident that perfection for the entire LIP A4all was not feasible. When it came to perfection within single sub-processes (e.g. pile driving) then perfection was attainable, but with a maximum maturity level of 4.

To answer the main research question: *To what extent can Lean Philosophy be applied within a LIP and is it possible to create a research model as a management tool that can have added value for LIPs?* it had to be concluded that this was certainly applicable. Overall, it could be stated that Lean as a philosophy in itself was not a restrictive methodology when it came to its introduction within a LIP, provided that all participants in the consortium were willing to make their own mission, vision and corporate target secondary to a reformulated mission, vision and corporate target specific to the LIP. This included the consequent redesign of all relevant organisational and procedural structures, as well as a widespread awareness of what Lean Philosophy meant for all echelons within this one-off uniquely constructed project organisation.

With the analysis tool developed in this research, users are able to ascertain which process steps to take to improve Lean Maturity. In addition, the analysis model can formulate recommendations to increase Lean Maturity.

In the diagram on the next page the findings of the previous sections are displayed.

Conclusion Diagram

In the diagram below the findings of the sections (conclusions 4.8 and 5.4) are compiled, see Figure 16. Under very specific circumstances, as described in section 3.3 and 4.5, the organisation was able to reach a high level of Lean Maturity when dealing with complex issues that arose unexpectedly. These scores are marked with 0. The scores for the existing organisation and regular processes are displayed with an X. Many boxes are still unchecked. This means that the organisation would have to carry out certain activities for each of those aspects before implementation of Lean Philosophy is complete.

																				Way of life						
		Initial phase / reactive					Local standardization					Integrated standardization					Continuous Improvement					1. Autonomous Habit 2. Full Empowerment 3. External learning				
Organi- sation		1. Reactive Approach 2. Little/No involvement 3. Ad hoc learning					1. Formal structures 2. Only Specialist 3. Team learning					1. Goal orientated 2. Selected teams 3. Value stream leaning					1. Driven deployment 2. Majority involvement 3. X-Process learning									
Process		4. Black box 5. Improvisation by local heroes					4. Defined processes 5. Repeatable					4. Measurement KPIs 5. Local improvement processes					4. Proven improvement 5. Program-driven projects					4. Innovation as a predictable process 5. Ultimate process optimization				
		Stage 1					Stage 2					Stage 3					Stage 4									
7S Model (X)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Shared Values												X														
Strategy							X	X				X	X													
Structure		X	X	X	x	x	X	X	X			X	X													
Systems*		X	X	X			X	X	X	x	x	X	X	X	x	x	0	0	0			0	0	0		
Style		X	X	X			X	X	X			X	X	X			0	0	0							
Staff		X	X	X			X	X	X			X	X													
Skills*		X	X	X			X	X	X			X	X	X	x	x	0	0	0			0	0	0		
Lean Principles																										
Value																										
Value Stream																										
Flow		Overall based on the sum of the sub-processes.																								
Pull																										
Perfection																										
Lean Waste																										
8 types of Lean Waste		Overall based on the sum of the sub-processes.																								

Figure 16: Diagram with the findings of the sections

6 REFLECTION, CONCLUSION & RECOMMENDATIONS

In this chapter, the research question and the associated findings are again critically examined. This reflection will also shed light on the conclusions and recommendations for LIPs.

6.1 Lessons learnt: Reflection on the Findings

At the start of this thesis, the research question was formulated at a management level, focusing on Lean from the perception that Lean could provide the panacea for all management issues, such as issues aimed at improving processes and achieving more effective and more efficient production. This assumption proved unfounded because, despite the training provided, many employees involved were only marginally aware of what Lean entails. The first problem and research question focussed on the question of how the Lean process should be structured within large-scale processes and how it could be implemented. In fact, when Lean Philosophy was introduced, the hands-on mentality of those involved was neglected.

This proved to be an obstacle initially, but eventually it enriched the thesis. The research question needed to be reformulated. This thesis needed to look beyond the existing literature and a survey to be able to find suggestions for operational improvements that could be implemented.

With regard to the literature review, at the time of this research there were many books and articles on LIPs and on Lean separately. However, not many sources were available that referred to the combination of Lean and LIPs. Within the research and the available time, relevant material within the specified limit was gathered.

While it was acknowledged in advance that a properly designed Lean methodology could provide an answer to the question of how the consortium could effectively optimise its logistic and construction processes by analysing the logistics and optimising the operational process, working incrementally was a new approach for the parties in the sector. And although it was possible to recognise and exploit cost advantages that were unidentified in the past, the question remained whether Lean was applicable to a LIP like A4all. Lean was based on repeatability and was thus the ultimate tool for single process steps. While the whole A4all process could be divided into single process steps, the sum of the parts was greater than the whole, and Lean did not offer a solution for that.

At the beginning of my research it was unclear to me how to approach certain things. I actually started from the mistaken assumption that an awareness of Lean would be sufficient and that therefore a quest for improvement could be initiated within the distinguishable process steps. This was a major misconception. The survey amongst employees therefore did not yield the results I had initially expected.

Initially, the main question was formulated as follows: *To what extent does Lean Philosophy contribute to the effectiveness and efficiency of the execution of a LIP?*

This question was answered by the combination of a literature review, a case study and the application of analytical models derived from organisational behaviour theory. The investigation made use of available literature. Lean Philosophy is based on the notion that employee engagement is one of the keys to achieving a more efficient and effective production process. It was therefore expected that the employee survey would generate the bulk of material. Nothing was further from the truth. When conducting the survey, the expertise and experience of employees working on the A4all project was called upon. Most respondents were found to have little experience with Lean, though they were experts in their own respective fields within LIPs. The results of the survey should be seen in this light and had a limited scope. The questionnaire was developed in accordance with the literature. Three-quarters of the employees were educated. A survey and interviews were conducted. The issue of knowledge transfer to benefit potential improvement proposals was initially postponed, partly because those involved had insufficient knowledge of Lean methodology, and partly because they did not want to make time for it as the project progressed.

I was unsuccessful in re-addressing the image of Lean as a useful tool in such a way that the employees involved deemed Lean applicable as an overall philosophy.

The research question needed to be reformulated and a model had to be found to answer the question: "Why were the employees not enthusiastic about concepts from the Lean Philosophy?" This assumed a preliminary question: "Does an organisation require a certain amount of Lean Maturity?", which raises the question as to what model could investigate this, based on the reformulated Main Research Question: *To what extent can Lean Philosophy be applied within a LIP and is it possible to create a research model as a management tool that can have added value for LIPs?*

By considering these additional questions, the appropriate analysis model was eventually found in the McKinsey 7S model. With this model, certain aspects that were initially overlooked could be integrated afterwards.

After reformulating the main research question, the thesis focussed on the following sub-questions:

- a. *Based on the literature, what could be the added value of Lean for LIPs?*
- b. *What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?*
- c. *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?*
- d. *To what extent can the Lean Maturity of A4all be characterised?*
- e. *Is it possible to convert the lessons learned into a set of recommendations for future LIPs?*

Ultimately, it became apparent that, to apply Lean Philosophy successfully, the degree of Lean Maturity was of decisive importance. In order to determine the degree of Lean Maturity, a qualitative analytical method was used. The method offered insight into the big picture, thereby allowing room for generalisations. In addition, the analysis relied partly on snapshots in time. This was an inherent defect, because the results were not quantitative or representative, and only gave an indication of what was happening within the organisation and among employees.

When evaluating the outcome, it could be stated that the lack of time and the associated restrictive effects adversely limited the depth of the research. It was impossible to test all facets of Lean on all the unlimited aspects of the A4all LIP.

Reflecting on the results of the research, it can be concluded that the model created as part of this research could partly provide definitive answers to the research question and sub-questions. What this meant for the postulated model was that, as a result of the research, the answers to the research questions and the sub-questions might deviate from the reality within the LIP organisation. To make sure that the new model could actually prove its function in the real world, it would have to be tested on the next LIP.

The uniqueness and complexity of a LIP like A4all made it difficult to create a generally applicable tool that was based on and had proven its worth within the manufacturing industry. It is certainly not impossible, but it would require a degree of Lean Maturity within the industry adopting it.

6.2 Conclusion

This thesis investigated how Lean Philosophy might be applicable to Large Infrastructure Projects, what Large Infrastructure Projects were and whether the theory could be applied to A4all. It furthermore examined whether Lean Philosophy could be applied to LIPs.

In this thesis, the theory of Lean Philosophy, methodology and techniques were tested in practice, in order to identify opportunities to optimise processes within the consortium and, where possible, formulate proposals for improvement. The starting point was the question: *What is the level of Lean Maturity of the A4all organisation?*

For the first question, it was necessary to understand the characteristics of LIPs and whether these characteristics applied to A4all. The answer to the question: *What are the characteristics of a Large Infrastructure Project and to what extent do these apply to the A4all project?* was affirmative: A4all was a LIP.

The next question asked: *Based on the literature, what could be the added value of Lean for LIPs?* The answer to this question was partly affirmative.

Lean Philosophy has its roots in mass production and was invented by Toyota. Lean management in the manufacturing industry, however, cannot be copied directly to (road) construction, as the two sectors differ too much. Lean Construction differs from traditional construction in two ways. While traditional construction mainly focuses on conversion (from input to output), Lean Construction focuses more on the flow (of information and materials) and creating value for the customer and stakeholders. The formulation of the project assignment is not a static starting point. One of the features of LIPs is a long lead time. Due to this long lead time in particular, clients may be forced to adjust the formulation of their project assignment.

The main distinguishing characteristics between construction and production are: the uniqueness of the product, production on location, and temporary cooperation between multi-organisations. These

specific construction characteristics frustrate the process to reach an effective flow and value generation: the flows consist of more variety and complexity. Where Lean Production is focussed on flows and generating value, Lean Construction also needs to try to eliminate the specific site construction characteristics as much as possible. The Lean Construction company carries the process-based approach to building further, through various forms of cooperation within the chain.

The 5 Key Principles of Lean teach us that, if the process steps can be deconstructed, Lean can make a positive contribution. The 8 Types of Waste teach us that waste is defined as anything in a company that requires resources but does not add value for the customer.

As construction is a special form of production, as stated in 2.2.5, theory teaches us that the 5 Key Principles of Lean and 8 Types of Waste cannot be directly applied to the process. The main difference is that, in a production process, Lean is based on cyclical process steps, while in LIPs, construction is usually one-off and site specific.

Taking the above as our starting point, it was important to take into account the different characteristics and main factors, as described in chapter 2.

Process optimisation recognises diverse stages of maturity, from structuring to customer-oriented innovation. Each phase also implies an associated degree of organisational maturity. By taking this in account, the chance of a process optimisation process succeeding is considerably higher because the organisational boundary conditions are sufficiently present. In order to take the next step in the process maturity, the organisational implications would need to be considered.

Sub-question b: *What model would provide a good way of assessing the degree of maturity of the organisation in order to apply Lean?*

As described in Chapter 3 and 4, the project involved a high degree of complexity. Lean Philosophy provided a handle to deal with great complexity and variation. Lean Philosophy starts from the notion that a clear definition of value is or can be formulated. This was not the case in the A4all project. Lean Philosophy is also based on the premise that a product design process is an uninterrupted process that is realised in a one-to-one fashion according to the design. Such a process is based on a traditional planning process in which the work is compared to WHAT and HOW it should be done. The newly constructed analysis model takes into account complicating factors, such as cultural differences between the various participating parties, re-design during the realisation phase, or the need to halt processes due to incidents and weather conditions.

Considering the complexity and the nature of the product or service, one solution was that problems that were discussed in Value and Value Stream could be prevented by the boundary conditions, to be defined in advance, as mentioned in Chapter 5, and by letting the participants within the LIPs formulate the common objectives for every aspect of Value.

One of the factors did offer a good prospect. This was the flow factor. To achieve flow, potential causes for interruptions had to be reduced. Looking at the degree of standardisation and the difficulties that were encountered as a result, it could be stated that Lean Philosophy was certainly applicable to

the process. This was because the process steps were sequential, were of low complexity, had a high degree of predictability and could therefore be designed. Crucially, the process steps could be achieved in accordance with the design. With regard to the pull factor, the conclusion was twofold. Different cultural aspects could not be integrated. Yet pull was also based on the Just-In-Time principle, or delivery on demand. The survey among employees showed that this was the only aspect in which they have faith, provided that the Lean ideas were transferred and applied properly. This was certainly a conclusion from which a recommendation could follow. With regard to the final 'perfection', as previously concluded in Chapter 4.8, the ad hoc solutions, which illustrated the intellectual capital of the organisation, exemplified the way in which cooperation might take shape and the result that could then be achieved. Unfortunately, this conclusion did not hold when it came to the going concern principle. In day-to-day operation, disruptions were commonplace.

Sub-question d: *To what extent can the Lean Maturity of A4all be characterised?*

With the 5 Key Principles of Lean set out in section 4.8, it was concluded that, when it came to Lean Maturity, the LIP A4all knew a high degree of sub-optimisation. Sub-optimisation occurred at every step in the model. As a result, it could be stated that the Lean Maturity within the LIP A4all was highly insufficient.

This question relates to the topic of optimisation, where as many people as possible engage with the theory, based on the notion that Lean is not a collection of separate techniques. The components connect with each other logically and thereby strengthen each other, so that the whole is greater than the sum of its parts. The strength of Lean is founded on this integral approach.

As described in Chapter 2, Lean literature has identified 8 types of waste in order to achieve a reduction in cost. Overproduction – the most harmful form of waste – was common due to delays caused by the need to re-design processes and correct errors. As a result, employees had to wait for each other because of problems arising in the production process that had to be resolved first. Some aspects were unnecessary. The logistics process of the various documents caused problems. Better standardisation of processes would improve lead time. This process could be improved relatively easily by means of mutual coordination, based on the principle that 'a deal is a deal'. There was little to be done about design changes caused by stakeholders. They resulted in misunderstandings during implementation and, in Lean terms, underperformance or over performance, thereby causing waste in the inventory, unnecessary use of manpower, material, and occupied space, which caused capital loss on the inventory. In the A4all project, processes were illogically interrupted as a result of a poorly designed workplace, technical malfunctions and poorly designed processes. This led in turn to the re-describing of processes and extra quality inspections, due to the lack of a clear mission, vision and project objective. More attention to the interaction with stakeholders within the mission formulation process, more attention to the reformulation of the assignment, and reformulation of the objective of the project could add value, thereby eliminating the problems that frustrated the implementation of Lean Philosophy.

With regard to staff, it could be concluded that Lean Philosophy was not yet very well-known in the workplace. Even if employees had received training, it appeared that even if the expectations of what Lean could mean for them improved, the actual willingness to make it work only increased marginally. The only techniques that interested the staff were Lean planning, visualising and JIT. The sociodemographic characteristics made no difference.

To answer the main research question: *To what extent can Lean Philosophy be applied within a LIP and is it possible to create a research model as a management tool that can have added value for LIPs?* Certainly. Overall, it could be stated that Lean as a philosophy in itself was not a restrictive methodology when it came to its introduction within a LIP, provided that all participants in the consortium were willing to make their own mission, vision and corporate target secondary to a reformulated mission, vision and corporate target specific to the LIP. This included the consequent redesign of all relevant organisational and procedural structures, as well as a widespread awareness of what Lean Philosophy meant for all echelons within this one-off uniquely constructed project organisation.

With the analysis tool developed in this research, users are able to ascertain which process steps to take to improve Lean Maturity. In addition, the analysis model can formulate recommendations to increase Lean Maturity.

6.3 Recommendations - Answer sub-question e

Sub-question e: *Is it possible to convert the lessons learned into a set of recommendations for future LIPs?*

Recommendations can be distilled using the new analysis model: this means that for a new LIP, every single aspect of the newly constructed analysis model (5.4), see Figure 16, should be formulated in advance.

The analysis based on the McKinsey 7S model showed that the vision, mission and strategy to achieve the project objective were lacking at the LIP A4all. When a LIP is set up, it is often seen as a project, but in fact, a new organisation needs to be built, with the new organisation investing in the formulation of a clear vision, mission and strategy in consultation with the stakeholders. It is therefore important to note that a LIP is more than the sum of many organisations, each with their own interests.

If the project pays attention to the internal structures and the systems aimed at achieving the technical aspects of the project, and also pays attention to environment and the common interest of all stakeholders, then it is possible for the project to achieve Lean Maturity.

The strategy should focus on both the stakeholders and the LIP organisation itself. A clear unambiguous message aimed at all facets should avoid multiple interpretations of project assignments.

With regard to Style, Staff and Skills, phase 1 and 2 require a top-down approach, where roles and responsibilities are assigned to specific officials. However, phases 4 and 5 require an entirely different

approach. This requires a collaboration aimed at a commonly shared execution of the project assignment that is subject to internal and external change and a project culture that is continuously connected to the project assignment. These requirements ask for a personnel policy focused on continuity, flexibility and the employees' desire to constantly improve themselves.

Based on the 5 Key Principles of Lean, there appear to be omissions in value. Value requires the project to have a vision on environmental factors (e.g. legislation), so that the project, including the associated decision-making process, can be adjusted in good time in such a way that there is value creation for the stakeholders.

When looking at value stream, it is recommended to not lose sight of information flows and physical processes. In particular, the design of various sub-processes ought to be properly described and executed according to plan, because a product design that is difficult to build will negatively impact the 'physical transformation' value stream.

From flow follows the recommendation to learn concretely from process errors made, by using the expertise of the staff and capitalising on their skills and knowledge during the redesign. This gives them room to improve process steps from a delegated mandate.

Pull offers insight into the on-demand availability of that which is needed for the next process step. *"Don't make anything until it is needed; then make it very quickly."* This requires insight into the structure of the various sub-processes so that no work is done where the work is not necessary.

Perfection is all-encompassing. Lean Philosophy is applicable to all possible projects, but LIP management requires a completely different approach, collaboration and task maturity. A project is a sequence of activities that is performed by different stakeholders. In Lean planning, the next activity is only performed when the preceding activity asks for it, no sooner nor later.

The organisation must ensure that the term Lean is not a hollow phrase. Many employees tend to use the term Lean too easily. Lean Philosophy only works when the entire organisation is behind it and if the employees are very familiar with Lean methodology and techniques.

All parties are involved in the planning from the start: the contractor and all subcontractors, the client, architect and key suppliers. Potential conflicts are resolved by creative solutions on the one hand, and clear, firm agreements on the other. This way, value is continuously created, there is no need to wait and there are no unnecessary inventories.

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8 APPENDIX

A. Research Survey

Methodiek, dataverzameling en data preparatie

Methodiek

Om de onderzoeksvraag en bijbehorende deelvragen te beantwoorden zal een factor analyse worden uitgevoerd om de onderliggende structuur tussen de variabelen te beschrijven (Molin, 2011). Het vinden van een of meer achterliggende (mogelijk hypothetische) variabelen is het doel van de factoranalyse. Het primaire doel van een factoranalyse (Williams, 2010) is het reduceren van het aantal variabelen. De eigenschappen van een factoranalyse passen goed bij het te voeren onderzoek. Dit onderzoek heeft te maken met een aantal variabelen, namelijk verwachting, Lean kennis en acceptatie. De eigenschap van een factor is dat het een complex begrip is die niet rechtstreeks gemeten kan worden. De factor analyse zal worden gebruikt om uiteindelijk statistisch te kunnen toetsen en statistieken te kunnen maken. Deze resultaten van deze toetsen en statistieken zullen dan meer inzicht bieden in de deelvragen.

Populatie

Dit onderzoek speelt op twee niveaus. Voor het eerste niveau is projectdata van het gehele project inclusief vergelijkingen van alle mogelijke variabelen binnen het geheel van A4all infrastructurele project. Voor deze scriptie is het onmogelijk om hiernaar onderzoek te doen, helemaal wanneer bedacht wordt dat aan deze projectdata ook nog individuele data gekoppeld moet worden – die niet alleen niet voorhanden zijn maar nog verzameld moet worden, vandaar dat gebruik is gemaakt van het analyse model van McKinsey. Als tweede niveau is individuele informatie van belang. De doelpopulatie van dit deel van het onderzoek is gericht op de medewerkers van de Koepelorganisatie namelijk de disciplineleiders, de projectmanagers de leidinggevende medewerkers en uitvoerende medewerkers op de werkvloer die de deelprojecten van A4all daadwerkelijk coördineren en middels coördinatie tot stand doen komen. De data is verzameld op één moment, wat inhoudt dat alle geënquêteerde medewerkers die op dát moment werkzaam waren, gekoppeld zijn aan de projectdata. Een omissie daarvan is dat als het gaat om teamcohesie, de cohesie gemeten wordt op één statisch moment binnen het project.

Individueel niveau

Op individueel niveau verzamelen we data met betrekking tot de teamcohesie, de teamsamenstelling, werknemers verwachting, ervaring, motivatie (tevredenheid), planning, planningsproducten en de toepassing van planning en ervaring met Lean incl. verspilling. Hiertoe zijn 120 enquêtes uitgezet (zie Appendix I) onder alle genoemde medewerkers (zie populatie). Er is gebruik gemaakt van gesloten vragen waardoor de antwoord mogelijkheden voor alle respondenten gelijk zijn. De keuzemogelijkheden zijn voornamelijk volgens een 5-punts Likertschaal opgesteld.

Er is gekozen voor schriftelijke, gestandaardiseerde enquêtes. Elektronische enquêtes zouden wenselijker zijn geweest, maar was onmogelijk omdat niet alle respondenten een e-mailadressen hadden en er niet overal computers beschikbaar waren. Een eerste versie van de vragenlijst is bij 2 collega's in een test uitgezet om te verzekeren dat de vragen en antwoordcategorieën duidelijk en begrijpelijk interpreteerbaar zijn. Tijdens een rondgang langs alle betrokkenen - zoals genoemd onder populatie - op het project zelf is er voorlichting gegeven en de enquête tegelijkertijd uitgezet. Er is duidelijk gemaakt dat het vanuit het consortium gewenst is dat iedereen deze enquête invult. Ook is duidelijk gemaakt dat op geen enkele manier de individuele antwoorden ter herleiden zijn of persoonlijk aangesproken zal worden op de antwoorden die er is gegeven, zo is de validiteit en betrouwbaarheid van de vragenlijsten gewaarborgd. Er zijn echter geen controle gegevens om na te gaan of deze aanname juist is, daarom zijn de resultaten gegeneraliseerd. De individuele kenmerken van personen die werkzaam zijn en de enquête hebben ingevuld zijn geaggregeerd naar teamkenmerken. Zo werd mogelijk gemaakt de projectgegevens te koppelen aan de individuele gegevens.

De responsratio is niet precies te berekenen omdat het exacte aantal aanwezigen niet bekend is. Getracht is om alle medewerkers die wel aanwezig waren te enquêteren. Op het moment dat vragenlijsten zijn afgenomen, waren er ook mensen afwezig (ziekte, vakantie, elders werkzaam). In totaal zijn er 108 ingevulde formulieren teruggekomen.

Uit de testvragenlijst bleek dat de opgenomen restcategorie (weet niet/geen mening) niet relevant was en enkele vragen nog te onduidelijk geformuleerd waren. Over de routing waren geen adviezen of opmerkingen. De routing is eenvoudig gemaakt door vragen met dezelfde antwoordcategorieën bij elkaar te plaatsen en daarbinnen vragen over hetzelfde onderwerp te groeperen. Doordat de groep respondenten vrij homogeen is, is ervoor gezorgd dat alle respondenten alle vragen moeten invullen en geen nodeloos ingewikkelde routing gevolgd hoeft te worden. De doorlooptijd van projecten middels planning komt aan de orde omdat door Lean tools in te zetten mogelijk de planning en dus de doorlooptijd verkort kan worden en daardoor het rendement verhoogd. De doorlooptijd c.q. de planning is simpelweg de tijd die nodig is om het project op te leveren.

Veiligheid

Veiligheid is een van de aspecten van Lean (waste) ook als het gaat om het individu. Daarom is het belangrijk om ook de veiligheid van de projecten te meten. De (gemiddelde) Arbo score wordt gebruikt als maat voor de veiligheid in het algemeen. Het aantal daadwerkelijke ongevallen is té laag, er is te weinig variatie in, om dit te gebruiken in het onderzoek. De daadwerkelijke (on)veiligheid in een project zal hier dus niet gebruikt worden. En dus niet de veiligheid van de medewerkers uitgedrukt in bijvoorbeeld een *incident frequency*, die meet hoeveel ongevallen met minstens één dag afwezigheid tot gevolg per miljoen gewerkte uren voorkomen.

Kwaliteit

Voor de kwaliteit van de projecten zal gekeken worden naar het aantal reviewprocessen c.q. evaluatie van het uitgevoerde werk. Dit is een eenvoudige en betrouwbare maat om de kwaliteit van het

bouwproces te volgen. Wanneer tijdens de procesfase nog veel reviews niet in orde zijn, laat niet alleen de kwaliteit te wensen over vaak moeten er herstelwerkzaamheden worden verricht. Zo is een laag aantal reviews erg waardevol voor de klant op verschillende manieren en ook voor het consortium vanwege lage extra kosten voor nabewerking, wat pure verspilling is.

Teamcohesie

Teamcohesie is een multidimensionaal concept en heeft betrekking op de mate waarin de groepsleden worden aangetrokken tot het team en taken van het team, elkaar wederzijds beïnvloeden en gemotiveerd zijn om tot de groep te blijven behoren. De geïdentificeerde onderliggende dimensies van teamcohesie zijn taakcohesie, sociale cohesie en individuele aantrekkingskracht tot het team. Een team hoeft niet alle componenten van cohesie te omvatten om cohesief te zijn. Om de teamcohesie te meten gebruiken we informatie uit eerdere onderzoeken. Het onderzoek van Carless en De Paola (2000) zet de wetenschappelijke traditie voort en geeft een indeling van de meetinstrumenten naar verschillende onderdelen van teamcohesie. De vragen die zij na een factoranalyse onderscheiden voor cohesie zijn leidend voor de vragen die in dit onderzoek gebruikt worden.

Betrouwbaarheid en validiteit

Hier zullen de kwaliteitscriteria van dit onderzoek besproken worden. De betrouwbaarheid en de validiteit van de verkregen data staan centraal omdat aan de hand daarvan bekeken kan worden in hoeverre oorzakelijke verbanden vast te stellen zijn.

Betrouwbaarheid

De betrouwbaarheid betreft de mate van toeval van een waarneming ('t Hart, Boeije & Hox, 2005). Om de kans op de aanwezigheid van toevallige fouten zo klein mogelijk te houden is veel aandacht besteed aan het gebruik van betrouwbare operationaliseringen in de enquêtes.

Er is geen gebruik gemaakt van een aselechte steekproef. Een aselechte toewijzing van onderzoekseenheden aan verschillende groepen was – zoals betoogd onder 5.4.1. populatie – niet mogelijk. Er is wel op gelet dat de omvang van de onderzoeksgroep zo groot mogelijk is gehouden om toevallige fouten zo veel mogelijk tegen elkaar weg te laten vallen.

Interne validiteit

Naast de afwezigheid van toevallige fouten is de afwezigheid van systematische fouten van groot belang. De aanwezigheid van veel systematische fouten is een serieus probleem voor de validiteit van een onderzoek; de geldigheid van de interpretatie ('t Hart, Boeije & Hox, 2005; te Grotenhuis & van der Weegen, 2008). De validiteit valt uiteen in twee punten.

De interne validiteit is het eerste punt waar naar gekeken wordt. Er is niet zonder meer sprake van een hoge interne validiteit. Bij gebruik van een pre-experimenteel design blijft onzeker of y door x veroorzaakt wordt ('t Hart, Boeije & Hox, 2005). Storende factoren kunnen een rol spelen. Zo is het mogelijk dat in de tussentijd, in de tijd tussen de meting van de projectdata en de afname van de enquête, een extern voorval of 'rijping' heeft plaatsgevonden die de gegevens zoals die naar voren

komen uit de enquête kunnen vertekenen ('t Hart, Boeije & Hox, 2005). Dit is een onontkoombaar probleem. Doordat met zorg de controlegroep is uitgezocht en alle aanwezigen op een-en-dezelfde dag zijn gevraagd de enquête in te vullen, is deze interne validiteit in ieder geval optimaal.

Externe validiteit

De vraag is of vervolgens de resultaten gegeneraliseerd kunnen worden naar de doelpopulatie en naar andere omstandigheden. De populatievaliditeit en de ecologische validiteit zijn hierin van belang ('t Hart, Boeije & Hox, 2005).

De onderzochte groep is representatieve voor de algemene populatie. De manier en het tijdstip van onderzoek zou mogelijk een storende factor kunnen zijn, we weten immers niet of iedereen aanwezig was. Er zijn echter geen andere factoren bekend die hiervoor zouden zorgen. Daarmee is er geen reden om aan te nemen dat de onderzochte groep geen representatieve afspiegeling is van de algemene doelpopulatie. De populatievaliditeit hoeft daarom niet ter discussie te worden gesteld.

Verder is er met nadruk op gelet dat alle respondenten op eenzelfde manier in het onderzoek betrokken zijn. Ze kregen allemaal dezelfde vragenlijst, met dezelfde instructie. Overal was vooraf aangekondigd dat de enquêtes zouden worden afgenomen en altijd was een onderzoeker aanwezig om de respondenten te garanderen dat het invullen ordelijk, gestructureerd en overal op eenzelfde wijze gebeurde. Van een selectieve perceptie vanuit de onderzoeker kan geen sprake zijn omdat de antwoorden ondubbelzinnig en niet interpretatieafhankelijk geanalyseerd worden middels kwantitatieve methoden: overal is sprake van gesloten antwoordcategorieën. Vertekeningen op basis van de omstandigheden waarin de enquêtes zijn afgenomen, vergeleken met de daadwerkelijke situatie worden verwacht niet aanwezig te zijn. Respondenten zijn in hun eigen omgeving onderzocht. Zoals betoogd in paragraaf 5.4.1. individueel niveau is er een lage mate van non-respons en missende waarden. Sociale wenselijkheid en selectieve respons lijkt hier niet uit te spelen. Sociale wenselijkheid is nooit volledig uit te sluiten, maar er zijn geen aanwijzingen dat hierdoor vertekeningen op kunnen treden.

We volgen de methode van Carless en de Paolo (2000) en voeren een principale factoranalyse uit over alle items voor teamcohesie. We hopen zo tot hetzelfde onderscheid te komen als in het onderzoek van Carless en de Paolo (in taak- en sociale cohesie) zodat dit onderzoek niet alleen theoretisch maar ook empirisch gevalideerd is.

Familiariteit

De familiariteit is het eerste onderdeel van de teamsamenstelling. Espinosa, Slaughter, Kraut en Herbsleb (2007) stellen een omvattende definitie van team familiariteit op door eerdere onderzoeken samen te nemen. Zij stellen dat team familiariteit gemeten moet worden als eerdere werkervaring met hetzelfde team, voorkennis van andere teamleden en voorgaande werkervaring met dezelfde teamleden in soortgelijke eerdere taken. Idealiter wordt dit gemeten als netwerken van alle personen in een team. Voor dit gelegenheidsproject is een dergelijke vraag niet relevant.

Heterogeniteit

De heterogeniteit is het tweede onderdeel van de teamsamenstelling. De heterogeniteit van een team valt, zoals verondersteld in hoofdstuk twee, uiteen in verschillende onderdelen. Deze zullen we hier afzonderlijk bespreken.

Opleidingsniveau

Het opleidingsniveau wordt gemeten via de Standaard Onderwijsindeling (SOI). De SOI is een gevalideerde en betrouwbare methode om onderscheid te maken naar opleidingsniveaus en is ontwikkeld voor gebruik bij statistiek en onderzoek in 1978 en wordt sindsdien elk jaar geactualiseerd in verband met voortdurende veranderingen in het Nederlandse onderwijsbestel (CBS, 2011a). De SOI die wij gebruiken is up-to-date tot 2010/2011 en wordt ondermeer ook gebruikt door het Centraal Bureau voor de Statistiek. De SOI wordt reeds gedurende lange tijd veelvuldig toegepast en heeft zijn waarde in de theorie, wetenschap en praktijk bewezen. Het wordt het meest gebruikt als meetinstrument voor opleidingsniveau in Nederland (CBS, 2011b). In een aparte publicatie (CBS, 2010c) wordt de indeling volledig verantwoord, zowel methodisch als inhoudelijk.

Omdat voor dit onderzoek interessant is welk denkniveau iemand heeft, is het hoogst voltooide opleidingsniveau bevraagd en niet bijvoorbeeld het aantal jaren onderwijs.

Leeftijd

De leeftijd van de respondenten is gevraagd in categorieën om de betrouwbaarheid te vergroten (in verband met onduidelijke handschriften en om de anonimiteit van de respondenten te borgen) ook al betekent dat een afname van de nauwkeurigheid van de meting. Er zijn vijf categorieën gemaakt, de eerste voor 20 jaar of jonger, de tweede voor 21-30 jaar, dan voor 31-40 jaar, dan 41-50 jaar en tot slot 50 jaar of meer.

Alle antwoorden zijn vervangen door de gemiddelden van die categorie om parameters inhoudelijk beter interpreteerbaar te maken.

De enquête is afgenomen bij de werknemers van A4all die de respondenten vormen. Het profiel van de respondenten is als volgt:

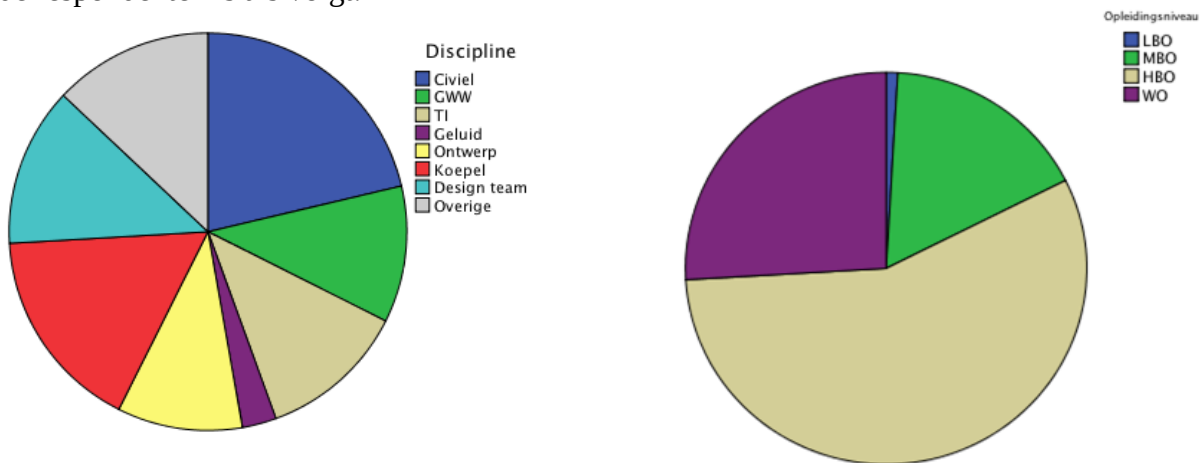


Figure 18: Profile respondents in relation to Discipline

Figure 17: Profile respondents in relation to Education

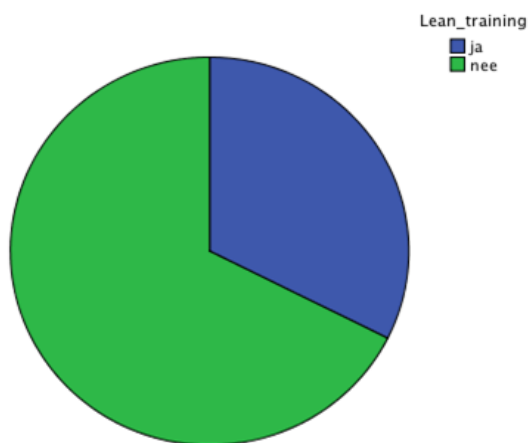


Figure 19: Percentage of employee with a Lean training

Voor de steekproefgrootte moeten er in totaal minimaal 50 respondenten zijn, bij voorkeur meer dan 100 (Molin, 2011). Met een steekproefpopulatie van 108 respondenten wordt er dus aan de eisen voldaan. Ook aan de voorkeur De disciplines zijn gelijkmatig verdeeld zoals het hoort, alleen dit is niet het geval voor opleiding. Deze is scheef verdeeld met 56% van het HBO. Ook het gevolgd hebben van een Lean training is een niet helemaal gelijk verdeeld, 68% heeft de training niet gevolgd. Hier moet dus goed rekening mee worden gehouden bij de conclusies.

De vragen uit de enquête en overkoepelend welke thema's A4all belangrijk vindt zijn opgesteld in samenspraak met A4all. Hierbij heeft boek: ARPA Lean training als leidraad gefungeerd. De organisatie heeft hier bewust voor gekozen omdat een groot deel van de organisatie al op training is geweest en alleen kennis heeft genoten van de Lean filosofie theorie aan hand van dit boek.

Datapreparatie

In de datapreparatie wordt de verzamelde data gereed gemaakt voor modelschatting en verdere statistische analyses. Dit gebeurt dus bij de schaalconstructie na de factor analyse. Hierbij worden de somscores gemiddeld zodat ze vergeleken kunnen worden ten opzichte van elkaar en andere variabelen met dezelfde schaal.

Enquête onder medewerkers

Om het laatste deel van Research Question 2 te kunnen beantwoorden waren de volgende onderzoeksvragen opgesteld.

2.1. Is de Lean filosofie al bekend binnen het A4all project en wordt het al toegepast?

2.2. Welke Lean methodieken genieten de grootste voorkeur bij de betrokken projectmedewerkers

Factoranalyse

Om te onderzoeken of de factor analyse inderdaad geschikt is voor de gebruikte data is de MSA-waarde berekend en gekeken naar de steekproefgrootte. De steekproefgrootte is bij alle gebruikte stellingen in orde. Daarnaast gaven waren de MSA-waarde bij de meeste thema's voldoende, maar bij enkele thema's matig. Een belangrijk thema dat een matig oordeel kreeg was "motivatie", waarmee we uiteindelijk de bereidheid om te werken met Lean willen voorspellen. Dit is dus een belangrijk punt om rekening mee te houden.

Om het aantal variabelen te reduceren worden factoren gemaakt. Deze worden benoemd en er worden labels aangegeven. In deze paragraaf zullen de resultaten gepresenteerd worden van het aantal factoren en hun onderliggende indicatoren.

Teamcohesie

Na de factoranalyse te hebben doorlopen en telkens na iedere iteratie kritisch te kijken naar wat wel en niet mee moet worden genomen, is er een label benoemd. Er zijn twee factoren gevonden. De label "sociaal buiten werk" voor de eerste factor bevat de volgende stellingen:

- Ons team besteedt niet veel tijd samen buiten werktijd
- Ons team gaat zelden samen naar borrels of feesten
- Teamgenoten gaan liever zelf uit i.p.v. samen met het team
- (Mijn team zou graag samen buiten werktijd, tijd doorbrengen)

De tweede onderliggende factor met het label "gezamenlijke toewijding" bevat de volgende stellingen:

- Gezamenlijk trachten wij onze prestatiedoelen te behalen
- Ik ben tevreden met de toewijding van mijn team t.o.v. onze taken

Teamsamenhang

Bij de vragen over teamsamenhang zijn drie factoren gevonden. Indicatoren voor de eerste factor met het label “team planning” zijn:

- Alles wat ik nodig heb voor een taak is voorhanden
- Het werk tussen verschillende teams/disciplines is zo gepland dat het goed aansluit
- Ik vertrouw op de planning van anderen

Indicatoren voor de tweede factor met het label “eigen team” zijn:

- Ik zit liever met mijn eigen team in één kamer i.p.v. met verschillende disciplines.
- Het werkproces verloopt beter wanneer ik met mijn eigen team op één kamer zit i.p.v. met verschillende disciplines
- Ik overleg liever met mijn collega hoe een taak moet worden aangepakt, i.p.v. dat ik er zonder overleg aan begin.

Indicatoren voor de derde factor met het label “samenwerking collega storend” zijn:

- Wanneer een collega mij om hulp vraagt ervaar ik dit vaak als storend.
- Voorstellen van anderen voor verbeteringen in mijn werk beschouw ik als storend.

Motivatie

Voor motivatie is één factor gevonden, met het label “bereidheid innovatief te werken”. De indicatoren voor de factor zijn:

- Lean planning zal een positieve invloed hebben op mijn project aandeel.
- Het is de taak van de (project)leider, en niet die van het team, om faciliterend op te treden en het samenwerkingsproces in goede banen te laten leiden.
- Ik vind het leuk om met nieuwe en innovatieve technieken te werken.
- Ik ben altijd op zoek naar nieuwe manieren om mijn werk te doen.
- Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.

Planning

Voor planning zijn twee factoren gevonden. Indicatoren voor eerste label “Lean planning is nuttig” zijn:

- Lean planning leent zich goed om alle beschikbare kennis naar boven te halen.
- Lean planning leent zich goed om alle beschikbare kennis onder controle te houden.

Indicatoren voor de tweede factor met het label “ruim plannen” zijn:

- Ik schat de benodigde kosten en tijd liever ruim in.
- Ik plan liever iets meer tijd in dan daadwerkelijk nodig, om het risico op vertraging te verlagen.

Ervaring

Ervaring heeft één factor (Label: “ervaring Lean”) met de volgende indicatoren:

- Value Stream Mapping (VSM): waardestromanalyse van je processen
- Lean Planning: samen met alle betrokkenen een planning maken
- Concurrent Engineering: gezamenlijk aanpakken van de engineering door in 1 ruimte samen te werken
- Fouten vermijden – Poka Yoke
- Visualiseren (een plaatje zegt meer dan 1000 woorden): doelen en resultaten, veiligheidsaspecten, processen en de besturing daarvan.
- Just-In-Time (JIT): de juiste hoeveelheid van het juiste product op de juiste manier op het juiste moment op de juiste plaats.

Verwachting

Er is slechts één factor met de label: “verwachting Lean”. Alle indicatoren zijn hier meegenomen.

Schaalconstructiemodel

Nu de factoren zijn gelabeld kan de data worden aangepast om zo tot nieuwe variabelen te komen. Dit kan worden gedaan door factorscores of somscores te construeren of door surrogaat variabelen te kiezen. De drie belangrijke thema's voor dit onderzoek worden nu getest en er worden keuzes gemaakt voor welke constructie zal worden gebruikt.

Bereidheid innovatief te werken

“Ik vind het leuk om met nieuwe en innovatieve technieken te werken” heeft als enige indicator een lading die boven de minimale factorlading ligt. Er moet daarom onderzocht worden of deze indicator als een surrogaat variabele gebruikt kan worden. Als de betrouwbaarheid gecontroleerd wordt, komt er voor de vier indicatoren gezamenlijk een Cronbach's Alpha van 0.540 uit, wat een onbetrouwbare schaal zal opleveren. Daarom moet de indicator met de hoogste lading als surrogaat variabele gekozen worden. Dit is inderdaad ook de indicator die als enige boven het minimum ligt. Er hoeft hier dus niets nieuws geconstrueerd te worden. Het leuk vinden om met nieuwe innovatieve technieken te werken meet dus wat de bereidheid is van de werknemers om met innovatieve technieken te werken.

Ervaring Lean

Voor *ervaring Lean* zullen de somscores gebruikt worden. Er zijn namelijk meerdere hoog ladende indicatoren waardoor er gemakkelijker generaliseert kan worden naar de populatie dan met factorscores. De betrouwbaarheid moet weer gecontroleerd worden door middel van een Cronbach's Alpha test. Deze is met alle zes indicatoren 0.814 en met slechts de drie hoogst ladende 0.810. Minder dan drie indicatoren gebruiken, leidt hierbij niet tot een hogere betrouwbaarheid. De indicatoren JIT, CE en visualisatie zullen dus gebruikt worden en daarvan wordt het gemiddelde van somscores gebruikt.

Verwachting Lean

Alle indicatoren zitten boven de minimale waarden, maar nog niet op de streefwaarden. Alleen “Verwachting Lean” zit er erg dicht tegenaan met een waarde van 0.699. Bij een factorscore met alle indicatoren erin volgt er een Cronbach’s Alpha van 0.811. Wanneer er indicatoren verwijderd worden neemt deze waarde af. Daarom wordt de het gemiddelde van de somscore gebruikt, zodat er vergelijken kan worden met anderen.

Statistische analyses - deelvragen

Deelvraag 1 – Cirkeldiagram

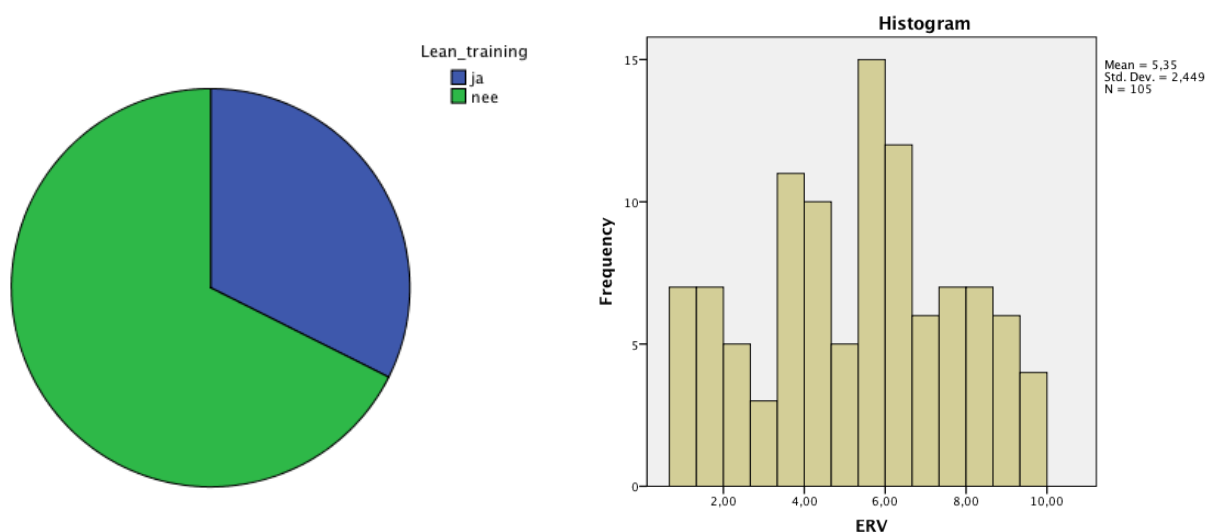


Table 3: How much employees have with Lean

Van de ondervraagde werknemers heeft slechts zo’n 32% de Lean training gevolgd en is hiermee bekend. Uit het histogram komt naar voren dat de gemiddelde ervaring een 5.3 scoort op een schaal van tien.

Deelvraag 2 - Onafhankelijke t-toets

Volgens de Levene’s Test mag de analyse uitgevoerd worden. Uit de t-test komt naar voren dat bij de verwachting $p < 0.05$ en bij het leuk vinden van innovatieve technieken om te werken $p > 0.05$. Uit de t-test komt dus naar voren dat er bij de houding ten opzichte van de verwachting wel een significant verschil is tussen het wel en niet volgen van de training. Er is geen verschil tussen de bereidheid om met nieuwe innovatieve technieken zoals Lean te werken en het wel of niet volgen van de training.

Deelvraag 3 - Staafdiagram van gemiddelden

Alleen VSM heeft een matige score. De andere indicatoren CE, 5S en fouten vermijden scoren voldoende (> 6) en Lean planning, visualiseren en JIT een ruim voldoende (> 7).

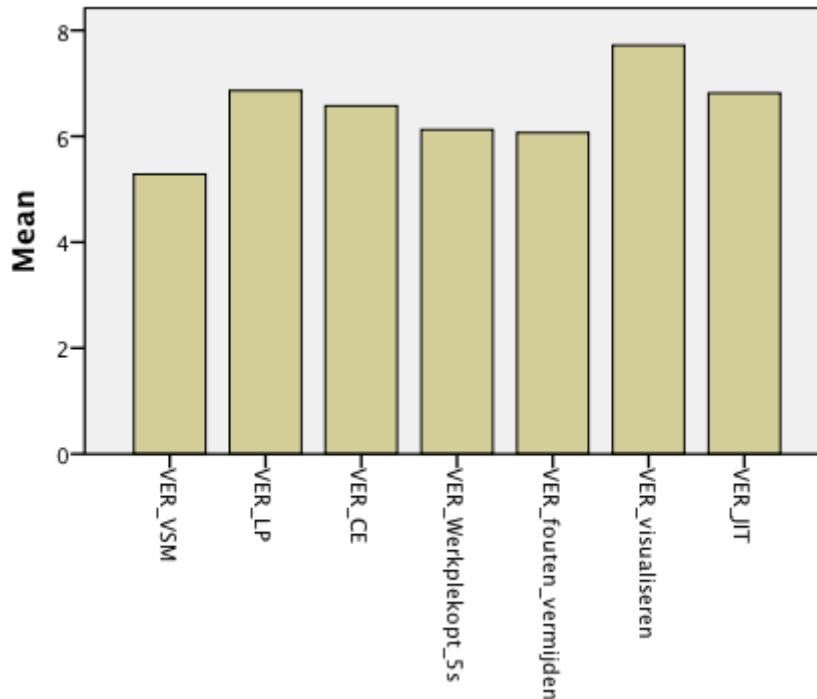


Table 4: Expectations of the Lean Methods and Tools

Deelvraag 4 – Variantieanalyse

Uit het controleren van de voorwaarden voor de test is gebleken dat de test uitgevoerd mag worden. Na het uitvoeren van de analyse wordt een waarde gevonden van $p > 0.05$, wat betekent dat het niet significant genoemd mag worden. Er is dus geen significant verschil tussen verschillende opleidingsniveaus en de mate van het leuk vinden om met nieuwe en innovatieve technieken te werken.

Deelvragen 5 en 6-Correlatie

Voor de deelvragen 5 en 6 zijn correlaties bekeken. Aan de voorwaarde dat de variabelen van interval/ratio meetniveau zijn om de correlatie te mogen toetsen wordt voldaan. Tussen alle variabelen is er een significant verband. De H_0 dat er geen relatie is tussen twee variabelen wordt bij elk geval verworpen. De drie relaties zijn allen zwak positief gecorreleerd.

Deelvraag 7 - ANOVA

Ook voor de laatste deelvraag wordt aan de voorwaarden voldaan, op eenzelfde manier als bij deelvraag vier om een ANOVA te mogen uitvoeren. Alleen de derde voorwaarde moet opnieuw worden gecontroleerd. Deze blijkt niet significant te zijn waardoor de H_0 wordt behouden en er verder gegaan kan worden met de analyse. Bij het uitvoeren van de test wordt een waarde van $p > 0.05$ gevonden.

Conclusie

De hoofdvraag van het onderzoek is: Wat is de optimale invoering van de Lean filosofie binnen het A4 Delft – Schiedam project, zodat het hoogste algemene waardering voor de Lean filosofie ontstaat en zoveel mogelijk betrokken projectmedewerkers participeren in deze filosofie? De deelvragen daarbij waren:

1. Is de Lean filosofie al bekend binnen het A4all project en wordt het al toegepast?
2. Is er een relatie tussen de medewerkers die een Lean training hebben gehad en de bereidheid om mee te werken aan en de verwachting van de Lean filosofie?
3. Welke Lean methodieken geniet de grootste voorkeur en verwachting uit bij de betrokken projectmedewerkers?

Deelvragen die betrekking hebben op de sociaal-demografische kenmerken van de betrokken projectmedewerkers zijn:

1. Wat is de relatie tussen het opleidingsniveau van de betrokken projectmedewerkers en de bereidheid tot participatie?
2. Wat is de relatie tussen de hoogte van kennis over Lean en de bereidheid tot participatie van de betrokken projectmedewerkers?
3. Wat is de relatie tussen de hoogte van verwachting over Lean en de bereidheid tot participatie van de betrokken projectmedewerkers?
4. Wat is de relatie tussen de functie van de betrokken projectmedewerkers en de bereidheid tot participatie?

De Lean filosofie is bij drie kwart van de medewerkers nog niet bekend en zij hebben nog geen training gehad hierin. Verder wordt de mate van ervaring met Lean door de medewerkers gemiddeld beoordeeld op een 5.3, wat ook matig is. Kortom, er kan geconcludeerd worden dat de Lean filosofie nog niet erg bekend is bij projectmedewerkers.

Er is geen relatie tussen het wel of niet volgen van een Lean training en de bereidheid om met nieuwe technieken als die van Lean te werken. Er is echter wel een significant verband tussen het wel of niet volgen van een training en de verwachting van de Lean technieken. Na een training te hebben gevolgd veranderen de verwachtingen van Lean, maar niet de bereidheid.

Het blijkt dat alleen werknemers van VSM matige verwachtingen hebben, bij de andere technieken geven ze een voldoende. Hierbij genieten Lean planning, visualiseren en JIT de grootste voorkeur onder de werknemers.

Kijkend naar sociaal-demografische kenmerken, kan er geconcludeerd worden dat de verschillende opleidingsniveaus geen relatie hebben met de bereidheid tot het werken met nieuwe Lean technieken. De filosofie is dus over de hele breedte inzetbaar. Verder kan er gesteld worden dat hoe groter de ervaring met Lean, hoe hoger de bereidheid tot het gebruiken van de technieken (ook al is dit verband niet heel sterk). Ook stijgt de bereidheid tot participatie wanneer de verwachtingen van Lean stijgen

(ook niet met een sterk verband te stellen). Tot slot kan er gezegd worden dat er geen verschil is tussen verschillende functies en de bereidheid tot participatie.

B. Data survey: Factor analyse

Geschiktheid factoranalyse

116 variabelen kunnen niet in één enkele factoranalyse worden onderzocht, dit volgt meteen al uit het criterium voor de steekproef grootte. Met 108 cases is dus de verhouding met variabelen niet in orde. Daarom wordt voor elk van de acht thema's een factoranalyse uitgevoerd.

wanneer goede factoroplossing?

- **meetniveau**
 - vereist: data van interval meetniveau,
 - enkele dummy variabelen kunnen toegevoegd worden
- **steekproef grootte**
 - beter niet indien $N < 50$, bij voorkeur $N > 100$
 - minimaal 5 maal zoveel cases als variabelen,
 - bij voorkeur verhouding 1:20
- **correlaties hoog genoeg**
 - veel correlaties groter dan .30
- **measure of sampling adequacy (MSA)**
 - index tussen 0 en 1
 - 1 is perfect; > 0.8 prima; $> .7$ gemiddeld; $> .60$ gematigd;
 - $> .50$ miserabel; $< .5$ onacceptabel

Figure 20: Requirements for a factor analysis (Molin)

Thema	Data voldoet aan eisen?				
	Meetniveau	Steekproef grootte	Correlaties hoog genoeg?	MSA-waarde	MSA-oordeel
Teamcohesie	Ja	Ja	Nee	0.630	Matig
Team-samenhang	Ja	Ja	Nee	0.588	Miserabel
Motivatie	Ja	Ja	Nee	0.583	Miserabel
Planning	Ja	Ja	Nee	0.534	Miserabel
Lijst Plannings-producten (toepassing)	Ja	Ja	Ja	0.860	Prima

Lijst Plannings- producten (relevantie)	Ja	Ja	Ja	0.905	Prima
Ervaring	Ja	Ja	Ja	0.839	Prima
Verwachting	Ja	Ja	Ja, redelijk: 16 v/d 21 is hoog genoeg	0.789	Gemiddeld
Verspilling	Ja	Ja	Twijfel:14 v/d 28 goed	0.708	Gemiddeld

Thema	Conclusie: goede factoroplossing?
Teamcohesie	De vier thema's zullen wel een goede factoroplossing brengen, alleen de kans is wel groot dat dit niet tot een interpreteerbare oplossing leidt, omdat er niet aan alle voorwaarden is voldaan
Team-samenhang	
Motivatie	
Planning	
Lijst Plannings-producten (toepassing)	Deze drie thema's zullen goede factoroplossingen leveren en ook interpreteerbare oplossingen.
Lijst Plannings-producten (relevantie)	
Ervaring	

Verwachting	Ook goede factoroplossingen, alleen misschien net iets minder gemakkelijk te interpreteren dan de drie bovenstaande thema's
Verspilling	

Factoranalyse model

Stappenplan voor factoranalyse, gedeelte dimensie reductie (Molin, 2011).

1. Hangt elke indicator voldoende samen met andere indicatoren?
2. Hoeveel factoren zijn er?
3. Is er sprake van een Simple Structure?
4. Is de oplossing orthogonaal?
5. Kun je de factoroplossing interpreteren?

Streefwaarden van communaliteiten zijn 0.25 of groter, die van de factorlading worden als volgt beoordeeld:

streefwaarden factorlading

- streven naar factorlading > .70
 - dit noemen we een hoge lading van indicator op factor
 - dus deze indicatoren bepalen in sterke mate de factor
- minimale factorlading > .50
 - .50 is doorgaans de grens om van hoge lading te spreken
 - indicatoren met lagere ladingen spelen nauwelijks een rol
- factorlading > .30 en < .50
 - vaak te hoog om geheel te negeren, maar deze indicatoren doen nauwelijks mee aan interpretatie
- factorlading < .30
 - kan worden genegeerd

Teamcohesie

1. De indicator “Mijn team heeft verschillende verwachtingen voor de prestaties van het team” heeft een veel te kleine communaliteit ($0.047 < 0.25$). Deze wordt verwijderd en de factoranalyse (FA) wordt opnieuw uitgevoerd (it. 1). Na de iteratie is alles netjes boven de 0.25 gebleven.
2. Uit de tabel Total VarianceExplained komt naar voren dat drie factoren een eigenwaarde hebben van groter dan één. De derde heeft echter slechts één indicator en heeft slechts een marginale overschrijding van de grenswaarde en moet daarom niet worden opgenomen als een factor (it. 2).
3. Alle indicatoren laden steeds op maar één factor. Het is een simple structure en verder liggen ze allemaal boven de minimale grens van de factorlading. De eerste factor bevat de volgende stellingen:
 - Ons team besteedt niet veel tijd samen buiten werktijd
 - Ons team gaat zelden samen naar borrels of feesten
 - Teamgenoten gaan liever zelf uit i.p.v. samen met het team

- (Mijn team zou graag samen buiten werktijd, tijd doorbrengen)

Er kan goed een label worden gemaakt voor de eerste drie indicatoren samen en de vierde indicator past niet helemaal goed in het rijtje. Omdat deze ook maar net binnen de minimale grens zit van een geschikte factorlading (> 0.50) wordt deze weggehaald en opnieuw een iteratie uitgevoerd (it. 3). Hierdoor zijn alle andere ladingen enigszins verbeterd.

De tweede factor bevat de volgende stellingen:

- Gezamenlijk trachten wij onze prestatiedoelen te behalen
 - Ik ben tevreden met de toewijding van mijn team t.o.v. onze taken
4. Met een correlatie van 0.10 is de oplossing orthogonaal.
 5. De label voor de eerste factor over de drie indicatoren zal “sociaal buiten werk” worden genoemd. Voor de tweede label zal de naam “gezamenlijke toewijding” worden gebruikt.

TEAMCOHESIE	Factor	
	1	2
Ons team besteedt niet veel tijd samen buiten werktijd.	,808	
Ons team gaat zelden samen naar borrels of feesten.	,634	
Teamgenoten gaan liever zelf uit i.p.v. samen met het team.	,539	
Ik ben tevreden met de toewijding van mijn team t.o.v. onze taken.		,835
Gezamenlijk trachten wij onze prestatiedoelen te behalen.		,627

Teamsamenhang

1. Na twee iteraties zijn de twee stellingen verwijderd:
 - Ik pas altijd nieuwe informatie van derde toe in mijn werk.
 - Ik vraag na afloop van een overleg wat de afspraken zijn.

De derde communaliteit die onder de 0.25 ligt is erin gelaten:

- Ik overleg liever met mijn collega hoe een taak moet worden aangepakt, i.p.v. dat ik er zonder overleg aan begin.

Deze kan toch waardevolle informatie geven omdat hij inhoudelijk wel in het rijtje past.

2. Er zijn drie factoren met een eigenwaarde groter dan één.
3. Er is niet meteen sprake van een simple structure. “Ik heb aandacht voor de persoonlijke situatie van collega’s” laad zwak op twee factoren. Deze wordt dus verwijderd (it. 3). Er is nu een simple structure.

4. De correlaties tussen de factoren zijn laag dus wordt de analyse orthogonaal uitgevoerd:

TEAMSAMENHANG	Factor		
	1	2	3
Alles wat ik nodig heb voor een taak is voorhanden.	,717		
Het werk tussen verschillende teams/disciplines is zo gepland dat het goed aansluit.	,698		
Ik vertrouw op de planning van anderen.	,564		
Ik zit liever met mijn eigen team in één kamer i.p.v. met verschillende disciplines.		,748	
Het werkproces verloopt beter wanneer ik met mijn eigen team op één kamer zit i.p.v. met verschillende disciplines.		,606	
Ik overleg liever met mijn collega hoe een taak moet worden aangepakt, i.p.v. dat ik er zonder overleg aan begin.		,329	
Wanneer een collega mij om hulp vraag ervaar ik dit vaak als storend			,753
Voorstellen van anderen voor verbeteringen in mijn werk beschouw ik als storend.			,575

5. Indicatoren voor de eerste label/factor:

- Alles wat ik nodig heb voor een taak is voorhanden
- Het werk tussen verschillende teams/disciplines is zo gepland dat het goed aansluit
- Ik vertrouw op de planning van anderen

Label: “team planning”

Indicatoren voor de tweede label/factor:

- Ik zit liever met mijn eigen team in één kamer i.p.v. met verschillende disciplines.
- Het werkproces verloopt beter wanneer ik met mijn eigen team op één kamer zit i.p.v. met verschillende disciplines
- Ik overleg liever met mijn collega hoe een taak moet worden aangepakt, i.p.v. dat ik er zonder overleg aan begin.

Label: “eigen team”

Indicatoren voor de derde label/factor:

- Wanneer een collega mij om hulp vraagt ervaar ik dit vaak als storend.
- Voorstellen van anderen voor verbeteringen in mijn werk beschouw ik als storend.

Label: “samenwerking collega storend”

Motivatie

1. De volgende drie zijn er uit gehaald:

- Bij dit project weet iedereen wat van hem verwacht wordt en hoe hun werk samenhang met het werk van andere betrokkenen.
- Ik ga gewoon verder met mijn werk wanneer werkinformatie ontbreekt.
- Ik vind het fijn wanneer andere afhankelijk zijn van mijn taak.

De volgende twee hebben een communaliteit net onder de minimale grens van 0.25, maar zouden wellicht toch goed passen binnen de factor. Deze zijn er dus nog niet uitgehaald:

- Ik ben altijd op zoek naar nieuwe manieren om mijn werk te doen.
 - Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.
2. Er zijn drie factoren, waarvan één een twijfelgeval is omdat hij net op de grens ligt.
3. Er is nog geen sprake van een simple structure. Vijf stellingen zijn twijfelgevallen:
- Ik controleer mijn werk liever wanneer het helemaal af is. → doet nauwelijks mee aan interpretatie en laad ongeveer gelijk aan twee factoren. Deze wordt verwijderd.
 - Persoonlijk houd ik niet van afwijkende of ongebruikelijke ideeën. → wordt om dezelfde reden als de vorige verwijderd.
 - Ik vind het leuk om met nieuwe en innovatieve technieken te werken. → Laad hoog op een factor en laag op een ander, deze wordt dus behouden.
 - Ik werk met gevoelige informatie en vind het daarom lastig dit te delen. → laad als enige op één bepaalde factor en wordt dus verwijderd.

MOTIVATIE	Factor	
	1	2
Ik vind het leuk om met nieuwe en innovatieve technieken te werken.	,548	
Ik ben altijd op zoek naar nieuwe manieren om mijn werk te doen.	,520	
Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.	,453	
Lean planning zal een positieve invloed hebben op mijn project aandeel.		-,736
Het is de taak van de (project)leider, en niet die van het team, om faciliterend op te treden en het samenwerkingsproces in goede banen te laten leiden.		,528

4. Omdat de correlatie in een grijs gebied ligt wordt de pattern matrix met de rotated factor matrix vergeleken in een orthogonale iteratie:

MOTIAVTIE	Factor
-----------	--------

	1	2
Lean planning zal een positieve invloed hebben op mijn project aandeel.	,718	
Het is de taak van de (project)leider, en niet die van het team, om faciliterend op te treden en het samenwerkingsproces in goede banen te laten leiden.	-,512	
Ik vind het leuk om met nieuwe en innovatieve technieken te werken.		,556
Ik ben altijd op zoek naar nieuwe manieren om mijn werk te doen.		,491
Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.		,442

De simple structure wordt niet veel beter benaderd bij een scheve rotatie, er wordt dan gekozen voor een orthogonale structuur. Er is nog geen volledige tevredenheid over de tweede factor omdat deze alleen één indicator heeft die voldoende laadt. Er moet daarom geforceerd worden om met één factor te benaderen.

MOTIVATIE	Factor
	1
Ik vind het leuk om met nieuwe en innovatieve technieken te werken.	,652
Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.	,461
Ik vind het leuk om met nieuwe en innovatieve technieken te werken.	,428
Lean planning zal een positieve invloed hebben op mijn project aandeel.	,389

Hoewel er veel is ingeleverd aan hoge ladingen, is er nu wel iets wat meer de deelvragen kan beantwoorden op gebied van bereidheid om een nieuwe methodiek aan te leren.

5. De indicatoren voor de factor zijn:

- Lean planning zal een positieve invloed hebben op mijn project aandeel.
- Het is de taak van de (project)leider, en niet die van het team, om faciliterend op te treden en het samenwerkingsproces in goede banen te laten leiden.
- Ik vind het leuk om met nieuwe en innovatieve technieken te werken.
- Ik ben altijd op zoek naar nieuwe manieren om mijn werk te doen.
- Wanneer iets niet helemaal goed loopt zoek ik het tot de bodem uit hoe en waarom.

Label: "bereidheid innovatie in werken"

Planning

1. Behandelde stellingen:

- Ik laat pas op het moment van de afspraak of deadline weten dat het werk langer zal duren. Deze wordt verwijderd door een veel te lage communaliteit.

- Deadline gaat voor resultaat. Deze wordt ook verwijderd om dezelfde reden.

2. Drie factoren, met een eigenwaarde van minimaal 1. Eén daarvan heeft slechts één indicator die er op laadt en moet daarom verwijderd worden. Er zijn dus twee factoren die worden meegenomen en dit wordt ook zo geforceerd.

3. Eerst dienen de laag ladende indicator nog weggehaald te worden:

- Efficiënter plannen kost werk voor de discipline.

Hoewel er nog één indicator op twee factoren laadt, is er nu simple structure benadering een scheve rotatie omdat het extreem hoog op de ene en extreem laag (net boven 0.30) op de andere laadt. Toch wordt de laatste indicator nog verwijderd omdat deze niet in het rijtje past:

- Het verkorten van de projectduur is positief voor mijn moederbedrijf.

Nu is de simple structure beter benaderd.

PLANNING	Factor	
	1	2
Lean planning leent zich goed om alle beschikbare kennis onder controle te houden.	,843	
Lean planning leent zich goed om alle beschikbare kennis naar boven te halen.	,803	
Ik plan liever iets meer tijd in dan daadwerkelijk nodig, om het risico op vertraging te verlagen.		,767
Ik schat de benodigde kosten en tijd liever ruim in.		,650

4. De oplossing is gezien de erg kleine correlatie (-0.038) orthogonaal.

5. Indicatoren eerste label:

- Lean planning leent zich goed om alle beschikbare kennis naar boven te halen.
- Lean planning leent zich goed om alle beschikbare kennis onder controle te houden.

Label: "Lean planning is nuttig"

Indicatoren tweede label:

- Ik schat de benodigde kosten en tijd liever ruim in.
- Ik plan liever iets meer tijd in dan daadwerkelijk nodig, om het risico op vertraging te verlagen.

Label: “ruim plannen”

Ervaring

1. Alle indicatoren hebben plausibele communaliteiten.
2. Er zijn twee eigenwaarden van minimaal een één, alleen één daarvan ligt heel dicht op de minimale grens. Het is dus nog een twijfelgeval.
3. Volgende indicatoren bekeken:
 - Werkplekoptimalisatie – 5s laadt met een lading in het twijfel gebied op twee factoren. Deze moet worden verwijderd, ook al behoort het tot de Lean methodieken. Hierdoor wordt er toch gekozen voor slechts één factor, wat in stap twee nog onduidelijk was.

ERVARING	Factor
	1
Just in Time	,786
Concurrent Engineering	,705
Visualiseren	,701
Lean Planning	,675
Fouten Vermijden	,538
Value Stream Mapping	,485

4. Er is slechts één factor dus hij is onafhankelijk.
5. De indicatoren zijn:
 - Value StreamMapping (VSM): waardestromaanalyse van je processen
 - Lean Planning: samen met alle betrokkenen een planning maken
 - Concurrent Engineering: gezamenlijk aanpakken van de engineering door in 1 ruimte samen te werken
 - Fouten vermijden – Poka Yoke
 - Visualiseren (een plaatje zegt meer dan 1000 woorden): doelen en resultaten, veiligheidsaspecten, processen en de besturing daarvan.
 - Just-In-Time (JIT): de juiste hoeveelheid van het juiste product op de juiste manier op het juiste moment op de juiste plaats.

Label: “ervaring Lean”

Verwachting

1. Alle indicatoren hebben plausibele communaliteiten.

2. Er zijn twee eigenwaarden van minimaal een één, alleen één daarvan ligt heel dicht op de minimale grens. Het is dus nog een twijfelgeval.
3. Omdat één factor makkelijker te interpreteren is dan twee, wordt hiervoor gekozen, aangezien beide gevallen goed kunnen zijn zoals uit stap 2 bleek:

VERWACHTING	Factor
	1
Lean Planning	,699
Werkplekopt 5s	,689
Visualiseren	,659
Just In Time	,641
Fouten Vermijden	,608
Concurrent Engineering	,548
Value Stream Mapping	,521

4. Er is slechts één factor dus hij is onafhankelijk.

Label: “verwachting Lean”

Schaalconstructiemodel

Er wordt eerst bekeken of factorscores, somscores kunnen worden geconstrueerd of dat er surrogaat variabelen moeten worden gebruikt. De collegeslide in figuur 3 geeft aan wanneer wat gekozen dient te worden en waarom:

samenvatting constructie nieuwe variabelen

- **surrogaat variabele**
 - eenvoudig, maar niet alle facetten meegenomen, en kans op hoge meetfouten
- **factorscore**
 - met weging voor mate waarin variabele factor bepaalt, maar ook laag ladende variabelen spelen rol
- **somscore / schaal**
 - compromis: alleen hoog ladende variabelen meegenomen en alle facetten zijn vertegenwoordigd
 - meestal het beste!

Deelvragen:

- 1) Is de Lean filosofie al bekend binnen het A4all project en wordt het al toegepast?
- 2) Is er een relatie tussen de medewerkers die een Lean training hebben gehad en de bereidheid om mee te werken aan en de verwachting van de Lean filosofie?
- 3) Welke Lean methodieken geniet de grootste voorkeur en verwachting uit bij de betrokken projectmedewerkers?
- 4) Wat is de relatie tussen het opleidingsniveau van de betrokken projectmedewerkers en de bereidheid tot participatie?
- 5) Wat is de relatie tussen de hoogte van kennis over Lean en de bereidheid tot participatie van de betrokken projectmedewerkers?
- 6) Wat is de relatie tussen de hoogte van verwachting over Lean en de bereidheid tot participatie van de betrokken projectmedewerkers?
- 7) Wat is de relatie tussen de functie van de betrokken projectmedewerkers en de bereidheid tot participatie?

Een overzicht van alle thema's en gevonden labels waarvoor schaalconstructies voor moet worden gemaakt:

Thema	Label	Hoort bij deelvraag:
Teamcohesie	Gezamenlijke toewijding	
Teamsamenhang	Samenwerking collega storend	
Motivatie	Bereidheid innovatie in werken	2, 4, 6, 7

Planning	Ruim plannen	
Ervaring	Ervaring Lean	1, 2
Verwachting	Verwachting Lean	2, 6

Bereidheid innovatie in werken

Motivatatie	Factor
	1
Motivatatie: leuk innovatief te werken	,652
Motivatatie: Ik zoek graag iets tot de bodem uit	,461
Motivatatie: Ik vind het leuk om met nieuwe en innovatieve technieken te werken.	,428
Motivatatie: Lean planning zal een positieve invloed hebben op mijn project aandeel.	,389

Als de betrouwbaarheid gecontroleerd wordt, wordt voor de vier indicatoren gezamenlijk een Cronbach's Alpha van 0.540 verkregen.

Ervaring Lean

ERVARING	Factor
	1
Just In Time	,786
Concurrent Engineering	,705
Visualiseren	,701
Lean Planning	,675
Fouten Vermijden	,538
Value Stream Mapping	,485

De betrouwbaarheid moet weer gecontroleerd worden door middel van een Cronbach's Alpha test. Deze is met alle zes indicatoren 0.814 en met slechts de drie hoogst ladende 0.810.

Verwachting Lean

	Factor
	1
Lean Planning	,699
Werkplekoptimalisatie 5s	,689
Visualiseren	,659
Just in Time	,641
Fouten Vermijden	,608
Concurrent Engineering	,548
Value Stream Mapping	,521

Bij een factorscore met alle indicatoren er in komt er een Cronbach's Alpha van 0.811 uit. Bij verwijdering van indicatoren neemt deze waarde af.

C. Geschiedenis A4all project

1953 De eerste plannen

De A4 Midden-Delfland komt voor het eerst ter sprake in een rapport van de provincie Zuid-Holland. De provincie dringt er bij de Minister van Verkeer en Waterstaat op aan om deze weg op te nemen in het Rijkswegenplan 1958. De weg staat bekend als Zoomweg, Beneluxweg, rijksweg 19 en uiteindelijk als onderdeel van rijksweg A of A4.

1968-1972 Gedeeltelijk uitvoering

Nadat hiertoe reeds in 1965 door de gemeente Schiedam een aanlegvergunning was verstrekt, wordt eind 1968 begonnen met de aanleg van het zandlichaam tussen het Kethelplein en de noordelijke grens van de gemeenten Schiedam en Vlaardingen. Aansluitend op de grondverwerving werd in 1972 in Midden-Delfland vanuit het zuiden begonnen met de opspuiting van het zandlichaam. Met de aanleg beginnen actiegroepen uit de omgeving hun bezwaren te uiten over de aantasting van het gebied en de geluidsoverlast; door de gepland aanleg op maaiveld zou een geluidsscherp van 15 meter hoog nodig zijn. Ook de provincie en het Openbaar Lichaam Rijnmond twijfelen aan de noodzaak. De in 1972 opgerichte werkgroep Stop Rijksweg 19 ontpopt zich in de loop der jaren tot grootste tegenstander.

1976 Werkzaamheden stopgezet

Bij de behandeling van het wetsontwerp Reconstructie Midden-Delfland in het najaar van 1976 wordt door de Tweede Kamer de motie Voortman (PvdA) aangenomen. In deze motie wordt gevraagd de werken stil te leggen en onderzoek te doen naar alternatieven zoals verbreding A13 en verbetering van het openbaar vervoer. Het bleek dat één Kamerlid zich had vergist waardoor hij tegen de aanleg stemde in plaats van voor.

1977-1980 Structuurschema Verkeer en Vervoer

In het 'Structuurschema Verkeer en Vervoer' uit 1977 wordt de aanleg van rijksweg A4 noodzakelijk geacht. De gemeenten Schipluiden, Schiedam en Rijswijk, de gemeenten over wiens grondgebied de A4 komt te lopen, hebben inmiddels de A4 in de bestemmingsplannen opgenomen. Op basis van de heroverweging naar aanleiding van de motie Voortman wordt door de Tweede Kamer in november 1980 ingestemd met voltooiing van rijksweg 4. Zij stelt daarbij als voorwaarde dat de weg alleen mag worden aangelegd conform de Motie Cornelissen als deze landschappelijk wordt ingepast in het kader van de reconstructie Midden-Delfland.

1984-1990 Inpassingsrapport

Rijkswaterstaat publiceert in 1984 het 'Inpassingsrapport van de A4 door Midden-Delfland' waarin wordt geconcludeerd dat landschappelijke inpassing mogelijk is; er volgen protesten van Delft, Vlaardingen, Schiedam en de werkgroep Stop Rijksweg 19. Inmiddels is de weg in 1985 in de streekplannen van Rijnmond en Zuid-Holland West opgenomen met een goede milieu hygiënische inpassing als voorwaarde.

1988-1990 Structuurschema Verkeer en Vervoer II

In 1988 leg de minister met de Reconstructiecommissie afspraken vast in een plan van eisen waarin hoogt van de weg, geluidswallen en geluidsniveau worden vastgelegd. In hetzelfde jaar noemt de vierde nota de A4 als internationale ontsluitingsweg van de Randstad, tegelijk presenteren natuur- en milieuorganisaties een plan voor gebruik van het zandlichaam als sneltramverbinding. In 1988 stemt de Kamer in met de voorgestelde inpassing, uitvoering laat op zich wachten door procedurele en budgettaire problemen. In 1990 na een grote publieksactie wordt de motie van Gijzel om de A4 af te voeren van het hoofdwegennet in het Structuurschema Verkeer en Vervoer verworpen.

1992 A4 Rijkswijk-Delft

In 1992 verliezen milieuorganisaties en een aantal burgers een rechtszaak tegen RWS en kan worden begonnen met de uitvoering van het gedeelte Rijkswijk-Kruithuisweg te Delft. Kort daarna wordt bekend dat voor de opname van de inpassing van de A4 tussen Delft en Schiedam nog wel een MER-procedure moet worden doorlopen.

1992-1996 Start procedure

In mei 1992 start minister Maij-Weggen de procedure, deze is in 1996 af en de ministers Jorritsma en de Boer kiezen voor een maaiveldvariant. Aanleg op het zandlichaam met geluidsschermen van 4,3 meter hoog in Midden-Delfland en 13 meter hoog tussen Vlaardingen en Schiedam op het al 6 meter hoge zandlichaam blijkt een weinig realistische oplossing. De beschikbare budgetten sluiten uit dat voor duurdere alternatieven en aanvullende inpassingsmaatregelen gekozen kan worden. De Tweede Kamer verwierpt deze optie. De provincie Zuid-Holland wil een verdiepte ligging en de Stadsregio wil een overkapping in het stedelijk gebied.

1998 Budget verplaatst naar spoortunnel Delft

Het budget in het Meerjarenprogramma Infrastructuur en Transport (MIRT) wordt opgehoogd, maar na een motie Giskes/Heemst worden de middelen verschoven naar onder andere de spoortunnel Delft.

1999 IODS

Tegenstanders en milieugroeperingen organiseren een Nieuwjaars wandeling tegen de aanleg van de A4. D66 en PvdA pleiten voor uitstel van de A4 Midden-Delfland. In september 2000 wordt een stuurgroep ingesteld onder leiding van de provincie Zuid-Holland, met als opdracht om binnen negen maanden te komen tot een kwaliteitsprogramma voor Midden-Delfland met daarin een beeld van de A4: de stuurgroep Integrale Ontwikkeling tussen Delft en Schiedam (IODS).

2001 IODS II

Op verzoek van de toenmalige minister van Verkeer en Waterstaat, mevrouw Netelenbos, ontwikkelen de provincie samen met andere partijen in 2001 een plan voor een integrale gebiedsontwikkeling: Integrale Ontwikkeling tussen Delft en Schiedam (IODS) dat in het rapport 'Kansen benutten, impasses doorbreken' is beschreven. Dit plan is ook bekend onder de naam 'Plan Norder', naar de gedeputeerde Marnix Norder, de initiatiefnemer van het plan. Op basis van dit plan

heeft de Tweede Kamer de minister van Verkeer en Waterstaat gevraagd de tracé/MER-procedure te hervatten en daarin de IODS-variant op te nemen. Oud-minister De Boer van Verkeer en Waterstaat heeft Rijkswaterstaat opgedragen de studie naar de aanleg van de A4 Delft-Schiedam te hervatten.

2002 MER

De Tweede Kamer neemt de motie Giskes aan, waarin de Minister wordt verzocht ook het Veilingroute-alternatief met en zonder Oranjetunnel mee te nemen in de MER-studie.

2003 Voorbereiding wordt voortgezet

In het kader van het Meerjarenprogramma Infrastructuur en Transport (MIRT) stemt de Tweede Kamer op 15 december 2003 voor voortzetting van de voorbereidingen voor de A4 Delft-Schiedam.

2004 Startnotitie A4 Delft-Schiedam

In maart 2004 geven het Ministerie van VROM, V&W en LNV aan een financiële bijdrage te willen leveren aan de financiering van het kwaliteitsprogramma. Mei 2004 organiseren de tegenstanders van de A4 een groot protest op het zandlichaam. In juli 2004 verschijnen de richtlijnen voor de TN/MER A4 Delft-Schiedam.

2005 TN/MER

De studie van het alternatief A13 + A13/A16 blijkt een fout te bevatten in de berekening van het verkeersmodel. In dit model zijn ter plaatse van het knooppunt Ypenburg te weinig rijstroken ingevoerd (de omissie Ypenburg). Na herstel van deze fout, blijkt het alternatief wel geschikt om verder mee te nemen in de procedure. Stap één van de Trajectnota/MER moet worden herzien.

2006 TN/MER en IODS-Convenant

Eind januari geeft de Commissie MER haar toetsingsadvies voor de trajectnota/MER. Zij geeft aan dat het Bevoegd Gezag (de ministers van VROM en V&W) nu voldoende informatie heeft om een keuze te kunnen maken tussen de A4 en verbreding van de A13 in combinatie met de aanleg van de A13/A16. In juni maken de Provincie en het Ministerie bekend dat er 100 miljoen euro extra beschikbaar komt voor de A4 en de inpassing mits alle partijen een convenant tekenen. 23 juni tekenen alle partijen in Nieuwspoort het IODS-convenant.

2007 Herziening Trajectnota/MER

De herziene Trajectnota/MER stap 1, die eind 2007 klaar is, vervangt de eerdere versie uit 2005. Op basis van de nieuwe nota kozen de ministers van V&W en VROM twee alternatieven om in stap 2 verder te onderzoeken: de A4 Delft-Schiedam en de verbrede A13 + nieuwe A13/A16.

2008 Voorkeur A4 alternatief

In januari 2008 spreekt de minister op basis van de Trajectnota/MER stap 1 zijn bestuurlijke voorkeur uit voor het aanleggen van de A4 tussen Delft en Schiedam. Ondanks de voorkeur wordt in stap 2 ook het alternatief A13 + A13/A16 op hetzelfde niveau uitgewerkt.

2009 Keuze voor de A4 Delft-Schiedam

Op 3 september 2009 hakken de ministers Eurlings (Verkeer en Waterstaat) en Cramer (VROM) samen de knoop door. De keuze om de 7 kilometer van de A4 tussen Delft en Schiedam uit te werken in een Ontwerp Tracé Besluit is gemaakt. Het verkeersinfarct tussen Den Haag en Rotterdam en de leefbaarheid langs het onderliggende wegennet worden zo aangepakt.

2010 Ontwerp Tracébesluit (OTB)

In maart 2010 is het OTB gepubliceerd. In dit document staat de weg uitgebreid beschreven, met de aan te leggen bruggen/viaducten en andere bouwwerken, compensatiemaatregelen en andere belangrijke besluiten.

2010 Tracébesluit

Op 2 september 2010 besluiten minister Eurlings van V&W en minister Huizinga van VROM om de A4 Delft-Schiedam aan te leggen. Deze beslissing is nodig om de mobiliteit tussen Den Haag en Rotterdams en de leefbaarheid langs het onderliggend wegennet te verbeteren. De weg zorg, samen met de plannen voor een metro-achtige treinverbinding tussen Den Haag en Rotterdam, voor een impuls voor de mobiliteit in de zuidelijke Randstad. Gelijktijdig met het Tracébesluit hebben de bestuurlijke partijen binnen IODS aanvullende afspraken over IODS vastgelegd in de Bestuurlijke Overeenkomst IODS.

2011 Uitspraak Raad van State

Op 6 juli 2011 besluit de afdeling bestuursrechtspraak van de Raad van State het Tracébesluit A4 Delft-Schiedam onherroepelijk te verklaren.

2011-2015 Op weg naar realisatie IODS

Gelijk met de planvorming rond de A4 Delft-Schiedam zijn ook de andere IODS-projecten tot ontwikkeling gekomen. Zo heeft gemeente Midden-Delfland een Saneringstrategie Glas ontwikkeld en is voor de realisatie van natuur door provincie Zuid-Holland een Natuurbeheersplan opgesteld. Op basis van het Routestructuurplan 2009 kan in 2011 binnen IODS-verband worden gestart met de aanleg van de recreatieve voorzieningen. Om de melkveehouderij in Midden-Delfland impulsen te geven liggen plannen klaar voor onder meer de pilot Duurzaam boer blijven in Midden-Delfland. Gemeente Schiedam heeft voor de stedelijke ontwikkeling van het gebied tussen Schiedam en Vlaardingen het plan 'Alles onder een dak' gepresenteerd. Dit plan voorziet onder meer in sportvelden op het dak van de toekomstige landtunnel.

2011 Planning realisatie A4

Op 30 september 2011 verstuurt Rijkswaterstaat voornemen tot gunnen naar inschrijvers. De Nederlandse combinatie A4all (Boskalis BV, Heijmans Infra Geïntegreerde Projecten BV, KWS Infra BV, Van Hattum en Blankevoort BV, Vialis BV) heeft zowel de laagste aanbidding gedaan als de beste EMVI-score behaald. Op 18 oktober 2011 is het bouwcontract met A4ll getekend.

2012 Start aanleg

De aanleg is in 2012 gestart. De A4 Delft-Schiedam wordt in 2015 opengesteld.

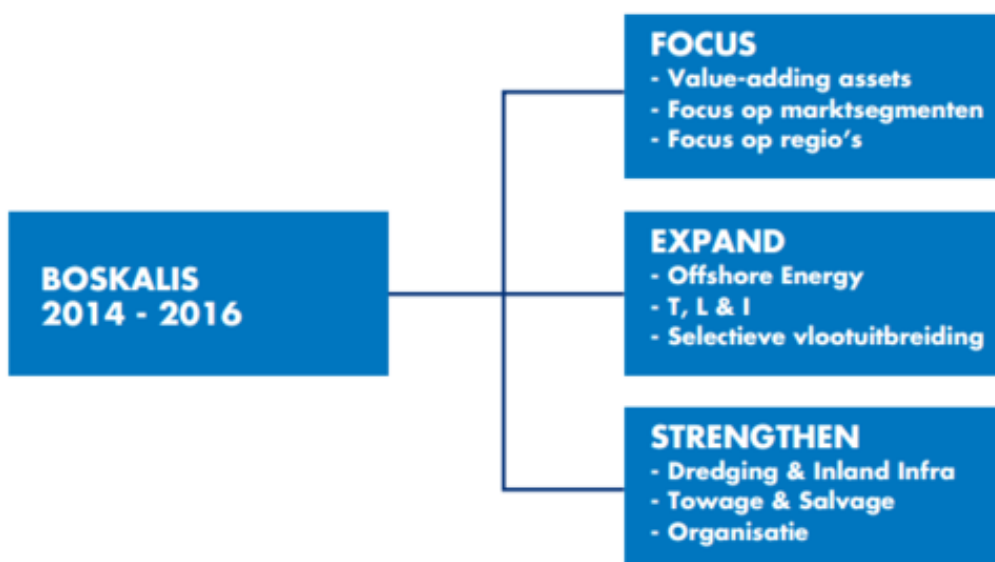
D. Strategy of the three A4all organizations

Boskalis strategie:

“De strategie van Boskalis voor 2014-2016 vloeit logisch voort uit onze missie en visie.

Wij zijn wereldwijd een toonaangevende dienstverlener en expert op het gebied van baggeren en maritieme diensten en creëren een nieuwe horizon voor al onze stakeholders. Dit doen wij door een unieke combinatie van mensen, materieel en activiteiten. Volgens de hoogste standaarden van veiligheid en duurzaamheid leveren wij innovatieve en competitieve totaal oplossingen voor onze klanten in de offshore energiesector, havens en kust- en deltagebieden.

Wij streven naar verdere expansie van ons bedrijf. We richten ons vooral op markten met structurele groei.” (Boskalis website, 2015)



Heijmans strategie:

Heijmans heeft de ambitie om de beste speler in de branche te worden. Dit bereiken we door de kernactiviteiten via inkoop, commercie, tender- en projectmanagement te verbeteren en te vernieuwen en zo ons marktaandeel in bestaande markten te vergroten en nieuwe markten te veroveren. Daarvoor is een cultuur van discipline en eenheid nodig.

Cultuur

Binnen Heijmans geldt een gedragscode. In deze gedragscode zijn de acht integriteitswaarden verwoord waarvan Heijmans verwacht dat deze door haar medewerkers worden gerespecteerd in hun werkzaamheden voor Heijmans. Basis hiervoor zijn drie gedragswaarden: professioneel-inventief-samenwerken. Voorwaarde voor integer handelen is openheid die onder andere wordt gestimuleerd door voorbeeldgedrag van het management. Daarnaast wordt medewerkers de mogelijkheid geboden melding te doen van gedrags- en integriteitskwesties. Daarvoor kunnen medewerkers terecht bij

aangewezen vertrouwenspersonen. In de Commissie Integriteit komen tweemaal per jaar issues, dilemma's en thema's op het gebied van integriteit en alle daaraan gelieerde onderwerpen aan de orde. Deze commissie doet op basis daarvan aanbevelingen aan het bestuur over het te voeren beleid. (website Heijmans, 2015)

VolkerWessels strategie:

“Belangrijke pijlers onder onze strategie zijn de bewuste keuze voor onze thuismarkten Nederland, Verenigd Koninkrijk en Canada/Verenigde Staten en een duidelijke diversificatie door een gezonde spreiding van onze disciplines en activiteiten. Tegelijkertijd zijn een zekere schaalgrootte en impact onmisbaar. We opereren in die markten waarin we substantieel het verschil kunnen maken. Dat betekent een kritische en vastberaden kijk op kansen en uitdagingen en een sterke focus op (kwalitatief) marktleiderschap, een brede positie in de waardeketen, meerjarige contracten en onderscheidende specialismes.

Innovatief en integraal

VolkerWessels ontleent een solide financiële positie aan een combinatie van ondernemerschap, financiële en operationele discipline, gedegen risicomanagement en proces- en kostenbeheersing. Die focus sluit aan bij ons strategisch speerpunt van operational excellence. Met duurzame innovaties en slimme concepten als onze motor. Daarbij zoeken we nadrukkelijk de samenwerking met betrouwbare partners. Ook intern werken onze werkmaatschappijen intensief samen. Want naast onze lokale en regionale betrokkenheid schuilt ook daarin de kracht van VolkerWessels: opdrachtgevers van dienst zijn met een integrale en multidisciplinaire aanpak.” (website VolkerWessels, 2015)

E. The 8 Types of Waste

Apart from the steps to analyse production processes and rules of thumb, Lean identifies different types of waste. Traditionally the Lean literature describes seven types of waste, later in time one is added to this list. Waste is everything in a company that requires resources and does not add value for the customer. The way to reduce cost prices is to structural elimination of this waste (ARPA, 2010, p. 28).

Overproduction

Over-production means producing more than is required for the next process. This is the worst form of waste, because it contributes to the other six types of waste. Overproduction is wasteful because: materials run out faster, the unnecessary use of manpower, unnecessary material is consumed, machinery unnecessarily occupied, there is unnecessary storage space used for the products produced, there is capital loss, there unnecessary transportation is necessary, and unnecessary administration is committed. It is often a result of fear for machine defects, long changeover times, many failures of products, fluctuation in personnel or machine capacity, depart optimization or unreliable delivery (ARPA, 2010, p. 28).



Waiting

Production personnel and/or equipment that are waiting on each other, defects, delayed deliveries, etc. are forms of waste. Waiting is waste because it adds nothing to the product. It is often a result of too few items or an operator who does nothing while his machine works (ARPA, 2010, p. 29).



Transport

The unnecessary transportation of goods, for example, to a warehouse or between one operation to the next operation. Transport is wasteful because it adds nothing to a product and there may occur loss of quality due to damage. It is often a result of work on isolated positions. (ARPA, 2010, p. 29).



Defects/over performance

Producing below or above requirements is a waste. Under or over performance are forms of waste because the unnecessary time and money involved the unnecessary use of manpower, it creates unnecessary waste of material and procurement operations and unnecessary raw material is stored. It is often a result of ambiguity slow reactions, design changes and a lack of understanding by operating personnel on customer demand. (ARPA, 2010, p. 29).



Inventory

Having an inventory is wasteful because of the unnecessary use of manpower, the unnecessary use of material, the unnecessary occupied space, the causes capital loss on the inventory, there is a risk of deterioration due to damage, there is a risk for decay (mainly food) and unnecessary administration must be conducted. It is often a result of overproduction or imbalance in the process. (ARPA, 2010, p. 29).



Motion/unnecessary actions

Production personnel can make unnecessary movements such as searching for parts, tools, information, etc. Movement is wasteful because it adds nothing to a product. It is often a result of a poorly designed workplace, the unavailability of materials, tools or information, the involvement of many parties in a decision process or working in isolated positions (ARPA, 2010, p. 29).



Corrections/disruptions

Quality inspections, making adjustments, resolving defects, are examples of activities that do not add value to the product and are therefore unnecessary. It leads to loss of production time and unnecessary inventories. They are often a result of technical malfunctions and poorly designed processes (ARPA, 2010, p. 29).



Not used creativity of employees

Not listening to your employees, not offering good equipment and resources, etc. This last waste is never mentioned by Toyota because they expect creativity of employees. Not using creativity of employees is a huge waste for identifying problems as solving problems. Creativity of employees could solve the other seven wastes (ARPA, Lean Bouwen Training, Waarde- Tijd - Leren, 2010, p. 30).



F. Lean Methods and Tools

Value Stream Mapping

When the entire value stream for each product or product family is identified the next step of Lean thinking is established. This step is rarely done by companies and could lead to staggering amounts of *Muda* (waste). Analysing the value stream will almost always lead to three types of actions happening along the value stream:

1. The most obvious action is that many steps will create value as perceived by the customer.
2. Many other steps will be found that create no value but are unavoidable with current production assets and technologies (e.g. inspections to ensure quality), type one *Muda* (**Muda 1**).
3. There will be steps that create no value and are immediately avoidable Type two *Muda* (**Muda 2**) (Womack, 2003, p. 38).

The value stream mapping approach can be used to create a value stream. The three categories mentioned above need to be identified in a value stream map. Womack mentions this organizational mechanism as the *Lean enterprise*, Lean thinking must go beyond the firm, to look at the whole, the entire set of activities have to be analysed. A Lean enterprise is a continuing conference of all the concerned parties to create a channel for the entire value stream, cooperation to eliminate all the *Muda*.

According to Rother (1999), the value stream mapping is an essential tool because:

1. Tool to visualize the whole process
2. Tool to see more than only waste
3. Common language is provided with this tool
4. Decisions about the flow recognisable
5. It forms the fundament of an implementation plan
6. Information flow and material flow is linked
7. Value stream mapping is a qualitative tool

With the three types of action, mentioned earlier in mind, with value stream mapping is meant the following: the path of service/product production has to be followed from customer to supplier and represented carefully in a drawing that represents every process in the information and material flows (Rother, 1999, p. 2). When the value stream map is made it is essential that there is one person responsible for making the value stream map. He has to become responsible for the whole material and information flow, call him the value stream manager (Rother, 1999, p. 5). This is necessary so one person is reliable and has the overview. In the following Figure an illustration is shown of the steps consisting of the value stream mapping process. Step 1, choose the product family. Step 2, drawn a current state map that shows the current value map. Step 3, make the future state map, this is the best case scenario without all the *Muda 2* (non-value adding activities). Step 4, a work plan has to be formulated and drawn, which is followed by the implementation (Rother, 1999, p. 7).

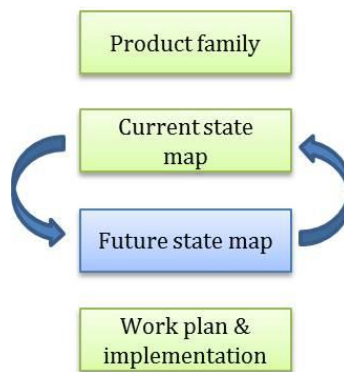


Figure 21: Value stream mapping steps

The current state map

In order to create a current state map that is specific and reliable, some important steps are to be followed. Step 1, collection of current state information needs to take place. Step 2, the entire value stream needs to be walked through. Step 3, an important aspect is that the work has to be done upstream. Step 4, measure the time, this is needed at various stages of processes to see whether there are flaws and to record times. Step 5, for the last step it is important that one person maps out the entire value stream (Rother, 1999, p. 10). The steps are visualized in Figure 22 underneath.

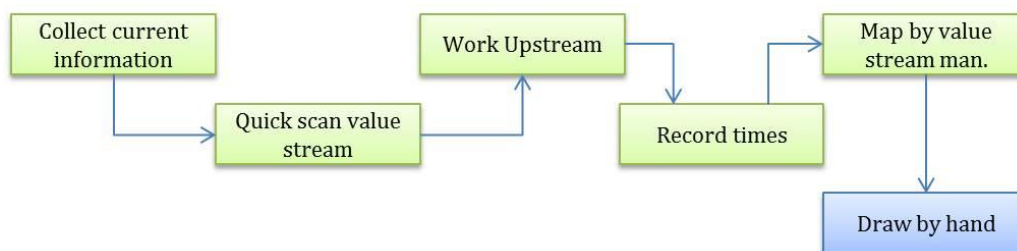


Figure 22: Steps current state map

The future state map

The objective of a future state map is to architect each processes as close as possible to contribute only what the customer needs, when the customer needs it. This is done by building a chain of production where the separated processes are connected to their customers by continuous flow or pull (Rother, 1999, p. 49). The terms flow and pull will be explained in the coming sections.

Concurrent Engineering

“Concurrent engineering (CE) is a method that is used in the product development process. It is different than the traditional approach from the product development in which it uses simultaneous, something that sequential, processes. By finishing the tasks simultaneously, product development can be obtained more efficiently and in substantial saving in costs.

In the traditional approach finishing all the physical manufacture of a prototype before realizing any test, but In the concurrent engineering it allows to design and multiple analyses to happen at the same

time, and at different times, before the real unfolding. This multidisciplinary approach accentuates work in equipment with the use of cross-functional equipment, and allows so that the employees work in the end of collaboration in all the aspects of a project of the beginning.

Also known like the iterative method of the development, concurrent engineering requires the continuous revision of the progress of equipment and the frequent revision of the plans of the project.

The analysis reasoned behind this creative, modern approach is that whichever previous those errors can be shortages, easiest and less expensive they are to correct.

The concurrent engineering professionals explain from their experience that this system of management and design offers several advantages, including the quality of the increasing product for the end user, faster times of the product development, and lower costs for the manufacturer and the consumer.

There are some disadvantages associated to the putting in initial practice of concurrent engineering, including the necessity of the considerable reconstruction of organization and the extensive retraining of workers. Such potentially breaking changes and requisite aggregates of work can be fulfilled resistance of in charge and other employees. Also, there are generally considerable difficulties in data of transference between employees in diverse departments that can require additional pursuit of computer software applications. Besides these significant initial investments, the organizations whom they adopt a concurrent model of the work of engineering must typically wait for several years before considering the advantages of this transition” (UKessays, 2013).

Workplace Optimization – 5s

The 5S refer to the five dimensions of workplace optimization: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). The 5S Program defines the steps that are used to make all work spaces efficient and productive, help people share work stations, reduce time looking for needed tools and improve the work environment. Additionally, there is an additional phase, safety, which is sometimes included.

Sorting (Seiri): Eliminate all unnecessary tools, parts, instructions. Go through all tools, materials, etc., in the plant and work area. Keep only essential items. Everything else is stored or discarded.

Straightening or Setting in Order (Seiton): There should be a place for everything and everything should be in its place. The place for each item should be clearly labelled or demarcated. Items should be arranged in a manner that promotes efficient work flow. Workers should not have to repetitively bend to access materials. Each tool, part, supply, piece of equipment, etc. should be kept close to where it will be used (i.e. straighten the flow path). Seiton is one of the features that distinguishes 5S from "standardized cLean-up".

Shining or Sweeping or cLeanliness / Systematic cLeaning (Seiso): Keep the workplace tidy and organized. At the end of each shift, cLean the work area and be sure everything is restored to its place. This makes it easy to know what goes where and ensures that everything is where it belongs. A key

point is that maintaining cleanliness should be part of the daily work – not an occasional activity initiated when things get too messy.

Standardizing (Seiketsu): Work practices should be consistent and standardized. Everyone should know exactly what his or her responsibilities are for adhering to the first three S's.

Sustaining the discipline (Shitsuke): Maintain and review standards. Once the previous four S's have been established, they become the new way to operate. Maintain focus on this new way and do not allow a gradual decline back to the old ways. While thinking about the new way, also be thinking about yet better ways. When an issue arises such as a suggested improvement, a new way of working, a new tool or a new output requirement, review the first four S's and make changes as appropriate.

Poka Yoke

Poka yoke is a Japanese term used in Lean manufacturing and means fool proof (a Poka is an unintentional error and yoke means possible). It is a method to form a production process in such way that it becomes almost impossible to make mistakes. An operation is carried out in a way that the correct operation is forced. The concept was launched by Shigeo Shingo as part of the Toyota Production System.

An example is the SIM card in GSM. It is designed in such a way that they can be placed in a way in the GSM device. There is a "cut" corner.

Kaizen

Continuous improvement (Kaizen) with use of the Deming cycle. Deming was one the founders of quality management. He created for continuous improvement a standardized working method: the PDCA-cycle of Deming-cycle.

- 1) **Plan:** Make a plan of action, for example: analyse the problem within the process, set a standardized work method. When a process is new, this step is bulkier. In that case, a process should be defined with all the preconditions, tasks and responsibilities.
- 2) **Do:** Execute the plan. Work with the new process or newly made agreements.
- 3) **Check:** Are the result conform the plan? If so move forwards to the next plan, If not, what should be changed in such way to prevent this failure to occur and the next time the plan will be executed in the right way.
- 4) **Act:** implement the adjustments en go on with the improved process and/or adjusted agreements.

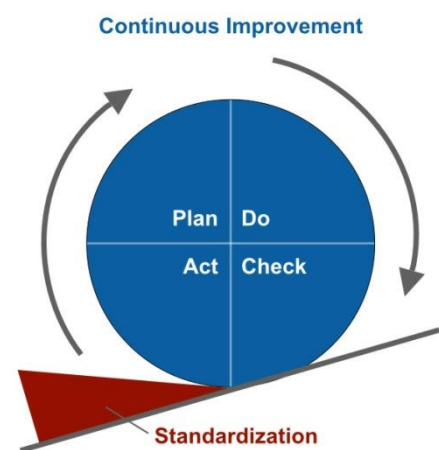


Figure 23: Plan, Do, Check & Act

To make the improvement part of the process, it is necessary to make the improvement standardized. During the implementation a lot of attention should go to the

processes that already operated in a good manner don't decrease after implementation of the new process and/or agreements.

Visualization

Goals and results visualization

A process-based approach of companies – that is focussing on company processes - makes it possible to set clear goals and to evaluate. It is often possible to present goals or objectives visually, such as number of errors, average margin, profit, efficiency, etc. The same goes for goals that can be made by teams or individual employees.

In the first instance should be the goals established in collaboration with the leadership. This feature is that the SMART goals are formulated. In any case, this ensures that the goal for everyone is clear and measurable. There is thus an indicator defined to measure the performance in relation to that goal.

On the basis of the measured results will have to be a space for improvement actions based on the Plan-Do-Check-Act principle. To be successful, the results of improvements in the process should always be positive. Effective goal setting can only be justified when the indicators are consistent with the goals, the data up-to-date is and it is used for effective control and improvement.

Visualization of safety aspects

People can react differently in panic situations and for the obvious things forgotten. Therefore it is important that things are clear with regard to safety maintenance and improvement at a glance. Examples include:

- Emergency calls on any phone
- Clear work wear that everyone first aider or BHV
- Photos of first aider and emergency response officers hang
- Visitor badges
- Signs for emergency exits
- Imagination of unsafe situations
- Visible operating instructions
- Indication of dangerous substances.
- Indicate required personal protective clothing and resources

Processes and operating the system visualizing

Visualization is very useful to steer a business process simple, unambiguous and even person independently. When a process is visually clear, there is much less consultation, a faster response time, deviations easier detected, complicated tracking and tracing systems are unnecessary, etc. For visualizing and controlling of processes a good 5s workplace optimization is required. For a process the following aspects could be made visually:

- The input and output of a process

- The progress of a process,
- The working method of a prices
- Agreements and standards within a process
- The progress of improvement activities

Just-In-Time

Just in time (JIT) is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs. To meet JIT objectives, the process relies on signals or Kanban between different points in the process, which tell production when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. Implemented correctly, JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality, and efficiency. To achieve continuous improvement key areas of focus could be flow, employee involvement and quality.

JIT requires quick responses of personnel to order new stock once existing stock is depleting its critical mass, which saves warehouse space and costs. However, JIT relies on other elements in the inventory chain as well. For instance, its effective application cannot be independent of other key components of a Lean manufacturing system or it can "end up with the opposite of the desired result. It is important for a good functioning JIT system that the whole process chain – inclusive suppliers – are reliable and operate in a controlled way.

2-Bin and ‘Kanban’

The ‘**2-BIN**’ system, see Figure 24 below, is a system handle supplies in an easy manner. In principle the following is done, for every product which is in need of a supply two bins are created. When one bin is empty the process start to full up this bin (Pull), meanwhile the other bin is used. In this process the reduction of the product and the lead time to refill a bin are key for the amount of supply per bin. If necessary it is possible to use more bin then two.

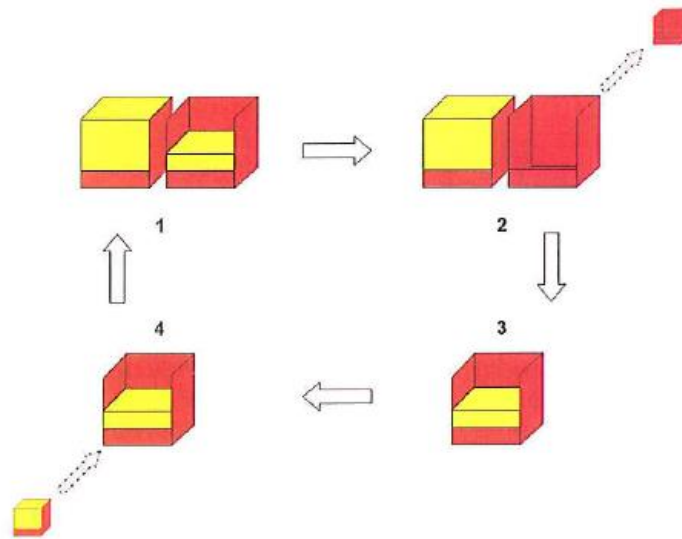


Figure 24: 2-Bin and Kanban (ARPA, 2010, p. 76)

When more bins are used, or when the production of refilling of the bins is organized from multiple locations or is distanced far from the location, it is possible to use other signals. This system is called '**Kanban**' (=map or signal). The moment when the need for new supplies exists, a signal goes to the supplies to deliver the right amount of supplies.

Lean Planning

Lean Planning is a completely different approach of project management and collaboration. A project is a sequence of activities that is performed by different stakeholders. Lean Planning actually means that the next activity is only being performed when the preceding surrounding asks for it, and not earlier and not later. In this way, continuously create value, there is no need to wait and there are no unnecessary inventories.

In the traditional way of planning a strong separation between planning and execution exists. The planning phase is relatively long, has many transfer moments and changes, double work and painstaking selection and contracting procedures. During the implementation phase unforeseen issues always appear and the original plan often disregarded in favour of improvisation ability of the various implementers. Spout, failure costs and conflicts are often the result.

When Lean Planning is used within a project, all parties are involved from the beginning with the planning: the contractor and all subcontractors, the client, architect and key suppliers. Potential conflicts are resolved by creative solutions on the one hand and clear firm agreements on the other. When all ambiguities are resolved jointly, the planning can be compressed. Then the schedule is regularly checked against the actual progress at work. This is done by the implementers at work, who know the progress of the work in detail (ARPA, Lean Bouwen Training, Waarde- Tijd - Leren, 2010).



Figure 25: Lean Planning Session 1

What's in it for building companies on short term?

Specifically, a successful application of Lean Planning results in that a project is manageable within the prescribed timeframe, budget and quality is delivered. Compared to the old way of planning are the following advantages (ARPA, 2013):

- The duration of the plan will be reduced to one day;
- There are considerably fewer ambiguities during the project;
- There remain no unresolved issues behind;
- There is great commitment from all stakeholders;
- The interfaces between the various activities receive much attention and are well organized;
- Strong reduction of required reserves or buffers;
- Significantly shorter time and therefore earlier delivery.



Figure 26: Lean Planning Session 2

Long-term benefits

In the longer term, Lean Planning according to its proponents leads to even greater and lasting benefits. It provides the basis for a long-term partnership, in which the entire team continues to develop and become better attuned to each other. In this way creates solid partnerships that specialize in a particular type of building and therein leave the competition far behind. In practice there are examples of construction teams that have achieved within 5 years a lead time reduction of 60% and the number of errors back to 0 (ARPA, 2013).

Team

Maar niet alleen processtappen zijn belangrijk. Team is een fundamenteel onderdeel van iedere werkorganisatie. De theorie over zelfsturende team zegt dat deze belangrijk zijn binnen organisaties met een onzekere opdracht (Smith en Comer, 1994). Ook het werken in teams is van groot belang volgens Batt en Doellgast (2010) vormen de teams de kern van Lean management. Door gebruik te maken van goed geschoolde teams op alle niveaus van de organisatie kan de natuurlijke verspilling die ontstaat bij een hiërarchische georganiseerde organisatie verminderd worden omdat teamleden elkaars taken kennen en zo nodig kunnen overnemen als één van hen uitvalt.

The downside

Experience has shown that the implementation of Lean Planning also should take into account aspects that successful result can hinder. We mention a few (ARPA, 2013):

- Contractors have to understand and exploit the advantages of lead time reduction; a longer planning is not better.
- Have to change the belief that working faster would be accompanied by working harder, quality loses and higher costs
- Uncertainty has illusory advantages and it is not always easy to give this up.
- Habitual patterns and 'wisdom through trial and error' are not easy to change.
- The focus on solutions instead of problems.
- True cooperation, e.g. immediately fix damages or help colleagues.
- Moving away from low bids and to aim for more work on the job.
- Continue to apply and maintain the agreed Lean methods when under pressure.