Master Thesis

Implementation of Lean in the preparation phase of building projects

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Summary

This is a research assignment for the Master Business Administration, of the master track 'Innovation and Entrepreneurship' at the University of Twente. The research is completed at the company BAM Equipment B.V. at Lelystad.

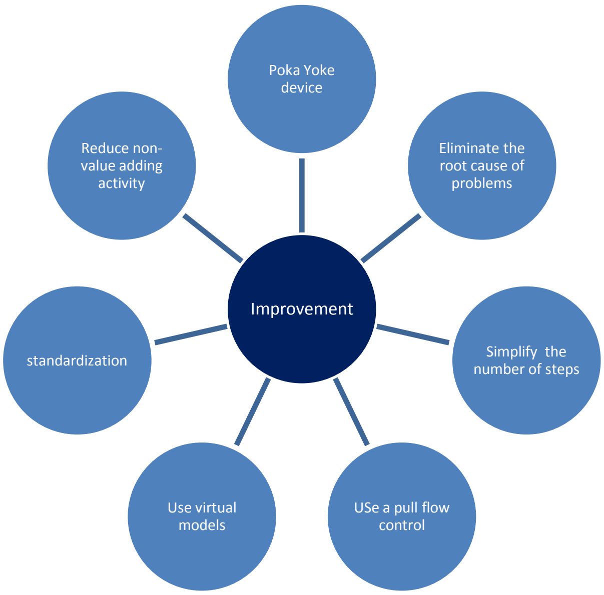
Introduction

BAM Equipment is supplier of building materials for the building projects of the Royal BAM Group. BAM Equipment designs, makes and delivers new equipment solutions. Due to the economical crisis in the Netherlands, especially in the building industry, it is necessary to reduce costs and work more efficiently. Therefore, improvement of the current processes of BAM Equipment is required. BAM Equipment intends to improve the preparation phase according to the condition of 'Lean'. For this phase, the management will face the problem by translating the literature concepts of 'lean' into practical improvements.

The research question is:

- ***How can the preparation phase at BAM Equipment become more efficient according to the conditions 'Lean'?***

'Lean' is a popular term and is used in different ways. In the literature review of this thesis, the term 'Lean' is further defined for this specific feature and conditions of the term are explored. The important conditions for the improvement are stated in this model:



The improvement must contain all conditions of 'Lean' as showed in the model.

Analysis

To find the main problem in the preparation process, the method value stream mapping is used. With the value stream mapping method an overview (current state map) of all processes in the preparation phase will be made. Each process step is marked as added value or added non-value for the customer. The main non-value adding activity is further investigated. This process step is called ‘production drawing’. Based on the current state map a future state map will be created. In this map all non-value added actions are eliminated. To achieve the future state map from the current state map, the process must be improved by eliminating non-value added activities.

Interviews with employees indicated that the products, which are called accessories, can be further standardized. Analysis of the process indicates that most time is spent on drawing the accessory of the product ‘end stop’. Therefore the focus of this research is on this product and the related preparation activity.

Improvement

After analyzing all produced ‘end stops’ in 2011, the product is able to be standardized with the theory of platform thinking. The product is divided in one standard platform, five different face elements, and four different top elements. By combining these elements with the platform, all possibilities needed for the projects can be created. Creating a production drawing is not necessary anymore, only the type of numbers and the variables of breadth and height are needed. This improvement gives a time reduction of 10,5% for the preparation phase and results in a benefit of €165.628,8 per year. To implement this standardization an investment of €216.540,- is needed, which will be paid back in 1,3 years. However, this improvement contains not all prescribed ‘Lean’ conditions; three conditions are not included in the current improvement. These conditions are: ‘Poka Yoke device’, ‘virtual models’, and the creation of a ’pull control effect’.

To fulfill all conditions, a software update is recommended. This software uses ‘virtual models’ and can generate all variables needed for the production of the accessories from the value adding process step ‘routing’. Standardization of the products is also needed for this improvement, otherwise the software can’t generate drawings automatically. By implementing this second improvement 27% of the time can be saved in the preparation phase, with a benefits of €268.210 per year. The investment costs are €100.000 and will be paid back in 0,37 years. The first improvement is needed to implement the second improvement, and the second improvement is needed to be ‘Lean’.

Conclusion

The preparation phase at BAM Equipment can become more efficient according to the conditions of ‘Lean’ by standardizing the accessories with the theory platform ‘thinking’ and by updating the software. These adjustments will reduce time in the preparation phase. To become more efficient according to the conditions of ‘Lean’ in the preparation phase the following steps are required:

- Elimination of the non-value added process steps for the customer by standardizing products based on the theory platform thinking.
- Update software into virtual programs and create programs which generate the required information automatically, driven by the customer.

Foreword

In the beginning of this research I started like an idiot reading everything about 'Lean'. And there is a lot to read. I made a literature overview and learned a lot about 'Lean'. However, finished reading all theories, I still did not have a clue what to do. The goal was to improve a process, but getting correct data and the correct process steps was very difficult. None of all available data seemed to be true or stored correctly. Besides that, a big reorganization was planned to happen. Getting information to improve a process was therefore a major problem. The mood in the company was minus 10 and people where waiting for the big happening. Next to the reorganization, the organizational structure changed as well in the same period, changing processes, jobs, and tasks in a short period. I struggled a lot in this period due to all alterations, not having a clear process to improve.

Luckily in that period I was involved in a team which was responsible for the plan of the organizational change. Some persons in the team and my supervisor at BAM Equipment helped me to get the right information. Thanks to all people in the organization for their time. I will especially thank my supervisor at BAM Equipment: Dennis Grimbergen; his advice and support helped me very much.

Furthermore, I'd like to thank my supervisors Erwin Hofman and Joop Halman at the University of Twente. They helped me reach each next step in the process when I was stagnating. Each time, after the meetings at the University, there were a lot of points to improve and I came to a new point of view. Furthermore, I thank the organization of BAM Equipment to give me the opportunity to elaborate my assignment.

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1 BAM Equipment B.V.

1. Introduction

This master thesis is the last part of the master study Business Administration of the master track 'Innovation and Entrepreneurship' at the University of Twente. The thesis is completed at the company BAM Equipment which is located in Lelystad.

BAM Equipment B.V. is part of the Royal BAM Group NV. The BAM group is an European construction group and unites operating companies in five home markets. The administrative center is located in the Netherlands and listed at Euronext Amsterdam. BAM is active in the following areas: construction, property, civil engineering, public private partnerships, mechanical and electrical contracting, consultancy and engineering, and facility management. The Royal BAM Group has around 26.000 employees and BAM Equipment around 300. BAM Equipment designs, produces, and delivers equipment solutions for building projects in the Netherlands. An example of a new equipment design is the equipment used at the project 'JUBI' in The Hague (figure 1). For this project the steel form could be lifted upwards hydraulically. This system was especially designed for this project. The picture shows all other equipment as well that has been developed for this project, like the scaffolding around the two towers and the cranes.

Figure 1; JUBI in The Hague

1.2 Structure of the Report

This report is structured according to the phases described by Kempen and Keizer (2000). The report can be divided in three phases. 1) Orientation phase: 2) Research phase: and 3) Solution phase. An overview is shown in figure 2. Kempen and Keizer described an implementation phase as well, however, this phase is not part of this research. The chapters for each phase are given in light blue boxes.

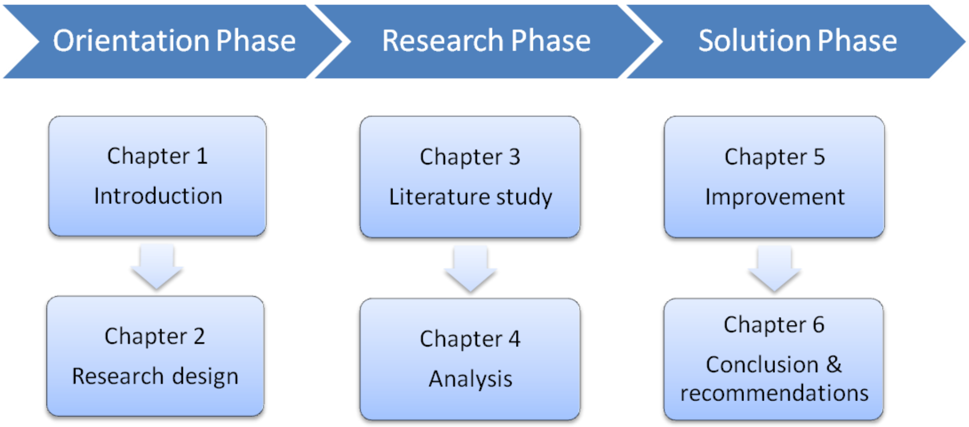

Figure 2; Research structure (Kempen and Keizer, 2000)

The orientation phase

The orientation phase starts with introducing the case and company. In the second chapter the research design is outlined. Here the research problem, objectives and research method are discussed.

Research phase

The research starts with a literature study (chapter 3). Here, the theories which are necessary are explained and a model of the conditions for improvement is made. In Chapter 4 an analysis is made of the current processes in the preparation phase and how the processes should look like.

Solution phase

In chapter 5 the improvement is explained and the benefits of the improvement are calculated. The improvement is evaluated with the conditions of 'Lean' from the model derived from chapter 3. In chapter 6 the used method will be evaluated and some recommendations for the company are explained ending with the final conclusion.

2 Research design

In this chapter the research design is explored, starting with the analysis of the problem. In section 2.2 the demarcation of this research is described. In section 2.3 the problem statement is summarized in a problem definition. Finally, in section 2.4. the main research question and sub questions are described.

2.1 Problem analysis

To handle the crisis in the building industry, the BAM Group wants to work more efficiently. This might be reached for BAM Equipment by implementing the conditions of 'Lean' in the organization. Krafcik (1988) defined 'Lean' as a bundle of practices aimed at eliminating, or at least reducing, wasteful efficiencies during the production process.

'Lean' was first introduced by Womack, Jones and Roos (1990). It is a philosophy that makes it possible to improve the process continuously by eliminating waste in the process, like unnecessary actions which don't add value for the customer (Liker, 2004). The management of BAM Equipment faces some difficulties for the preparation phase to implement 'Lean', like the translation from the theory of 'Lean' to practical improvements. This problem occurs in the preparation phase due to hidden information in digital batches and not visible product paths. Liker (2004) described the same problem for 'Lean' in an information process: the difficulty to understand the information processes of the workflow in the same way as a physical product.

2.2 Demarcation of the Problem

A building project at BAM Equipment is divided in four different phases. (1) Advise, (2) work out phase, (3) realization, and (4) transportation. This research focuses on the first two phases. The four phases are shortly described here:

Advice:

When a customer of BAM Equipments signs in for a tender project he needs some advice and a price for the supportive materials. When the tender phase is won by the customer a definitive assignment will be made.

Work out phase:

When the assignment is definitive the project can be elaborated. In this phase detailed drawings will be made for all materials necessary for the project.

Realization:

The materials for the project will be manufactured from the drawings which are developed in the work out phase. In this phase the elements needed are ordered to manufacture the materials.

Transportation:

In this last phase the materials are transported to the project. Some materials are already necessary in an early stage of the project whereas some others later on, so timing in all the phases is important.

The phases 'advice' and 'work out' together are called the preparation phase. The phases 'realization' and transport' together are called the supply chain. An overview is presented in figure 3.

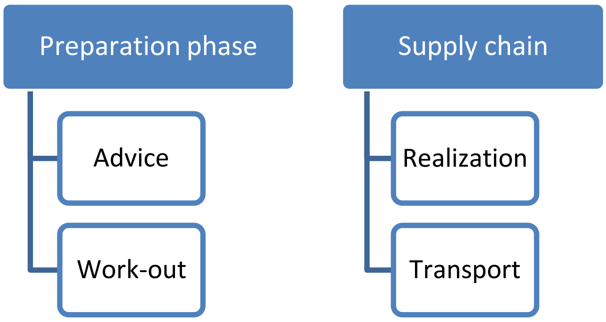

Figure 3; Organization structure of BAM Equipment B.V.

This research is demarcated at the preparation phase, because some improvement projects are already starting in the supply chain phase and the management faces some difficulties to improve the preparation phase.

2.3 Problem definition

BAM wants to become more efficient to be able to survive the current (economical) crisis in the building industry. For the preparation phase the management foresees problems in creating practical improvements based on the literature of 'Lean'.

Problem statement

How can concepts of 'Lean manufacturing' make the preparation phase for building projects more efficient?

2.4 Research objective

The goal of this research:
The goal of this research is to make the preparation phase of BAM Equipment more efficient.

The goal in this research:
The goal in this research is to search for possible efficiency improvements, by applying the principles of 'Lean' for the preparation phase at BAM Equipment.

2.5 Research question

After defining the problem and clarifying the objectives, the following research question can be formulated:

- ***How can the preparation phase at BAM Equipment become more efficient according to the principles of 'Lean'?***

To answer this question three sub-questions are formulated. Each sub-question contains a small explanation.

Sub questions:

- **What is 'Lean construction'?**
  - The literature of 'Lean' will be described and a model will be created based on the conditions of 'Lean'. This model is the foundation of the improvement. To generate the model, literature will be studied.
- **What are the activities in the preparation phase at BAM equipment?**
  - This sub-question will give a clear overview of the current preparation process. To create an overview, method value stream mapping will be used. Interviews combined with empirical data will give a detailed overview.
- **How can the preparation phase be improved according to the described conditions?**
  - Based on the processes of analysis and literature review an improvement will be created. This improvement should be able to make the preparation phase more efficiently compared to the current situation.

Definition

Lean manufacturing:

Lean manufacturing is a systematic approach to identify and eliminate waste (non-value added activities) through continuous improvement by flowing the product driven by the customers need for perfection. (NIST/ MEP, 1998)

3 Literature review

The chapter describes different concepts of the term 'Lean'. The first part of this literature review elaborates on the subject business process redesign and other options to change an organization. Section 3.2 explains the theory 'Lean'. Section 3.3 elaborates on the implementation of 'Lean' in the organization and the method value stream mapping. Section 3.4 elaborates on 'Lean construction'. Section 3.5 shows the most important conditions from the literature presented in a model.

3.1 Business process redesign

Globalization, political realignments, and the rapid advance of information technology changes the environment of an organization. Leaders caught the concept of Business Process Redesign (BPR) to react on changes in the environment (Kettinger et al. 1997). The term BPR was first introduced by Hammer (1990) and Davenport and Short (1990). In the beginning the concept was mainly prescribed as 'principles' for radical change. Stoddard and Jarvenpaa (1995) concluded that the BPR concept frequently attempts to 'revolutionary' (radical) change, but because of political, organizational, and resource constraints, it was implemented in evolutionary (incremental) steps. Nowadays BPR practice evolves more emphasis on strategic linkage, smaller projects, fast-cycle methods, and active bottom-up participation. BPR is recognized as a form of organizational change and augments the organizational performance by improving efficiency, effectiveness, and adaptability of key business processes (Wastell et al, 1994).

Several authors have provided their own interpretation of the changes being applied to organizations. Hammer and Champy (1993) state that ´A business process is a collection of activities that takes one or more types of input and creates an output that is of value to the customer'. The definition 'A business process has a goal and is affected by events occurring in the external world or in other processes´ describes the importance of the outcome of a process. Davenport and Short (1990) described a BPR as the analysis and design of workflows and processes within and between organizations. Here, the focus is on the process itself. Davenport (1993) describes a process as 'simply a structured set of activities designed to produce a specified output for a particular customer or market'.

'Lean' is not the only theory that describes a plan to improve a process. There are different theories regarding how to improve business processes. Other theories to change a process are (Hayes, 2002):

- Collective learning organizations
- Appreciative inquiry
- High performance management
- Total quality management
- Lean manufacturing

A small description of each theory is given below.

Collective learning

Lank and Lank (1995) argued that the quality of individual and organizational learning is an important determinant of organizational effectiveness. Geus (1988) suggested that the ability to learn faster than competitors might be the only sustainable competitive advantage. Collective learning occurs when a group recognizes something that offers a more effective way of functioning (Hayes, 2002).

Appreciative inquiry

Appreciative inquiry is a process of exploring the best practice. With this process, positive points will be underlined instead of eliminating the negative points. The essence of appreciative inquiry is the generation of a shared image of a better future via a collective process of inquiry into the best practice. This imagined future creates a pull effect that guides development of the organization (Hayes, 2002). Bushe (1999) described the process of appreciative inquiry that can be divided into three parts: 1) discovering the best of a subject, 2) understand what creates the best of that subject, and 3) amplify the people or processes that exemplify the best of that subject. According to Elliot (1999), the key is to transform an organization from a negative view of itself to a positive view enhancing quality of life for all stakeholders. There are three stages in this theory: first, dreaming about what might be, second, designing provocative propositions that will achieve the dream, and third, delivering the dream (Hayes, 2002).

High performance management

According to Bailey (1993) human resources (HR) are frequently underutilized because employees perform below their maximum potential. High performance management seeks to improve performance through HR practices that elicit discretionary efforts from employees. Pfeffer's (1998) mentioned seven practices: employment security, selective hiring, self-managed teams and decentralized decision making, high compensation contingent on performance, extensive training, reduced status distinctions, and extensive sharing of information.

Total quality management

The author who first introduced total quality management (TQM) was Feigenbaum, defining the concept as an effective system for integrating quality development, quality maintenance, and quality improvement efforts of the various groups in an organization so to enable production and service at the most economical levels which allows for full customer satisfaction (Feigenbaum, 1986).

TQM philosophy stresses the following points (Hayes, 2002):

- Meeting the needs and expectations of customers
- Covering all parts of the organization
- Everyone in the organization is included
- Investigating all costs related to quality (internal and external)
- Getting things right by designing in quality
- Develop systems and procedures supporting quality improvements
- Develop a continuous process improvement.

3.2 Lean manufacturing

Many tools and visions are described in combination with 'Lean'. In the section 3.2.1 different point of view about the subject 'Lean' are described. In section 3.2.2 the Toyota production system is described and the term 'Lean' is introduced. In section 3.2.3 some limits of 'Lean' and the value stream method are described.

3.2.1 Lean

Scherrer-Rathje et al. (2009) differentiated the tools and techniques within a Lean philosophy. They explained the term 'Lean' as a management philosophy focused on identifying and eliminating waste throughout a product's entire value stream. Not only within the organization but also along the company's supply chain network' (Scherrer-Rathje et al., 2009). Liker (2004) saw 'Lean' more from a practical or operational view. He described 'Lean' as a method that involves implementing a set of shop floor tools and techniques aimed to reduce waste at the production floor and along the supply chain. Tools and techniques in Lean manufacturing are: 'just in time' inventories, the 'seven' wastes or total productive maintenance (Liker, 2004). Others see 'Lean' more as a philosophy (Shah and Ward 2007, p 791) and defined 'Lean production' as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability." Womack, Jones and Roos (1990) described five principles to explain 'Lean', which will be explained below:

Principle 1 Specify value

The first principle and step to implement 'Lean' is to specify the value. Womack and Jones (1996) argued that it can be hard to define value, because many producers focus too much on the product or services they are already making or what they are getting already. The value should be specified for the whole product.

Principle 2 Identify the value stream

Once the value is specified a value stream can be set up to expose waste. Womack and Jones (1996) defined a value stream as all actions required to bring a specific product or product family by means of the three critical management tasks of:

1. Problem solving – from concept design towards detailed design to product launch.
2. Information management – from order taking towards detailed scheduling to delivery.
3. Physical transformation – from raw materials towards finalized product or service to the customer.

By mapping the value stream, each action in the process will be analyzed. With this process waste will be recognized. The action in the process can be categorized into (Hines and Rich, 1997):

- Non value adding action. This action is pure waste and involves unnecessary actions which should be eliminated completely. For example waiting time or double handling.
- Necessary but non value adding actions. These action are necessary because they usually need to be executed for the next actions. E.g. walking a long distance to a printer or starting the computer, which will costs an additional 10 minutes.
- Value adding actions. This action adds value to the end product. Like painting the product for delivering.

Hines and Rich (1997) described seven commonly accepted wastes:

1. Overproduction. This waste will lead to excessive work-in-progress stocks, resulting in physical dislocation of operations with consequent poorer communication.
2. Waiting
3. Transport. During transporting products add no value to the end product.
4. Inappropriate processing. This occurs when the procedures are too complex which might easily lead to failures.
5. Unnecessary inventory. This will increase lead time, identification of problems will be difficult and space is needed for the inventory.
6. Unnecessary motion. During the production operators have to stretch and bend, leading to poor productivity and often to quality problems.
7. Defects. When a defect occurs the production can't be continued and the defect costs time and money.

Principle 3 Make a value flow

A value flow is a stream of value adding activities. Non value adding activities must be eliminated from the process (Hines and Rich, 1997). Womack and Jones (1996) advocated a three-prong approach defining the value flow. The first approach is just following the product as it moves along the value stream. Second, ignore traditional boundaries to be able to make a continuous flow. Third, rethink specific work practices and tools to eliminate backflows, and scrap all sources of unnecessary stoppages to proceed the process continuously.

Principle 4 Let the customer pull value

The pull principle involves that none will produce anything until someone downstream requests the product . Womack and Jones (1996) argued that when products are 'pushed' through a production system into a sales forecast, any unanticipated fall in demand can lead to a rapid build-up of unwanted finished goods (waste) that, if not scrapped, may have to be sold off at a heavy discount. The tool 'just in time' helps to deliver the asked product on the desired time of the client. In 'Lean', a pull system is the ideal state of 'just in time' processes: 'Giving the customer what he or she wants, when he or she wants it, and in the amount he or she wants it' (Liker, 2004. p.105).

Principle 5 Pursue perfection

Perfection is the complete elimination of waste. Womack and Jones see it as "Trying to envision it (and get there) is actually impossible but the effort to do so provides inspiration and direction essential making progress along the path" (Womack and Jones, 1996. p.95). Subsequently, a culture must be created at which there is always a strive for improvement, even when it cannot be reached in the near future.

3.2.1 Toyota production system (TPS)

The book *The machine that changed the world* (Womack et al. 1990) introduced the term 'Lean' and used Toyota as an example. Toyota was in fact the model for 'Lean'. The Toyota production system became the best-known example of 'Lean' processes in action. It has become a model for competitive manufacturing throughout the world (Liker and Morgan, 2006). The philosophy behind the Toyota production system is based on the principles stated in Figure 4. This is the model of the Toyota production system.

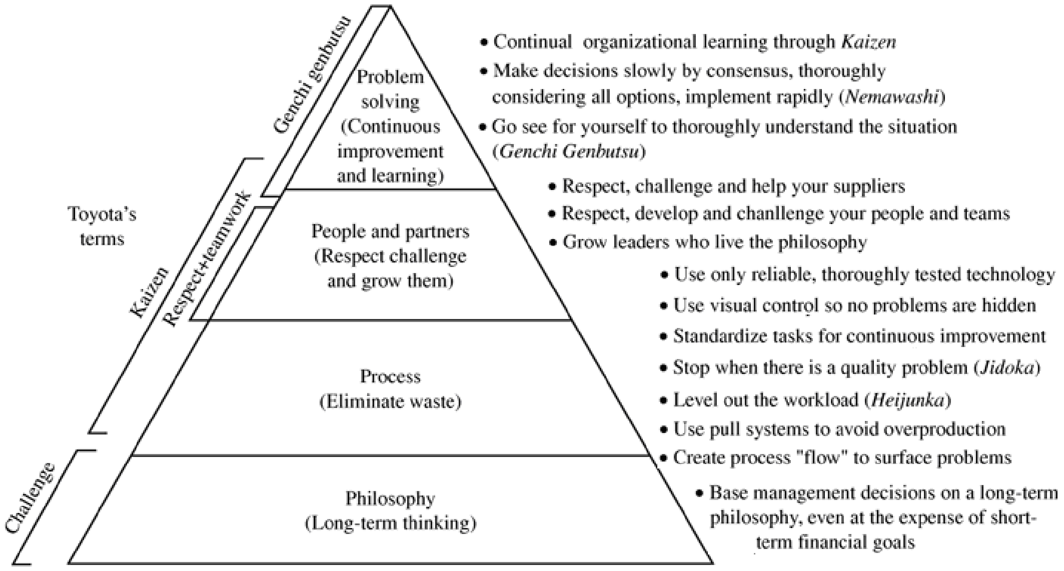

Figure 4: Toyota house (Liker & Morgan, 2006)

The model is divided in four categories, all starting with a 'P' and is therefore named the four P's: Philosophy, Process, People/partners, and Problem solving. The terms left of the triangle are terms used at Toyota. The term 'kaizen' is used for continuous improvements. The term 'Genchi genbutsu' is used to describe the personal involvement to solve problems, including a cultural change. At the right side of the triangle 14 principles are stated and each of them are connected to a specific category. The model shows that 'Lean' is much more than improving the process only. Besides process improvements, a long-term philosophy must be created and people and partners in the process need to support the philosophy and strive for improvements as well. Everybody in the process needs to strive for continuous improvements. In order to reach this, besides the change in the process, also culture needs to be changed (Liker, 2004).

3.2.3 Limits of Lean

A lot of positive points are mentioned about the Lean philosophy, but there are some limitations as well for this management philosophy. In the 1970's Nissan discovered a practical problem. The delivering of the components 'just in time' failed because of the urban congestion near the factory. Nowadays components for production are produced in other countries and are transported by ships. Here, 'just in time' is not possible. Another obvious limitation is the need for a reliable supplier. The suppliers must deliver small orders to the factory frequently. The transportation and short production runs lead to higher costs which was not acceptable for Toyota. Another problem was that foreign workers from Southeast Asia, the middle East, and South America where not allowed to work in Japan. The language difference made it difficult to train the workers and therefore quality and reduction in worker flexibility occurred (Cusumano, 1994).

3.3 Implementing 'Lean' in the organization

This part of the theory elaborates on the implementation of 'Lean' in the organization. The first paragraph shows some examples of failures. The second paragraph presents a guideline to change the organization. The last paragraph explains the method to analyze the processes.

3.3.1 Failures of implementing 'Lean'

Some managers and employees are skeptic to implement 'Lean' in the organization, because the project of implementation failures. Failures by the implementation of Lean are: lack of senior management commitment, lack of team autonomy, and lack of organizational communication about 'Lean' and the interest of it (Scherrer-Rathje et al., 2009). Managerial support is an important issue in the implementation of Lean management. Due to a lack of senior management commitment and interest in 'Lean', the employees who were affected by 'Lean' changes did not understood how the changes and the project were related to other projects (Scherrer-Rathje et al., 2009).

The failures that occurred by implementing 'Lean' are:

- Lack of managerial support
- The effect of the change is not visible
- The benefits are not communicated, by which motivation went down
- There was no authority to improve the process.

3.3.2 Implementing change in the organization

Kotter (1995) described eight steps to change the organization. The eight steps are explained below:

Step 1; Establish a sense of urgency

The first step in changing the organization is to establish a sense of urgency to change the organization. The urgency to change must be high enough to change successfully, therefore, this first step is very important. The motivation to change depends on the urgency to change, and therefore the urgency can be increased if necessary. The urgency can be a potential crisis or a major opportunity.

Step 2; Forming a powerful guiding coalition

The idea to change or to see the opportunity starts with just one or two persons. To change successfully this small group must grow fast in the beginning. Senior managers always form the core of the group. A high sense of urgency within the managerial ranks helps substantially in forming a guiding coalition.

Step 3; create a vision

The guiding coalition develops a perspective of the future which is easy to communicate. A lack of a vision in this phase can lead to a failure or a list of confusing and incompatible projects. In failed transformations, there are usually too many plans, directives, and programs.

Step 4; Communicate the vision

Within an organizational change three different manners are usually used to communicate. The first one is to communicate the vision in a single meeting. Only a few persons understand the problem and vision. The second pattern is that the head of the organization spends some time to present for groups of employees, because not everybody already knows how to change. The third pattern is to communicate the vision into newsletters and presentations. Usually in this last pattern the result is that the cynicism among the employees increases, while belief in the communication decreases. Communicating the vision is a challenge and the change can only succeed in case almost all people are willing to help. To communicate the vision all possible communication channels to communicate needs to be used, like turning newsletters into lively articles, create meetings, and discuss the vision and transformation. It is necessary to use education to focus on the problems and change. The final possible communication is the so called 'walk the talk'.

Step 5; Remove obstacles to change

In a changing organization some obstacles occur. Sometimes the obstacles are the organizational structure like narrow job categories or sometimes the director is not willing to change. The obstacles must be removed to succeed.

Step 6; Planning for and create shot-term wins

Most of the people won't proceed unless there are short-term wins of the change. A transformation takes time so planning is important to win overtime reaching the end goal.

Step 7; Consolidating improvements and producing still more change

Celebrating a win is fine, declaring the war won can be catastrophic. The change which is build up in two years might slowly disappear by stopping the change.

Step 8; Institutionalizing new approaches

To succeed, new programs and behaviors must be rooted in social norms and shared values. To reach this, the advantage of the new approaches must be shown to the employees. Second, sufficient time must be taken into account to personalize the new approach by the next generation managers.

3.3.3 Value stream map method

Womack and Jones described a value stream map as "*all actions (both value added and non value added) currently required to bring a product through the main flows essential to every product"* This can be the production flow from raw materials to a product or a preparation process starting from concept to launch. Using a value stream method requires an overview of the current process (current state map). Important in this current state map is to define the process steps which add value for the customer and which ones don't add value. The definitions for value adding and non value adding activities are used from Koskela (1992):

- *"Value adding activity: Activity that converts material and/or information towards that which is required by the customer ".*
- *"Non value adding activity (also called waste): Activities that takes time, resources or space but does not add value".*

From the current state map a future state map can be created. The goal of the future state map is to create a flow of the process which is linked to the customer with only value added activities. "E*ach process gets as close as possible to produce only what its customer needs when they need it"* (Rother and Shook, 1998). The method value stream mapping describes three steps in the value stream map process:

1. Create the current state map
2. Draw the future state map from the current state map
3. Improve the current state map via the future state map

In the first step the current processes will be analyzed and ordered in a schematic overview. Activities will be marked as value added or non value added. When for each process step a time indication is added, the ratio between value added and non value added hours becomes visible. By completing the current state map, the future state map can be created. This is the second step in the method. Here, is the process line of the first state map will be changed into value added activities only. All non value added hours are deleted from the process. This future state map is the ultimate goal to achieve in the future. To achieve this goal the non value added activities must be eliminated in this process. Therefore the third step in this process is to improve the non value added activities.

3.4 Lean Construction

The term 'Lean' was introduced in a car factory as described in section 3.2.1. Currently, 'Lean' is introduced and applied in other industries as well, like the construction industry. Some specific conditions are important in combination with 'Lean'. Section 3.4.1 describes 'Lean' construction. Section 3.4.2 describes the software building information modeling. Section 3.4.3 describes a theory to standardize products and processes with the needed flexibility for projects.

3.4.1 Lean Construction

"Lean construction, like the current practice, has the goal of better meeting the customer needs while using less of everything" (Howell, 1999). It is a new approach for complex and uncertain projects. 'Lean' construction uses the same definition of waste as the 'Lean' production theory. "Failure to meet the unique requirements of a client is waste" (Howell, 1999). So, the 'Lean' construction theory accepts the principles of the philosophy of 'Lean'. But how can this theory be applied to projects that always change in difficulty, size, and in products? To manage such a project, the project has to be breaked down into pieces. The pieces must be arranged in a logical sequence and for each piece time and resources must be made clear. Managing the interaction between activities, it is essential to combine effects of dependence and variation to finalize the project in the shortest possible time. Minimizing variation and combinated effects are important issues in case complexity increases. Howell (1999) defined complexity as the number of pieces or activities that can interact.

Furthermore, 'Lean' uses a simplified control system which is an inventory based control system, replacing a central push in a pull system, reducing the work in place. This results in lower work capital and decreases costs by switching time between activities in the process (Howell, 1999). By giving authority to floor managers, (transparency) decisions can be made through visible production.

To deliver projects in the shortest possible time, the interaction between activities must be managed. The combined effects and variation in the activities are essential. However, according to Santos and Powell (1999), there are two causes that influence variation. The first one is a random type which occurs in projects. This random factor includes size or number of orders or delivery speed. The second type is variability in products or other assignable causes. Taguchi and Clausing (1990) proposed this to the random causes of variability by designing products in a different way with less variations. Planning and programming with less variation is much easier. When there is variability in the production more corrections are usually needed in the process which increases the cycle time (Shingo 1989). According to Koskela (1992) variation can be reduced by implementing three approaches:

- Measuring, finding and eliminating the root cause of problems
- Standardization
- Installation of Poka-Yoke Devices

Liker (2004) explained ‘Poka-Yoke’ as activities that are mistake-proofing, error-proof or fool-proof. So it is nearly impossible for an operator to make a mistake. This is created by electronic and mechanic instruments built into the process in order to guarantee 100% inspection.

3.4.2 Building information modeling

Building information modeling is defined in the BIM Handbook (Eastman et al. 2008) as “a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation”. BIM and ‘Lean’ are independent and separated but there are some synergies (Tribelsky and Sacks, 2010). ‘Lean’ prescribes that documentation and information must be easily visible. BIM software uses virtual models of buildings. The Computer Advanced Visualization Tools (CAVT) is a method that uses the principles of ‘Lean’. Based on a case study by Rischmoller et al. (2006) CAVT results in a waste reduction, improved flow and better customer value.

3.4.3 Platform thinking

According to the theory of ‘Lean’ serving, the client needs and wishes is one of the main findings. More variety in products will make it more likely that each consumer finds exactly his or her needs (Halman et al, 2003). The challenge that companies face is to produce the product variety in an economical way. A study from Mac Duffie et al.(1996) shows that a high variety in product parts has a negative effect on productivity. The options to standardize are often limited in a project based organization. “Construction projects can be seen as a temporarily organization between and within organizations, and therefore standardization at the multi-project level is difficult as project teams and product designs change from project to project (Hofman, 2006). Platform thinking is a successful strategy to create variety with an efficient use of resources (Halman et al. 2003).

The leading principle is to balance common potential and differentiation needs within a product family. A product family is defined by Halman et al. (2003) as the collection of products that share the same assets. A basic requirement is the decoupling of elements to achieve the separation of common elements which are called platforms. A platform is defined as the basis of all individual products within a product family. There are different kind of platforms:

A product platform

“A product platform is a relatively large set of product components that are physically connected as a stable sub-assembly and are common to different final models” (Meyer and Lehnerd, 1997)

A process platform

“A process platform is the set-up of the production system to produce easily the desired variety of products” (Halman, 2003). To create a flexible process, product differences must be standardized. This can be created by manufacturing module based products.

Modularity

Modularity is described by Ulrich and Tung (1991) as “*a relative property of a product structure as opposed to an integral structure”.* In a module-based product family, product family members are created by adding, substituting and/or removing one or more functional modules from the platform (Simpson, et al, 2006). In this way, modularization allows the overall product to be differentiated to a high degree and satisfying all customer’s requirements while development and production costs are minimized by the reuse of the modules at a multi project level (Ulrich, 1995). There are five different approaches to standardize a product with modularity (Ulrich and Tung, 1991) (Figure 5).

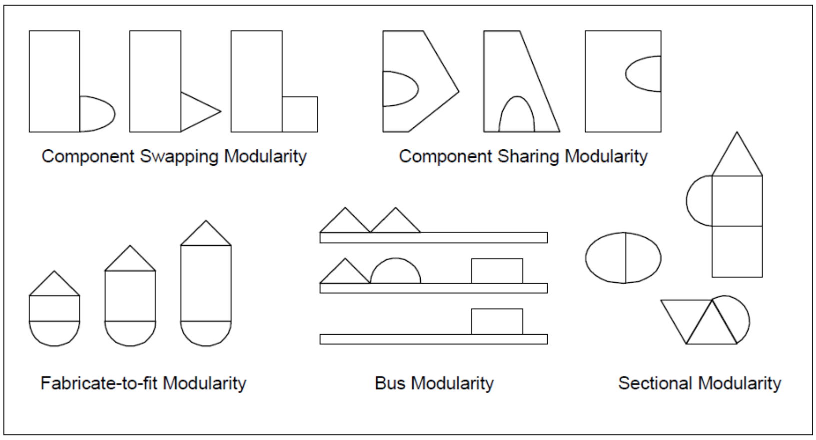

Figure 5: Approaches to standardize (Ulrich and Tung, 1991)

With this approach, component swapping modularity into a standard variation is added to a basic platform. With the component sharing modularity a standardized variation fits different platforms. Fabricate-to-fit modularity has a flexible standard with standard variation. The bus modularity has a basic platform and different standard variations can be added (figure 4). These different standard variations can be placed in any possible point of the platform. The final approach is the sectional modularity where a product can be created by connecting two or more standardized variations. The use of standard components can lower the complexity, cost, and lead time of product development (Ulrich, 1995).

Platform planning process

To design a platform and the related components Robertson and Ulrich (1998) describe a loosely structured process. This platform planning process is focused on three information management tools: the product plan, the differentiation plan, and the commonality plan.

- In the product plan, the portfolio of the products to be developed must be identified. All product related information must be used. This might be general or specific information like product technologies. In this phase all major variants and options of the products will be indentified.
- The next phase is the creation of a differentiation plan. Here the different characteristics of the product attributes are identified. Also in this phase it is important not to get lost in details.
- The commonality plan describes the extent to which the products within the plan share physical elements or at which parts of the product elements are the same (Halman, 2012).

With the gathered information of the mentioned three steps a platform and needed elements can be designed.

3.5 Conditions for improvement

As described in this chapter the term 'Lean' is used in different ways. From the literature review a model is developed, showing an overview of the most important 'Lean' conditions. In conclusion, a process improvement is 'Lean' when it meets the following conditions of the model (See also figure 6):

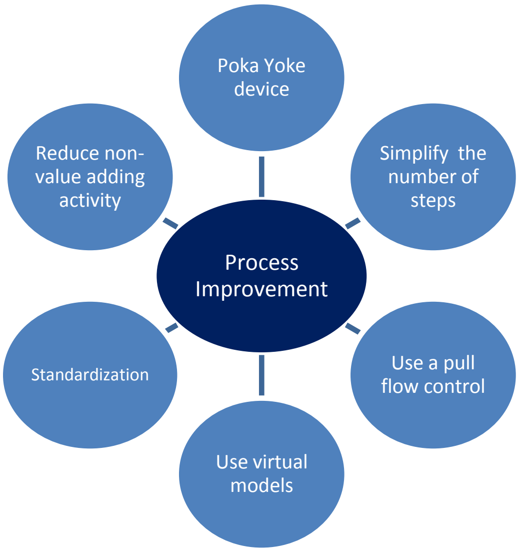

Figure 6: Conditions form the literature

Poka Yoke device:

Poka Yoke is a Japanese term and is also called error- proofing or fool-proofing. Poka Yoke devices are creative tools that makes it nearly impossible for an employee to make an error (liker, 2004). The chance to make a mistake at a certain task is reduced or eliminated. Usually automated devices helps to achieve this condition (Koskela 1992).

Simplify the number of steps:

Reducing the number of steps in the process, reducing the number of actions to complete a task, and reduce the number of components of a product.

Use a pull flow control:

With a pull system developed to provide information in the organization, workload is reduced at the work place. The activity starts in case there is a request from the customer. This pull effect gives control (Howell, 1999).

Use virtual models:

Virtual models make projects easy to analyze by means of reducing mistakes and fasten the process (Rischmoller et al., 2006).

Standardization:

Koskela (1992) concluded that standardization is important to become ‘Lean’. When there is a lot of variation, more corrections and more tasks are necessary, increasing the cycle time (Shingo 1989). With standardization less tasks are needed.

Reduction of non-value added activities:

According to Hines and Rich (1997), activities that don’t add value for the customer can be seen as waste in the process. The definitions for value adding and non value adding activities are used from Koskela (1992):

“Value adding activity: Activity that converts material and/or information towards that which is required by the customer ”.

“Non value adding activity (also called waste): Activity that takes time, resources or space but does not add value”.

3.6 Conclusion - what is Lean?

Lean manufacturing and lean construction

'Lean' is a management philosophy that intends to create continuously learning and improvement in an organization. The employees recognize waste in the process and use their creativity to reduce or eliminate that waste. By eliminating waste or non value added actions the process becomes more streamlined and efficient. The philosophy of 'Lean' can also be applied at construction projects. Construction projects always change in difficulty, size and it is difficult to create an efficient project. Therefore some specific conditions are important at construction projects. The conditions are:

- Use virtual models
- Use Poka Yoke devices
- Make products and processes standardized.

The last point of the three conditions for construction projects is difficult to realize, because projects change and the products need to change as well. The theory platform thinking explains a manner to standardize a product and maintain the needed flexibility. A lot of variations are possible by combining standardized elements with a basic platform. The product and related processes can be standardized in this way.

Value stream map method

To change the processes in the organization a value stream method can be used. The value stream method includes three steps.

1. Create the current state map
2. Draw from the current state the future state map
3. Improve the current state map to go to the future state map

The first step in this value stream map is to create an overview of the current processes. This overview is called a current state map and each activity is marked as value added or non value added for the customer. From this current state map a future state map will be created. In this future state map all non value added activities are eliminated. To change a process from the current state map to the future state map the non value added activities must be eliminated by a process improvement.

Conditions for improvement

The process improvement that are necessary to derive the future map from the current state map must contain all principles of 'Lean'. These conditions are placed in a model, which has seven conditions as listed below:

- Poka Yoke device
- Simplify the number of steps
- Use a pull flow control
- Use virtual models
- Standardization
- Reduce non value adding activities

4 Methodology and process analysis

The method and steps taken in this research are explained in section 4.1. The first step in this research is the creation of the current state map. In this current state map all the process steps necessary for a product in the preparation phase are identified, placed in order and marked as value added or non-value added for the customer (section 4.2). In section 4.3 the future state map is explained. To derive the future state map from the current state map non-value added process steps must be eliminated by process improvements. A list of the main non-value added process steps is created (section 4.3.2). The main non-value added process step will be further analyzed in section 4.4. This chapter ends with a conclusion in section 4.5.

4.1 Methodology and data gathering

The value stream map method, used in this research, is described in the literature review section 3.3.3. The first step in this method is to create the 'current state map'. In this map all process steps are identified and placed in order. From this current state map the future state map can be created. This is the current state map without non-value added activities. To derive the future state map from the current state map, non-value added activities must be eliminated by process improvements. The non-value adding process parts are ranked in a list from large to small. The largest activities should be eliminated first. The process improvement needs to lead to the derivation of the future state map from the current state map and should contain all the conditions of 'Lean'.

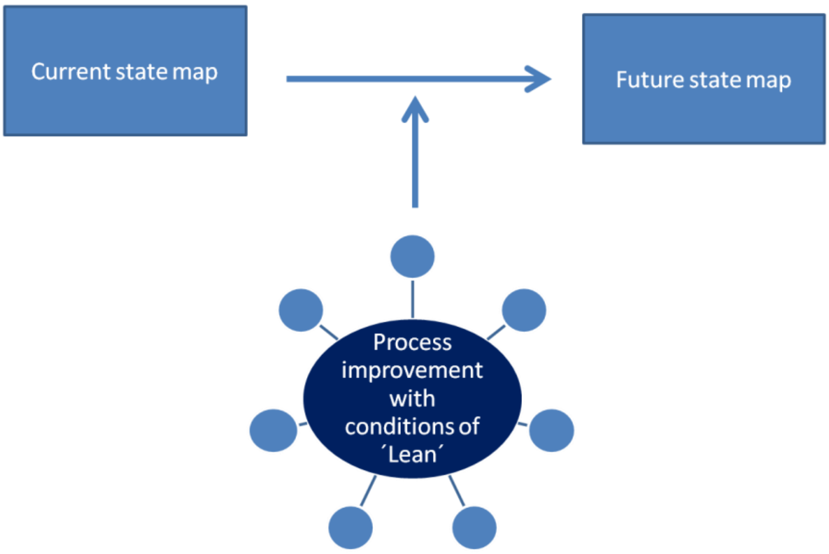

Figure 7: Schematic overview of the value stream map method

At the left in figure 7 the current state map is drawn. The arrow to the right indicates that the current state map needs to be changed into the future state map (right of Figure 7). The derivation of the future state map from the current state map can only be achieved by process improvements. The conditions for this process improvement are the conditions of 'Lean' (section 3.5). The process steps that have no value for the customer will be eliminated first. The following steps will be made in this research.

Table 1 : Research steps and gathered data

	What	How
Creating the current state map	Set up the product related process steps of the preparation phase in one overview. Each process step will be marked as value added or non-value added and a time estimation will be add to it.	The products of two projects are analyzed and the six involved employees are interviewed. Due the limited available data six projects from 2009 are used for the work-out phase for the time estimation.
Creating future state map	For the analyzed products a process will be created without all non-value added process steps.	From the current state map all non - value added process steps will be eliminated. The definition of value is used from Koskela (1992)
Creating a list of process steps to improve	A list will be created with the process steps which can be improved. The list is ranked from a big process step in hours to a small process step in hours.	The non value added process steps which are deleted for the future state map are listed and ranked.
Explore biggest non value added process step	From the created list in the previous step the biggest step will be further analyzed.	The activity steps are set up by interviewing the involved employees from the same two projects as at the current state map (first step). Also here six projects are used for a better time estimation.
Applying theory of platform thinking	The product 'endstop' will be improved according to the theory platform thinking. This improvement saves time in the preparation phase and brings the current state map closer to the future state map.	The analysis of the 'endstop' is based on 25 project from 2011. For the time saving the head production is interviewed. For the redesign of the product the engineer is interviewed.

In the current state map the current process steps to complete a product are drawn. These steps will be elaborated in the next section. Each step will be marked as value added or non-value added. The time indication of a process step in red will be a non-value adding process step. The time indication in blue will be a value adding activity for the customer. This current state map has been created with six employees for the workout phase six older projects from 2009 are analyzed.

From the current state map, a future state map can be created based on the recommendation given by Koskela (1992). The future state map is the current state map without all non-value added process steps. To derive the future state map from the current state map process improvements must eliminate non-value adding process steps. These improvements must contain the conditions of ´Lean´.

4.2 The current state map of the preparation phase

In appendix 1 the current state map of the preparation phase is presented. In this current state map four processes are analyzed of four different products. The process steps of each product are drawn by the six interviewed employees (appendix 5). The analyzed products are:

- Steel tunnel formwork (section 5.2.1)
- Steel wall formwork (section 5.2.2)
- Housing (section 5.2.3)
- Scaffolding (section 5.2.4)

4.2.1 Process steel tunnel formwork

An more detailed explanation of the product steel tunnel formwork is presented in appendix 6. In the process of a steel tunnel 42% of the total time is a value adding activity for the customer and 58% are activities which add no value (non value adding activities) for the customer (figure 8). The biggest process step of the steel tunnel formwork which don´t adds value is the step 'creation of production drawings' (appendix 1). To complete this process step 97 hours are needed. This is 31,2 % of the whole time to complete the preparation phase for a steel tunnel form.

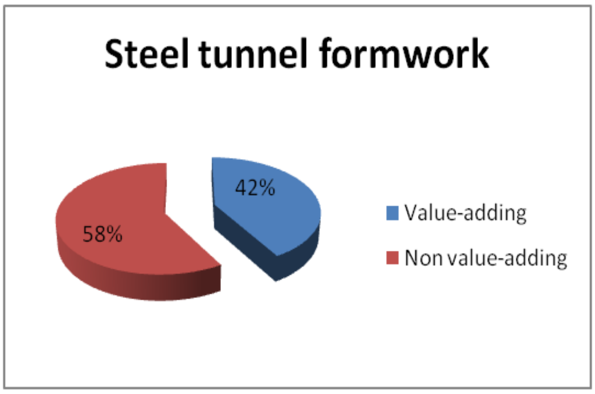

Figure 8; process steel tunnel formwork

4.2.2 Process steel wall formwork

In the process of a steel wall formwork 45% of the total time are value adding activities and 55% are non-value adding activities (figure 9 and appendix 1). The process of a steel wall formwork is similar to a steel tunnel formwork. The same process steps are needed to complete the product. Also in this process the biggest non-value added process step is the creation of drawings for manufacturing.

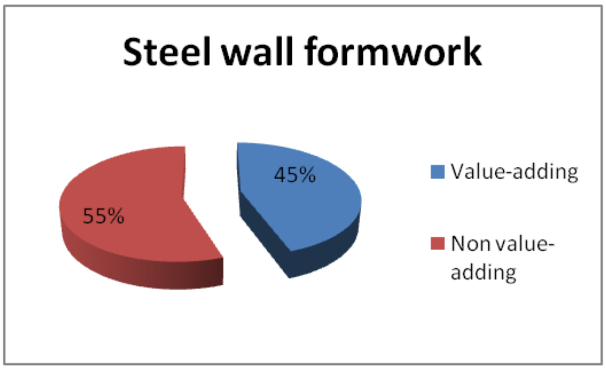

Figure 9; Process steel wall formwork

4.2.3 Process housing

In the process housing, 68% of the total time are value adding activities for the customer and 32% is non-value adding (figure 10) and appendix 1). The most important process step which don´t adds value is buying the materials. This process step takes 9,8% of the total process time.

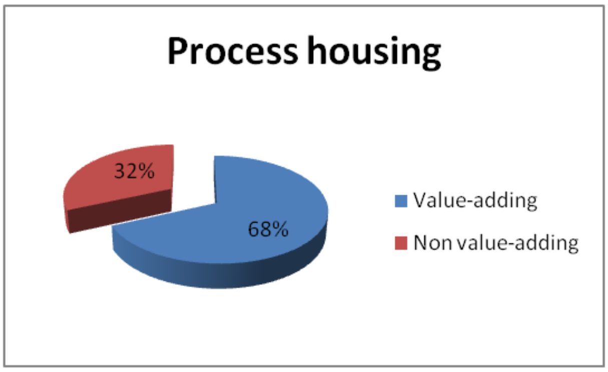

Figure 10; Process housing

4.2.4 Process scaffolding

In the process scaffolding, 85% of the total time are value adding activities for the client and 15% non-value adding (figure 11 and appendix 1). The most important process step which don´t adds value is the process step counting the requirements from the drawings. This process step takes 7,5% of the total time.

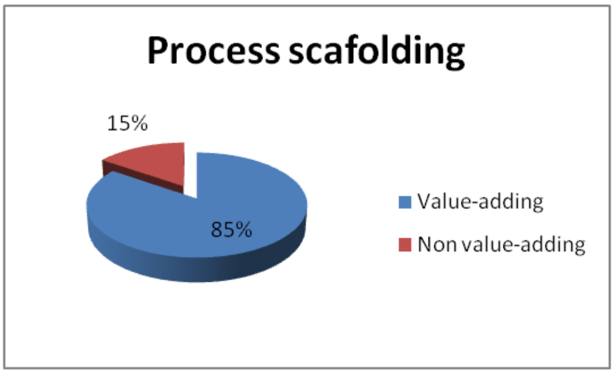

Figure 11; Process scaffolding

4.3 The future state map of the preparation phase

In appendix 2 the non-value added activity steps are colored grey. All these activity steps must be eliminated in the future. The non-value added activity steps of the products steel tunnel formwork, steel wall formwork, housing and scaffolding are eliminated. At the end of the process line for each product, the future process time is visible. In table 2 the differences in time between the current state map and the future state map are presented. The differences are calculated in percentages and called the time benefit (right column of table 2).

Table 2 : Overview of time reduction opportunities

Process	Current time (hrs) to complete the process	Future time (hrs) to complete the process	Time benefit in percent
Steel tunnel formwork	310,5	129	58%
Steel wall formwork	231	103	55%
Housing	20,5	15,2	26%
Scaffolding	106,4	90,1	15%

The overview in table 2 shows that the largest time reduction can be realized in the process steel tunnel formwork is 58% and for the process steel wall formwork 55%. To realize the time reduction non-value added process steps must be eliminated. Table 3 gives an overview of the biggest non-value added process steps ranked from large to small.

Table 3; Non value added process steps

Process	Process step	Activity time (hrs)	Percentage of the total process time
Steel tunnel formwork	Production drawings	97	31,20%
Steel wall formwork	Production drawings	49	21,20%
Steel tunnel formwork	Programming	16	5,20%
Steel wall formwork	Programming	14	6%
Steel tunnel formwork	Transport list	8	2,60%
Steel wall formwork	Transport list	7	3%

The activity step 'production drawing' in the steel tunnel process gains most time (97 hrs) (table 3). This activity step is strongly linked to the activity step 'production drawings' of the steel wall formwork process (the second point on the list). The largest time reduction can be realized by improving the process step 'production drawing'. The process of the product steel tunnel formwork and steel wall formwork are similar and for both products the process step 'production drawings' will be further analyzed in section 5.4. The focus of this research will be on the process step 'production drawing' for the process steel tunnel formwork and steel wall formwork, because for both this is the most important non-value added process step.

4.4 Biggest non-value adding process step: 'Production drawings'

In appendix 3 the process step 'production drawing' is described in more detail. The activity steps in the process step 'production drawings' can be divided in three groups (figure 12). The first one is creating production drawings for the steel formwork itself (blue part). The second for helping materials like safety platforms (red part), and the third one for accessories (green part). The ratio in hours between the three categories is shown in figure 12. Most time is spend at the creation of the accessories.

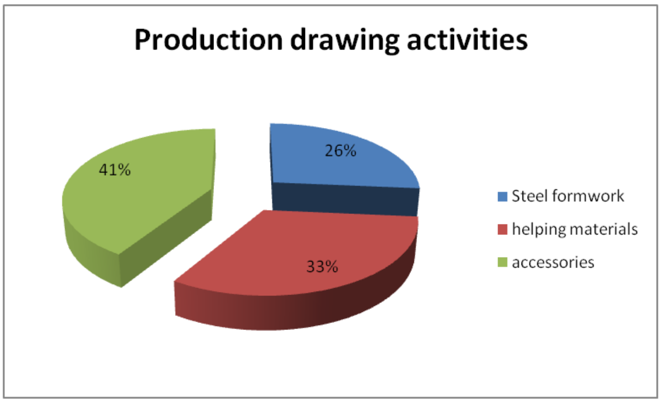

Figure 12; Ratio of activity

Accessories are relatively small materials to stop the concrete at the formwork. One of them is the ´end stops´, other products are a floor stop, window stop, lintel and doorstop. The focus in this research is only at the 'end stops', the other products can be improved using the same method. The product 'end stop' is explained in appendix 6.

During the value stream map sessions, each employee answered the question what kind of options might improve the current preparation process. All employees mentioned the option to standardize the drawings of the accessories and especially the 'end stop'. The interviews are presented in appendix 5.

4.4.1 Process of the product 'end stop'

The current situation for the accessory 'end stop' is that there are 151 standard drawings. Most of them are not correct and extra time will be spent to change some details to complete the production drawing. This situation is derived through the fusion of the locations 'Broekland, Nederweert, and Lelystad' by putting together three different production processes and preparation processes. **The employees in the production expect that the products can be produced 30% faster.**

4.5 Conclusion - what are the activities in the preparation phase

Of the four analyzed products, the processes of the products steel tunnel formwork and the steel wall formwork have the most non-value added hours. The future map shows that a time reduction of 58% is possible in the process steel tunnel formwork and 55% in the process of the steel wall formwork. **The biggest non-value added process steps is the step 'production drawing'**. This process step is further analyzed and **in this process most time is spent (41%) at the creation of 'production drawings' for accessories**. **The interviewed employees confirm that the accessory 'end stop' can be standardized further.**

The current situation of the 'end stop' is that there are 151 standard drawings. It takes too much time to find the correct drawings takes and most of them are not correct at all. **Therefore the process step 'production drawings' needs to be improved while focusing on the product 'end stop'.**

5 Process improvement of the process step ‘production drawings’

In this chapter the process of improvement is presented for the process step of ‘production drawings’ presented for steel tunnel formwork and steel wall formwork. The focus of this improvement is on the creation of production drawings for accessories, because most of time is spend here. Two improvements and one alternative are presented in this chapter. In section 5.1 the first improvement is described. Different subsections describe benefits, costs, and the investment. The improvement will be evaluated with the conditions of ‘Lean’. In section 5.2 a second improvement is explained. Subsections will be made to explain further details. In section 5.3 an alternative is presented. In section 5.4 the conclusion of the improvements is stated.

5.1 Improvement 1

The process step ´production drawings´ will be improved by standardizing products of the accessories. The accessory ´end stop´ is selected, because the interviewed employees expect the largest opportunity for improvement here (appendix 5). The ´end stop´ will be standardized based on the philosophy of the theory platform thinking which has been explained in section 3.4.3. Based on theory, a basic platform will be designed and different elements will be added to the platform. The goal in standardizing the product ´end stop´ is to create a standard platform where different elements can be added. By adding one or a few elements many variations can be created. With these variations the necessary flexibility for the product in building projects can be realized.
By standardizing the platform and elements there is no need to create a production drawing anymore, because the production drawing is always standard now. This will save time in the work-out phase. To identify the platform and elements the following steps are made:

1. From the available projects in 2011 all used endstops are piled up.
2. Based on the piled up picture the product is divided into different parts.
3. For each part the differences used are investigated. For each difference a new element will be made.
4. A schematic overview will be made of the possible variations.

5.1.2 Analysis of the product ‘endstop’

To define the platform, 25 building projects are analyzed. Of the 25 projects all end stops are piled up. The result is presented in figure 13 on the next page. A platform will be part of the product that doesn´t change. The product parts that change between projects are the elements. These elements can be added to the platform. From the piled up ‘end stops’ a platform and elements will be defined.

Figure 13 shows different parts of the product. A platform can be created when the lines are drawn on the same place. The lower part shows some differences in the fastenings points. The fastenings points are drawn on different places, because different production types are used. The fastenings points can be seen as a whole. In the upper part a lot of different lines are visible indicating that the product must be flexible at this point. At the face of the end stop (vertical lines at the left) changes between projects are visible as well, because the lines are not drawn on the same place but close to each other. Also flexibility is needed here.
At the top four different elements are used. All show some small changes in breadth and height. Therefore, four stretchable elements at the top are needed. At the face side of the product five different elements are used. Three of them differ in depth and all show some little changes in the breadth. The construction in the lower part doesn’t change. the different fastening points. A schematic overview (figure 14) gives a better view of the needed elements. In appendix 7 the differences between the used endstops are described in detail.

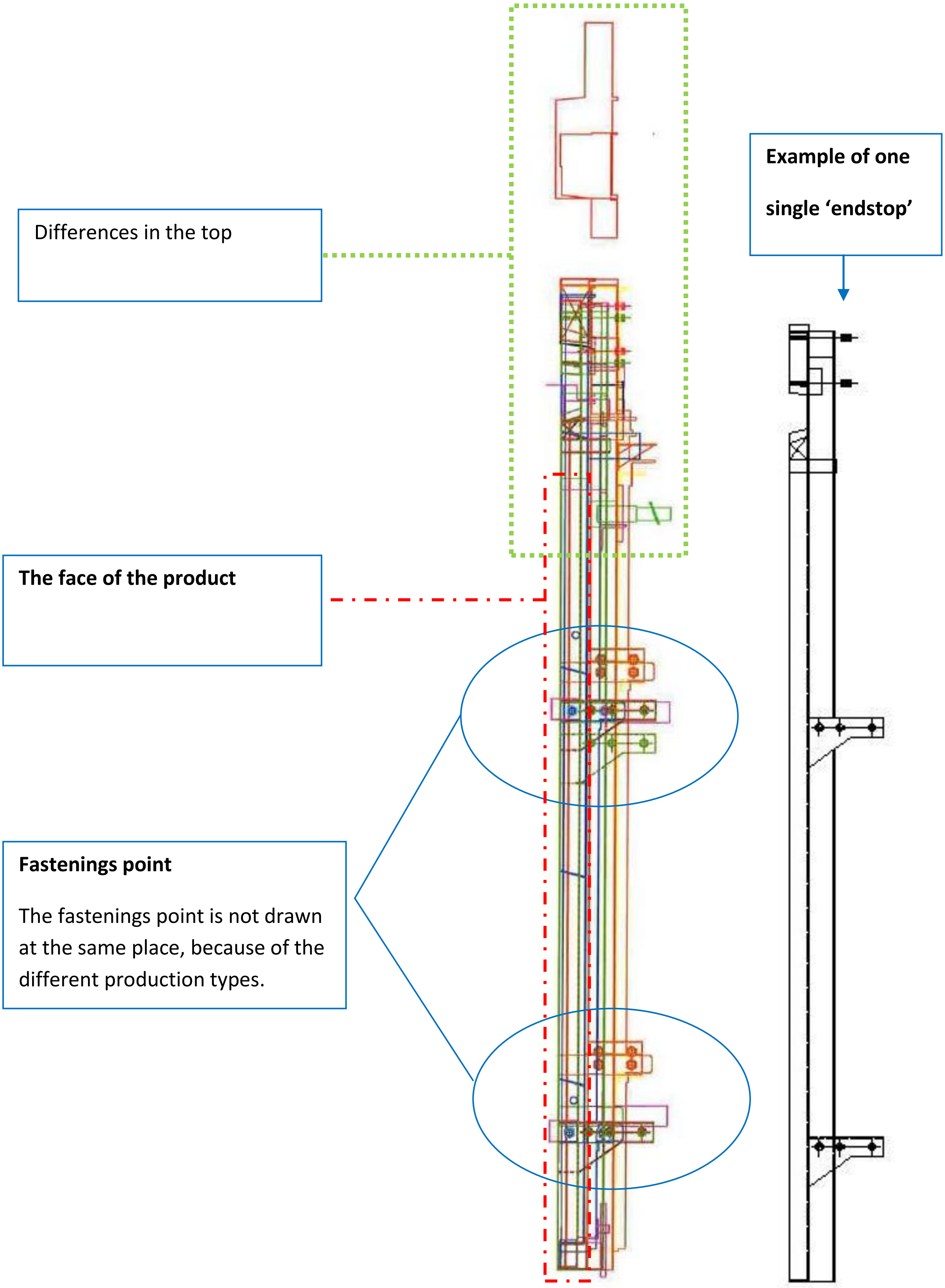

Figure 13; End stops analysis 1

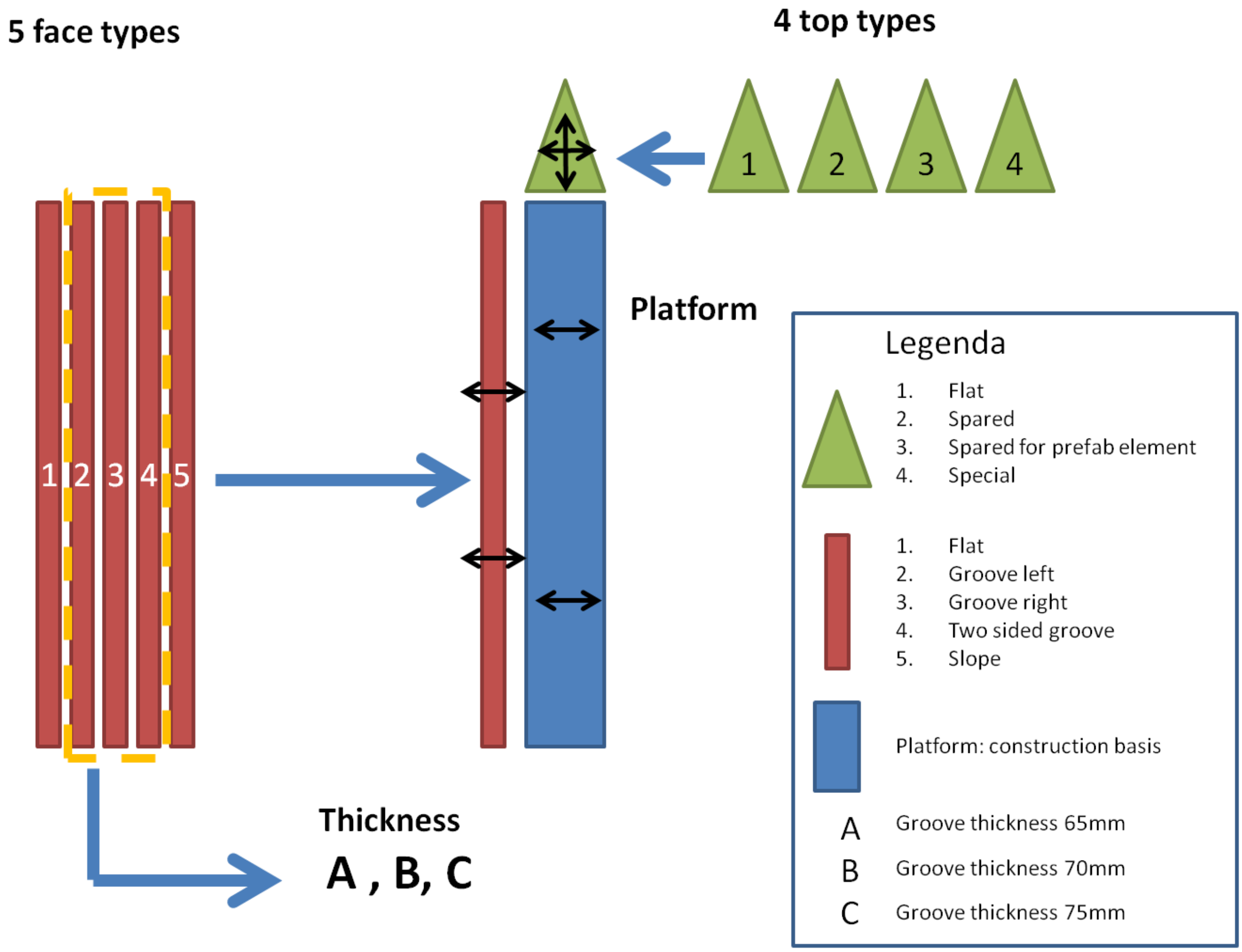

Figure 14; Schematic overview of a standardized end stop

In figure 14, the blue rectangle is the platform which is the construction basis for each 'end stop'. This bases must be stretchable in the breadth. There are five different faces (red) and four different top types (green) which can be added to the platform. The face type must also be stretchable in the breadth like the platform basis, because both must have the same breadth. Three of the five face types are marked with a yellow punctuated line. For these types three different types of thickness are used. The thickness types are named in the picture A, B, and C. The top form must be stretchable in breadth and height. The breadth is needed to fit on the platform and the length is needed for changes between projects. The black arrows in the picture indicate the direction to stretch. Each used element within the 25 projects is counted and shown in a graph. In the next section, the analysis of the top elements is described first. Second, the face elements are described.

5.1.3 Analysis of the top elements

The four different types of the top elements are:

1. Flat
2. Spared
3. Space for prefabricated concrete element
4. Special

The ratio of the used top forms are presented on the right in figure 15. **Striking is that in 48% of the cases type 1(flat) is used.**

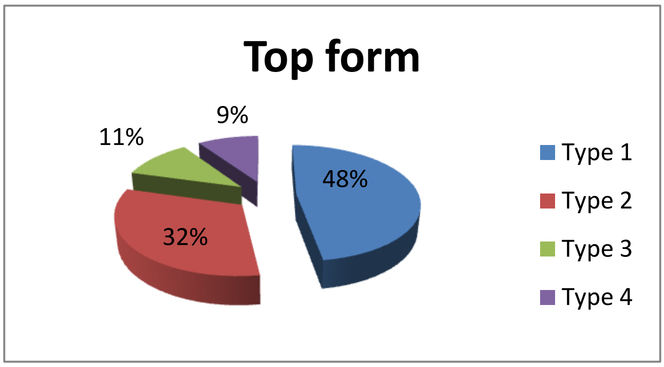

Figure 15; Ratio topform end stop 1

5.1.4 Analysis of the face elements

The five different face elements are:

1. Flat
2. Groove left
3. Groove right
4. Two sided groove
5. Slope

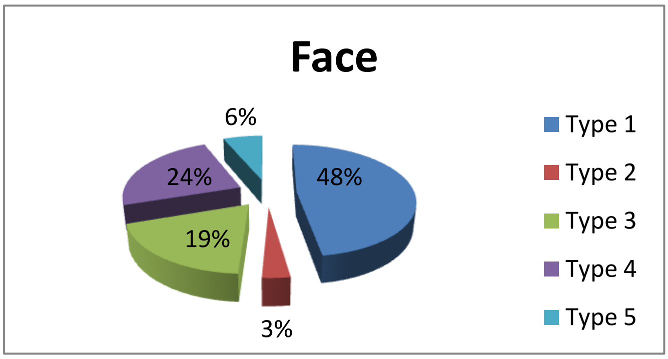

Figure 16; ratio of the face

The ratio of the five applicable faces are presented in figure 16. **Also here in 48% of the cases type 1 (flat) is used.** The types 2, 3, and 4 can't be selected directly because at these types a thickness must be chosen. In the analyzed projects three different thickness types are used. Figure 17 shows the ratio between the three options.

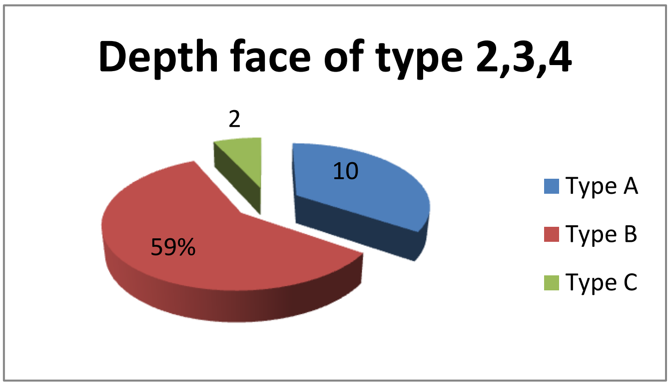

Figure 17; ratio depth face

From the analyzed projects in 59% of all cases type B is used. Type A is used 10% and Type C 2% (figure 17)

5.1.5 Variation possibilities with the platform and elements

When standardized elements are combined with a platform less resources are needed without reducing the variation possibilities of the product. In this section the relation between the number of resources and the amount of variation are explained. There are now eleven face elements, including the thickness options, and four top elements (15 elements in total). It is possible to add or delete a top or face element. The opportunities to create an end stop increases strongly by adding a new element to the current set. This is presented in the following tables. Table 4 shows the amount of variation by adding or deleting a top element. Table 5 shows the amount of variations by adding or deleting a face element.

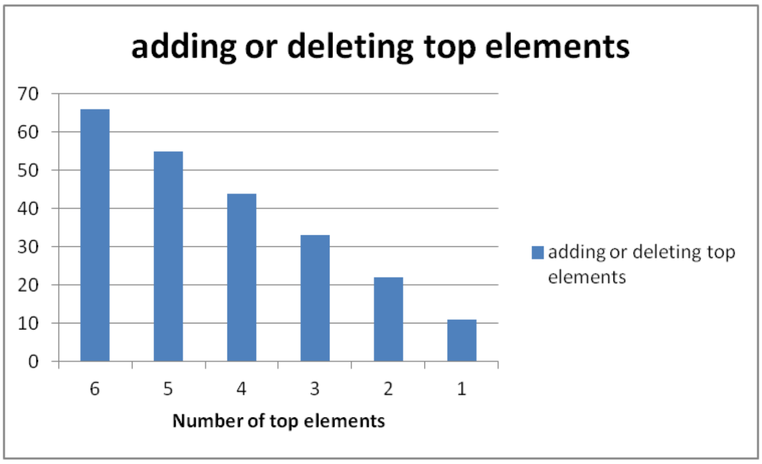

Figure 18; Adding or deleting top elements

Figure 18 shows the amount of variations of adding or deleting a top element. The analysis (figure 14) includes four top elements. With four top elements and eleven face elements forty-four different types can be created. When there is only one top element eleven variations are possible. When there are six top elements sixty-six variations are possible.

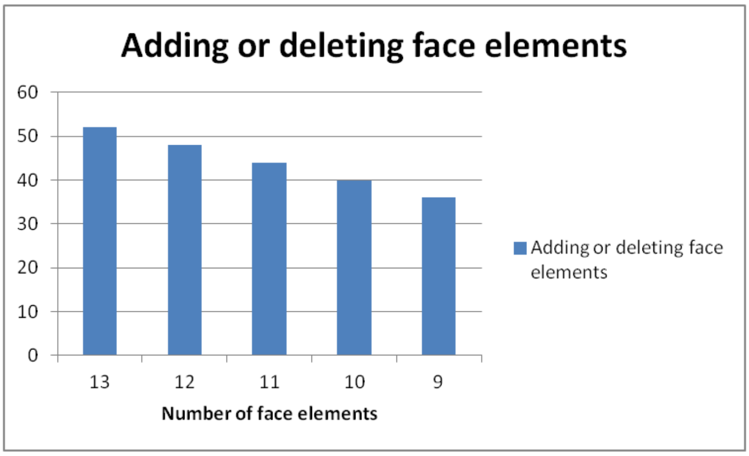

Figure 19; Adding or deleting face elements

Figure 19 shows the amount of variations of adding or deleting a face element. The analysis (figure 14) includes eleven face elements. With eleven face elements and four top elements forty-four variations are possible. When there are thirteen face elements twenty-five variations are possible and with nine face elements thirty-six variation are possible (figure 20).

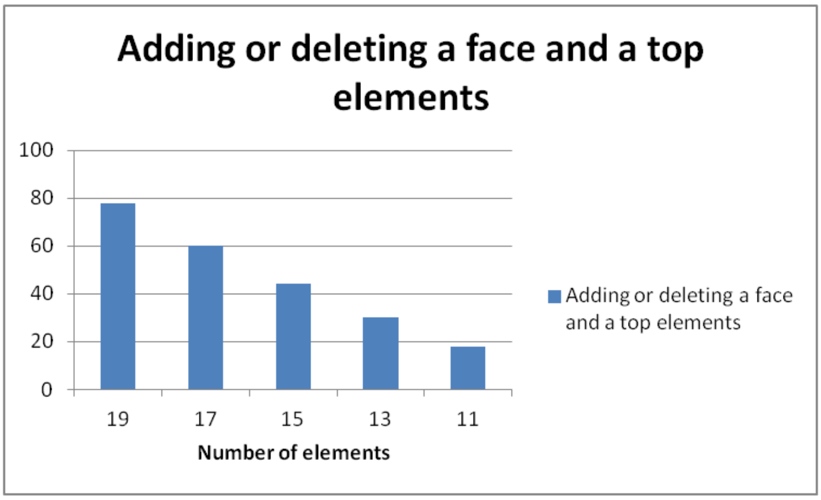

Figure 20; Adding or deleting face and top elements

When a face element and a top element are both added or deleted the possible variations grow fast. Figure 20 shows that with nineteen standard elements 78 variation can be created. From the 25 analyzed projects only 15 standard elements are needed, leading to 44 variation possibilities.

When the drawings are standardized the employees for production only need to know the height and breadth of the selected elements. Only communicating this information saves a lot of time in the preparation phase. The benefits and investment costs are calculated in the next sections.

5.1.3 Calculations of improvement 1

This section has three subsections. In 5.1.3.1 the time savings are calculated. In section 5.1.3.2 the benefits per year are calculated. In section 5.1.3.3 the investment and payback time is calculated.

5.1.3.1 Calculation of the time saving

Table 4; Profits of the standardization

Process	Total hours	Capacity in persons	Total hours (year)	Saving time	New total hours	time saving %	Time saving hours
				Preparation			
Tunnel	310,5			34	276,5	11%	
Wall	231			23	208	10%	
Total	541,5	8	16640	57	484,5	10,50%	1752
				Production			
	Units/year	**Hours/ unit**	**Total time**	**Reduction %**	**Saving time**	**New total hours**	
Endstop	1082	1,6	1731				
Doorstop	367	2	734				
Window stop	316	4	1580				
Floorstop	349	1,6	558				
Lintel	111	1,6	178				
Total			4781	30%	1434	3347	

In table 4 the total hours are shown which are necessary to complete the process of the steel tunnel formwork. This is 310,5 hours in total. The total hours to complete a steel wall formwork are 231. For the calculation, the time of the two processes are added, leading to a total of 541,5 hours. The capacity of employees to work out the production drawings is 8 in total. When the division of projects for steel tunnel formwork and steel wall formwork is

equally divided (both 50%) four employees can draw a steel tunnel formwork and four employees can draw a steel wall formwork.
Eight persons can work 16640 hours in a year, based on 260 workday's (8x8x260=16640). **With this capacity 31 projects can be completed in a year (16640/541,5=31)**. The saved hours at the steel tunnel process are 34, 11% of the total steel tunnel formwork process. The steel wall formwork process can save 23 hours, 10% of the total wall process. **The total hours of the two projects minus the savings is 484,5 hours, a reduction of 10,5% in time. In the new situation 34 projects can be completed in a year (16640/484,5=34).** The standardization creates also some time saving in the production phase. According to the head of the production, the standardization of the accessories can save 30% of the production time. The savings are: less time needed to check materials necessary for production, reading production drawings can be done faster, and one manner for production saves time and control. The saved time can also be calculated in money. This is calculated in table 5.

5.1.3.2 Benefits of improvement 1

The standardization eliminates the need to create a production drawing. This saves 1752 hours in the preparation phase and 1434 hours in the production phase. An employee in the preparation phase costs € 62,41 per hour and an employee in the production €50 per hour. The total saving in the preparation phase is €109.342,30 and in the production €71.700, **leading to the total benefit of €181.042,30**

Table 5; benefits calculated in money

Total hours (year)	Time saving %	Time saving hrs.	Hourly wage	Total saving €/year
16640	10,50%	€ 1.752	€ 62,41	€ 109.342,30
		Production		
		€ 1.434	€ 50	€ 71.700
Total				**€ 181.042,30**

5.1.3.3 Investment

The current process can be improved by standardizing the accessories through platform thinking. Some costs are necessary to create the standard elements and the platform: 1) all elements must be designed; 2) the interaction between the elements must be tested; 3) the production drawings of all elements must be made; and 4) the new product must be implemented in the preparation phase as well as the production phase. Before it can be used, the shareholders of BAM Equipment must give their agreement for the product.

The theory of platform thinking must be applied at the end stops, Doorstop, windowstops, Floor stop, and Lintel. Therefore, five different groups must be redesigned. The investment costs to redesign the end stop is used as an indication for the other five products.

Calculation of investment for improvement 1

In table 6 the number of elements to design are set at 10, because the differences in depth of A,B, and C can be designed simultaneously. 400 hours are needed to standardize the products according to the described elements in figure 14. The calculation is made in table 6. The engineer who creates this new design costs €90 per hour. So the total costs to design the elements €36.000. For the new elements a drawing for production must be created, by drawing all different types. The employee who makes the drawing costs €62,48. Total costs for the drawings are €6.248. The new product elements must be presented to shareholders. 4 hours are expected to complete this activity. The production employees must practice the production of the new elements and some instructions are necessary with total costs of €700. Total costs to redesign one product group is € 43.308. To standardize all accessories 5 groups must be redesigned. **Total investment costs are €216.540.**

Table 6; Calculation of investment for standardization

	Design	Drawings		Shareholder		Production		Total €
Design 1 element	40	Complete 1 drawing	5	Inform stakeholders	4	instruction	1	
Needed elements	10	Total drawings	20			Practice	4	
Total	400	Total	100					
Hourly wage	90	Hourly wage	62,48	Hourly wage	90	Hourly wage	50+90	
Total €	36000	Total €	6248	Total €	360	Total €	700	**€ 43.308**
Product groups								x 5
								€ 216.540

Payback time of the investment

For some of the calculated investment costs interest must be paid. The interest for 5 years is €5.413,50. This amount of interest is discounted from the benefits per year. Also service costs of € 10.000 are discounted from the benefits per year. The total benefits after the discount of interest and service is €165.628,80. **The payback time of the investment/benefit is €216.540 / € 165.628,8 = 1,3.**

Table 7; Payback time of the investment

		Investment		
	Investment costs	Interest %	Total interest	Average in 5 years
Investment costs	€ 216.540	5%	€ 10.827	€ 5.413,50
		Profit		
	Benefit in €	**Average interest**	**Service costs**	**Total benefit**
Benefit	€ 181.042,30	€ 5.413,50	€ 10.000	€ 165.628,80
		Payback time		
	years			
Investment / benefit	1,3			

5.1.4 Are the 'Lean' conditions met?

Improvement 1 can save 10,5% of time in the preparation phase. But is this improvement Lean? To check this the conditions from the literature review will be evaluated. The conditions are as follows.

Poka Yoke device	• The standardization of the endstops and other product reduce the chance of making a mistake. But no device is implemented. Therefore this condition is not met.
Simplify the number of steps	• The activity of drawing a production drawing is eliminated. Only the variables and product types are needed to write down.
Use a pull flow control	• This improvement has not the ability to create a pull flow control. The information is still pushed through the organization
Use virtual models	• The standard drawings are not 3D. None of the created drawings are 3D.
Standardization	• The standardization theory platform thinking is used. The product is build up from standard elements whereby flexibility of the product is maintained.
Reduce non-value adding activity	• The creation of production drawings is after an analysis the biggest non value-added process step. This step is eliminated.

Not all conditions of 'Lean' are met. The three conditions 'Poka Yoke device', 'use a pull flow control' and 'use virtual models' are not met. An additional advice will be given to meet these two conditions.

5.1.5 Impact analysis of improvement 1

The improvement has impact on the organization of BAM Equipment. The consequences of the improvement are summarized here:

- The activity time to create a production drawing for the accessories is eliminated. Therefore the new standard drawings must be stored at the production hall.
- The communication between the preparation phase and the production phase will be different after the implementation. Only the needed element types and the variables (breadth and height) are needed to communicate. It is not necessary to send a complete production drawing.
- Because less activities steps are needed in the preparation phase the chance to make a mistake will be smaller.
- The use of standard elements creates lower production costs.

5.1.6 Conclusion of improvement 1

The time in the process step ‘production drawing’ in the work out phase, which is a non-value added for the customer, can be reduced with 10,5% in case the products of the accessories are redesigned with the theory platform thinking. One standard platform is designed where different elements can be added. Eleven face elements and four top elements are defined. In total forty-four different variations are possible to build an ‘end stop’. To realize the improvement an investment is needed of €216.540. The benefit per year is €165.628,80. The investment is paid back in 1,3 years. In the current situation, BAM Equipment can realize 31 projects. When the improvement is realized 34 projects can be realized in a year.

The improvement doesn’t meet all conditions of ‘Lean’. The conditions ‘Poka Yoke device’, ‘use a pull flow control’ and ‘use virtual models’ are not met. Improvement 2 will focus at these three conditions.

5.2 Improvement 2

This second improvement must fulfill the conditions from the model which are not met in improvement 1. In section 5.2.1 the improvement is explained. In section 5.2.2 the costs and profits are calculated. In section 6.2.3 the improvement is evaluated with the theoretical model.

5.2.1 Explanation of improvement 2

The products that are produced at BAM Equipment are not unique in the market. Therefore other companies must face the same difficulties. Last year, three out of five contacted companies with the same preparation phase and products as BAM Equipment have improved their preparation processes. All three companies implemented the virtual drawing software in the previous years. The new software has more advantages, next to virtual modeling. It is possible to generate production drawings automatically from the drawing ´routing´, which is a value adding activity. This is possible with standard drawings. A figure gives better insight of the advantages of the virtual modeling technique (appendix 4). The differences between the current method and the new method are presented in appendix 4. With the implementation of the new software, the process step ´production drawing´ can be eliminated because the drawings can be generated automatic by the software. The advantages of the software upgrade are summarized:

- The system upgrade uses 3-Dimensional models
- It eliminates the process steps ‘production drawings’ and ’daily scenario’
- The client asks for the drawing ‘routing’ and therefore a pull effect is created in the process.
- The software can generate drawings which reduces the change to make failures (Poka Yoke device).

For the second improvement some calculations are made.

5.2.2 Calculations for improvement 2

This subsection has four parts. Section 5.2.2.1 shows time savings in the process. Section 5.2.2.2 shows a calculation of the benefits per year. In section 5.2.2.3 the investment and payback time are calculated

5.2.2.1 Table of saving of improvement 2

In table 8 the time savings are calculated. In all, the process steel tunnel formwork and steel wall formwork need on average 541,5 hours to complete a project. Eight employees can complete these processes. They are able to work 16640 hours per year. The investment saves 97 hours for the steel tunnel formwork process and 49 hours for the process steel wall formwork. Together 146 hours can be saved, which is 27% shorter for the two processes together. In a year 4492,8 hours can be saved. **In the current situation BAM Equipment can complete 31 projects. When the improvement is realized 42 projects can be realized.**

Table 8; Time saving of improvement

Process	Total hours	Capacity in persons	Total hours (year)	Saving time	New total hours	time saving %	Time saving hours
Preparation							
Tunnel	310,5			97	213,5	31%	
Wall	231			49	182	21,20%	
Total	541,5	8	16640	146	395,5	27%	4492,8

5.2.2.2 Table of benefits of improvement 2

In table 9 the benefits of the investment are calculated. The time saving of 27% results in a benefit of €280.710,14. An investment is needed to update the current Auto CAD system into a three dimensional Auto CAD system. The upgrade is not a standard installation package but is a custom build software program. The costs for an upgrade is €100.000 (based on two offers).

Table 9; Benefits of investment 2

Benefits				
Total hours (year)	Time saving %	Time saving hrs.	Hourly wage	Total saving €/year
16640	27%	4492,8	€ 62,41	€ 280.710,14

5.2.2.3 Table of investment improvement 2

From the investment costs 5% of interest must be paid. The cost per year for an interest period of 5 years with 5% is €2.500 per year. This amount of benefits is subtracted from the benefits per year. Also the service costs of €10.000 are subtract from the benefits per year. The total benefits after the discount of interest and service is €268.210. The payback time is the investment/benefits, which is €100.000 / € 268.210= 0,37 years (Table 10).

Table 10; Payback time investment 2

Investment				
	Investment costs	Interest %	Total interest	Average in 5 years
Investment costs	€ 100.000	5%	€ 5.000	€ 2.500
Profit				
	Benefit in €	Average interest	Service costs	Total benefit
Benefit	€ 280.710,14	€ 2.500	€ 10.000	€ 268.210
Payback time				
	years			
Investment / benefit	0,37			

To eliminate the process step ‘daily scenario’ the use of standard elements is mandatory. So the first improvement must be completed before the profits of the new software can be taken. The improvement of new software is needed to implement a Lean improvement.

5.2.4 Are the ‘Lean’ conditions met?

The software improvement will fulfill the conditions of ‘Lean’ from the literature review. The conditions ‘Poka Yoke device’, ‘use virtual models’ and the use of a ‘pull flow control’ is created with the implementation of the new software. All conditions are now met (figure 22).

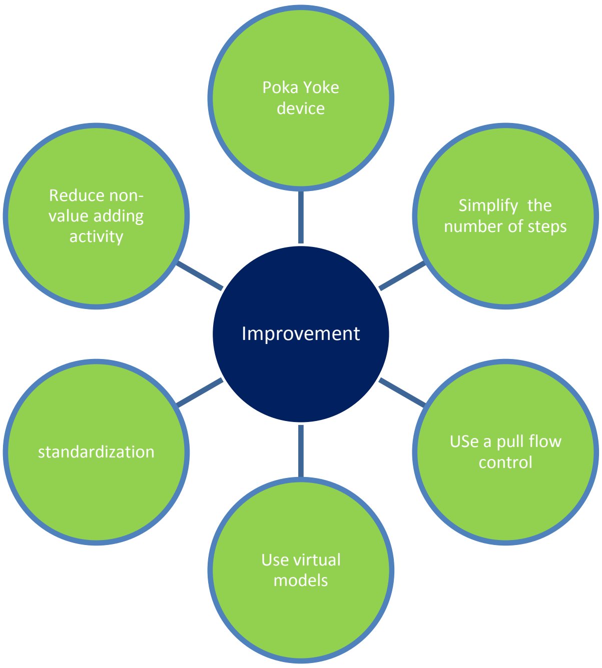

Figure 22; The theoretical model

Impact analysis of improvement 2

The improvement has an impact at the organization of BAM Equipment. The consequences of the improvement are summarized here:

- The variables to produce the standard elements will be generated automatically with the new software.
- The use of virtual models reduces the chance of making a mistake
- Paper packages are not pushed from the preparation phase to the production phase.

5.2.5 Conclusion of improvement 2

The process step ‘production drawing’ and ‘daily scenario’ in the work out phase can be eliminated. This is a time saving of 27% in the preparation phase. This time saving can be realized by updating the software. This new software use virtual models and creates a pull effect. The software update costs €100.000 and gives a benefit of €268.210 per year. The investment will be paid back in 0,37 years. **In the current situation BAM Equipment can complete 31 projects per year. When the improvement is realized 42 projects can be realized. When improvement 1 and 2 are implemented in the organization all conditions of ‘Lean’ are met.**

5.3 Alternative improvement

An alternative improvement is also possible. The analysis for improvement 1 indicates that one type of the ‘end stop’ is used in 48% of all cases. In section 5.3.1 the alternative will be explained. In section 5.3.2 the cost and benefits are calculated.

5.3.1 Alternative improvement

If it is not possible to standardize the products completely the best alternative is to standardize the most occurring types. An analysis of the ratio of the occurred differences is made for the ‘end stops’. The same ratio yields for the ‘floor stops’. The type flat is used in 48% of the analyzed cases. The same ratio must yield for the floor stops or other products, because they are linked to each other. So when a flat ‘end stop’ is used a flat ‘floor stop’ will be used as well. When this type is standardized, the creation of production drawings for this type are not necessary anymore. This will save some time in the preparation phase.

5.3.2 Calculation of the alternative improvement

The costs and benefits for the alternative are calculated. In section 5.3.2.1 the time savings in time and money are calculated. In section 5.3.2.2 the investment is calculated. In section 5.3.2.3 the payback time of the investment is calculated.

5.3.2.1 Table of time saving

In table 11 the total average process time of the processes steel tunnel formwork and steel wall formwork together is presented (541,5 hours). The total hours to draw the ‘end stops’ and ‘floor stops’ for the steel tunnel formwork and the ‘end stops’ for the steel wall formwork is 22 hours (appendix 3). There is a capacity of 8 employees, a total of 16640 hours per year. Of 22 hours, a reduction of 48% in time is possible. This is 2% of the average process. **Per year 332,8 hours can be saved, this is a benefit of 332,8 x 62,48= €20.793,4.** To standardize the most occurring end stop and floor stop some investments are needed. The calculations are presented in table 12.

Table 11: Calculated time saving

Total process time	Total (hrs)	Capacity per year (hrs)	Reduction	Time saving	Time saving % of the total process	New time	Saving in time
541,5	22	16640	48%	11	2%	530,5	332,8

5.3.2.2 Table of investment of the alternative improvement

Forty hours are needed to standardize the most occurring ‘end stops’ and ‘floor stops’. The engineer who creates this new design costs €90 per hour. So the design of the elements costs €3600 in total. For the new elements a drawing for production must be created. The employee who makes the drawing costs €62,48. Total costs for the drawings are €3.124. The production method must be practiced and introduced in the production phase, in total €700. **Total costs to redesign most occurring ‘end stop’ and ‘floor stop’ is €7.424.**

Table 12; Investment for the alternative improvement

	Design	Drawings		Production		Total €
Design 1 element	40	**Complete 1 drawing**	5	**instruction**	1	
Needed elements	1	**Total drawings**	1	**Practice**	4	
Total	40	**Total**	5			
Hourly wage	90	**Hourly wage**	€ 62,48	**Hourly wage**	€50+€90	
Total €	3600	**Total €**	3124	**Total €**	700	**€ 7.424**

5.3.3 Table of the paid back time of the alternative improvement

From the investment costs 5% interest must be paid (table 13). The costs per year for an interest period of 5 years with 5% is €185,6 per year. This amount of interest is subtracted from the benefits per year. **The total benefit is €20.607,74. The payback time is the investment/benefit, which is €20.607,74 / €7.424 = 0,36 years (table 13)**

Table 13; Payback time investment

		Investment		
	Investment costs	Interest %	Total interest	Average in 5 years
Investment costs	€ 7.424	5%	€ 371,20	€ 185,60
		Profit		
	benefit in €	**Average interest**	**Total benefit**	
Benefit	€ 20.793,40	€ 185,60	€ 20.607,74	
		Payback time		
	years			
Investment / benefit	0,36			

5.3.4 Conclusion of the alternative improvement

When the most occurring type of the 'end stop' and 'floor stop'(flat) is standardized, 2% of the time in the preparation phase can be reduced. With this standardization it is not necessary to draw a production drawing for the flat 'end stop' anymore. To standardize this 'end stop' and 'floor stop' an investment is needed of € 7.424. The total benefit of this standardized product is € 20.607,74. The investment is paid back in 0,36 years.

5.4 Conclusion – how to improve the process

The preparation process can be improved by standardizing the accessories with the theory platform thinking and updating the used software in the work out phase. The first improvement is the standardization of the accessories**. This results in a time saving in the preparation phase of 10,5%. The total benefit per year is €165.628,8. This improvement has investment costs of €216.540,- and is paid back in 1,3 years.** With this improvement 10,5% of the non-value added process step 'production drawing' is eliminated. The conditions use 'virtual models' and create a 'pull control'.

The software update of the second improvement can only be implemented in case improvement 1 is completed. Improvement 1 and 2 together fulfill the conditions of 'Lean'

The software update makes it possible to use virtual models and creates the needed information for production of the standardized accessories automatically. **The investment costs for the update are €100.000 and safes €268.210 per year. This investment is paid back in 0,37 years.**

An alternative to improve the process is to standardize the most occurring 'end stops' and 'floor stops' only. This creates a time saving of 2% in the preparation phase. The investment costs to standardize this 'end stop' type is €7.424. The total profit of this standardized product is €20.607,74. The investment is paid back in 0,36 years.

6 Conclusion and recommendations

In this chapter the findings of the analysis and improvements are described. The first section answers the main research question. Besides some recommendations and opportunities for further research are described. This chapter ends discussing the limitations of this research and the used method.

6.1 Research question

- ***How can the preparation phase at BAM Equipment become more efficient according to the principles of 'Lean'?***

The preparation phase at BAM Equipment can become more efficiently according to the conditions of 'Lean' by standardizing the accessories with the theory platform thinking and by updating the current software.

Of the four analyzed products, the processes of the products steel tunnel formwork and the steel wall formwork have the most non-value added hours. For both products the largest non-value added process step is creating 'production drawings' for accessories.

The first improvement is the standardization of the accessories**. This results in a time saving in the preparation phase of 10,5%. The total benefit per year is €165.628,8. This improvement has investment costs of €216.540,- and is paid back in 1,3 years.** With this improvement 39% of the non-value added process step 'production drawing' is eliminated, 10,5% of the whole preparation process. Three conditions of Lean are not met. These conditions are 'Poka Yoke device', 'use virtual models', and create a 'pull control'.

The second improvement fulfills all conditions of Lean, but this improvement can only be implemented when the first improvement is completed. The second improvement is a software update. This update makes it possible to use virtual models and creates the needed information to produce standardized accessories automatically. **The investment costs for the update are €100.000 and safes €268.210 per year. This investment is paid back in 0,37 years.**

An alternative to improve the process is to standardize the most occurring 'end stops' and 'floor stops' only. This creates a time saving of 2% in the preparation phase. The investment costs to standardize this 'end stop' type is €7.424. The total profit of this standardized product is € 20.607,74. The investment is paid back in 0,36 years.

The following conclusion can be drawn to become more efficient with the conditions of 'Lean':

- Eliminate non-value added process steps for the customer by standardizing products based on the theory platform thinking.
- Update software to virtual programs and create programs which generate the needed information automatically, pulled by the needs of the (??) customer.

6.2 Recommendations

With the knowledge of this research some recommendations can be made:

- By creating a database with time indications for all activities taken in the preparation and production phase more opportunities for improvement may become visible.
- Create a detailed database of failures made in the preparation phase. When each failure is investigated at which point the mistake was made, a relation between the failures and an activity step may become visible in the future. This activity step can be improved to avoid failures.
- Select one production type for the end stop as soon as possible. The variation in products creates failures and it takes more time than needed to complete a production drawing.
- Create a design team to standardize products and the related preparation processes. One of the problems in the current situation is that there is no capacity and time to standardize products or processes.
- The employees need to recognize waste in the processes and come up with improvement of the process by themselves. In other words implement the philosophy 'Lean' in the organization.

In conclusion, a lot of improvements may become visible when a detailed database for projects is created. With this database goals to improve the organization can be made and measured precisely. This research shows how the preparation phase can be improved with the conditions of 'Lean;, the philosophy must be adopted by the employees so they are able to detect waste and improve the processes by themselves.

6.3 Opportunities for further improvement

This research provides different opportunities for further research. The points are mentioned here in this section:

- Each non-value added process step must be investigated how this step can be eliminated with the principles of 'Lean'. The non-value added process steps are listed in section 4.3.
- Investigate the option to only start the work out phase when project information is definitive. This will lead to some time savings, because rework will be eliminated. Furthermore, the workload at the work floor is reduced resulting in more control and overview of the activities.
- Investigate the possibility to standardize other products with the theory platform thinking.
- Investigate the opportunities to receive useful digital information from the customer. With this, transforming the information isn't needed anymore.
- The opportunity and possibility to implement a software update is based on related companies. An internal research is necessary to confirm the possibility and precise costs of this improvement.

6.4 Discussion

In this section the limitations of the research are discussed first. Secondly, the used method is discussed.

Limitations of the research:

- Time estimations in the advice phase are only based on interviews, because no data was available for this process part. Interviewing more advisors was not an option, because there are only two of them and both advisors were already interviewed. This limited data gathering weakens the analysis of the process. For the work out phase limited data was available from 2009. Six projects were analyzed. The process and work method was not changed since 2009 therefore data was considered useful.
- The improvement of standardization is based on the interviews of eight persons. Besides the interviews the analysis indicated that the process step to create production drawing for the accessories must be improved. An alternative of standardization was explored. Outsourcing was an option but is not allowed by the management and is therefore not included in this research.
- The investment cost of the software update is based on two offers. The possibility to implement this software update is based on the implementation of related companies in the market. So the possibility to update and realize the benefits is not investigated in this company, however all competitors adopted the opportunity.
- The estimated time reduction is based on an interview with the head production. Also here no other data was available.
- The time estimation to design a platform and the elements is based on the estimation of the designer at BAM Equipment. Also for these activities no data is available.

The research method:

The used research method to improve the preparation phase is the 'value stream map' method combined with the steps to improve a product with the theory platform thinking. The steps taken in this method are described in detail in appendix 8.

This method is used in a practical assignment. The results of the research created many improvement opportunities in the preparation process. It's expected that by using this method, other processes can be made more efficiently.

To improve other products and processes the same described steps of this method can be used. By drawing the current state map and the future state map different opportunities improving the process become visible. This phenomenon is possible in any process. With the standardization of the product preparation time can be reduced.

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(www.bam.eu)

(www.joostdevree.nl)

Appendix 1: The current state map of the preparation phase

Appendix 2: The future state map of the preparation phase

Appendix 3: Activities in the process step ‘construction drawing’

Appendix 4: differences of the new and current software

Software upgrade

Improvement 2 has the advantage of the use of virtual models. To show the differences the two methods are compared. The first picture is the old method. A lot of information is given in the view. The picture shows two plans of two tunnel attitudes.

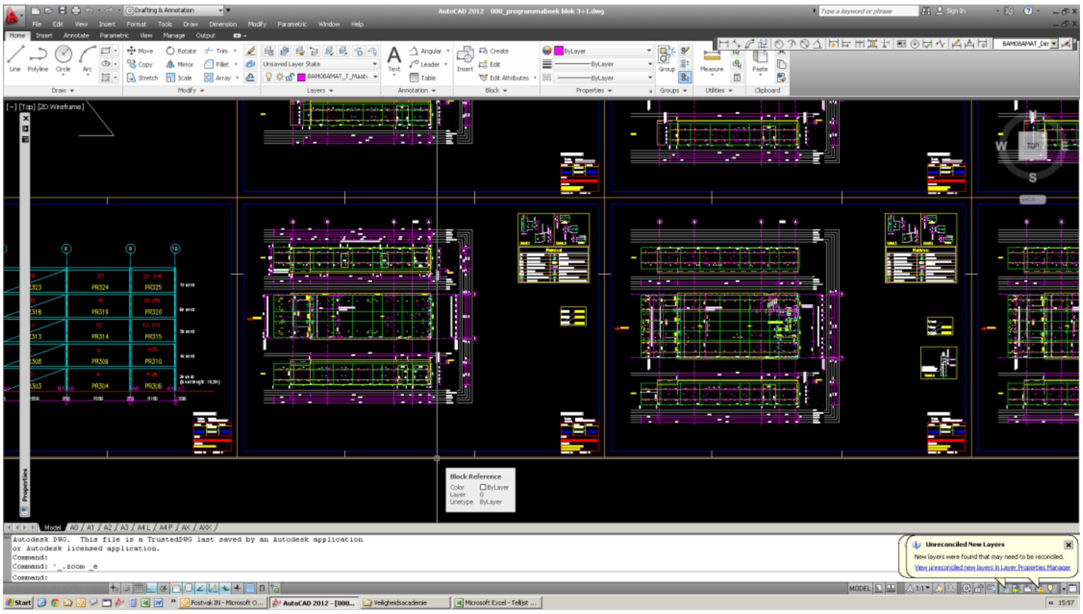


Figure 24; daily scenario BAM Equipment

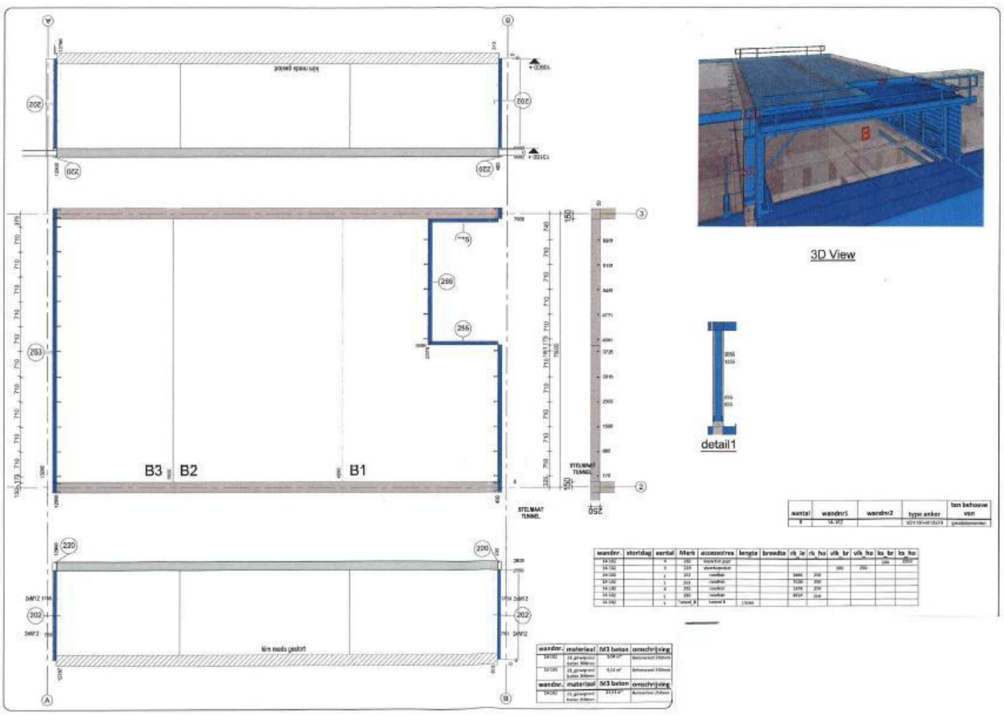


Figure 25; Daily scenario Smit's Bouwbedrijf

In the right upper corner is a 3D view of the work field. Left is the same plan but with less information. Standard elements are used, which gives a better overview. At the right a table with the specifications is show.

Appendix 5: Interviews

Table of employees for the value stream map session

Employee	Function	Project	Date
I. Baten	Advisor	Citadel	27/03/2012
I. Gries	Advisore/ project coordinator	Citadel	27/03/2012
D. Delissen	Draftsman	Citadel	22/03/2012
D. Timmermans	Draftsman	Ooievaar	14/03/2012
R. Hanssen	Advisor	Ooievaar	13/03/2012
J. Bron	Advisor/ project coordinator	Ooievaar	07/03/2012

Table 14; overview interviewed employees

Question how to improve the preparation phase?
Employee I. Baten; in the tender and assignment phase

Process: Steel tunnel form

How can the preparation process be improved?

- **Standardization**;
  - The most important point is the make standard drawings. At the moment the capability of the software is not used optimal.
  - To problem now is that there is internal no capacity to create standard drawings.
  - Also the documents the make an offer must be further standardized.

- **Information:**
  - The process can also be improved by getting as early as possible the final information of a project. Communication and rework of changed information can be saved.

- **Other improvements**
  - Keeping and creating good qualified personal saves the time for explaining and controlling.

Question how to improve the preparation phase?

Employee I. Gries; in the tender and assignment phase

Process: Scaffolding

How can the preparation process be improved?

- **Standardization**;
  - The drawings can be build up with standard elements. This can be further improved. The rest of the process is almost standard.

- **Information:**
  - The products which are send and coming back of the projects must be registered automatically. This will saves a lot of time. This will result in some time savings for the preparation phase and for the group employees who are counting the materials.

Question how to improve the preparation phase?
Employee D. Dillesen; in the work out phase

Process: steel wall form

How can the preparation process be improved?

- **Standardization**;
  - Through the standardization of elements and products is it possible to win some time in the preparation phase.
  - Another option is to use a 2nd employee who helps to complete the production drawings. An assistant.

- **Information:**
  - When the information of a project is totally complete. The work out phase can completed in a shorter time period. The document daily scenario can be completed at once. Now the document 'daily scenario' is send to the client and the changes must be adjusted before the document is completed.

- **Other improvements**
  - When the assignment phase and the work out phase is done by the same person, the time which is lost by communicating, explaining and miscommunication will be saved.
  - Now a day's the drawings of a project are received in a digital document. By starting up a project to work out I must print all the drawings. This takes a lot of time.

Question how to improve the preparation phase?
Employee D. Timmermans; in the work out phase

Process: Steel tunnel form

How can the preparation process be improved?

- **Standardization**;
  - Some drawings can be further standardized. Like the drawings of the accessories. In the current standard drawing are a lot of failures. This comes through the different production types from the past.
  - The capability of the software is not used optimal.

- **Information:**
  - Sometimes the agreements which are made in the assignment phase are not clear for the employees in the work out phase.
  - For some projects is the information to work out the project not complete. The result is that you must wait to finish the project.
  - Information which is changing at the last moment leads to failures.

Question how to improve the preparation phase?
Employee R. Hanssen in the tender and assignment phase

Process: Steel wall form

How can the preparation process be improved?

- **Standardization**;
    - The process can be improve by standardizing the drawings of the accessories
    - The products like accessories can be standardized further which will result in less preparation time. A possibility can be that there is one basic form which can be changed with different elements.

- **Information:**
    - The process can also be improved by getting as early as possible the final information of a project. Communication and rework of changed information can be saved.

- **Other improvements**
    - A better structure of the communication in the organization can probably save some time.
    - The time to print all the drawing can probably reduced by printing less or create a program which prints the selected drawings faster.
    - A program which generate automatically the lists for transportation can save some time.

Process: Housing

How can the preparation process be improved?

- **Standardization**;
    - This process is totally standardized

Appendix 6: Explanation of the products

What is a steel tunnel formwork

The form of a steel tunnel is a U form upside down. The form is used to build a building hull of concrete. A concrete wall and floor can be build in one time. The picture gives a better view of the steel tunnel formwork (figure 26).

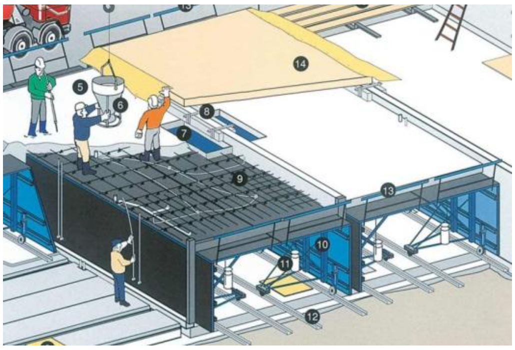


figure 26; steel tunnel form (www.joostdevree.nl)

What is a steel wall form

A steel wall formwork consists of two steel elements with an empty space in between. In the space concrete is cast. When the concrete gets enough strength the steel wall form will be removed and placed in the right position for the next wall. A concrete wall is the result (figure 27)

Figure 27; Steel wall form (www.joostdevree.nl)

What is an 'end stop'

An end stop is used to stop the concrete at the end of the wall which will be build. The end stop is fastened to the steel tunnel formwork or steel wall formwork. In picture 28 is a drawing of the steel tunnel form with in the red rectangle the end stop. The white mass which is laying down at the tunnel form is the concrete.

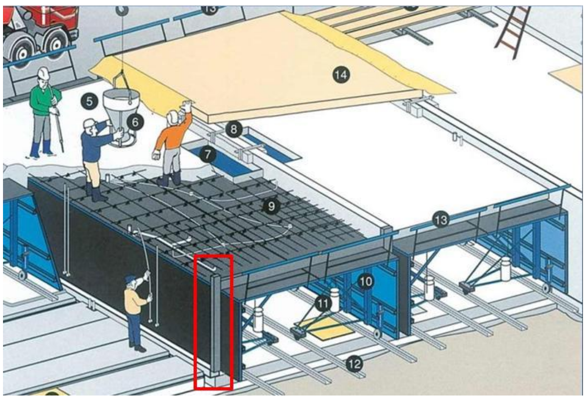


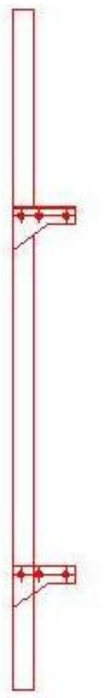
Figure 28; Steel tunnel form with end stop (www.joostdevree.nl)

The end stop is fastened at the steel tunnel form or steel wall form. In picture 28 a steel tunnel formwork is drawn.

Appendix 7: Defining the elements and platform

Platform

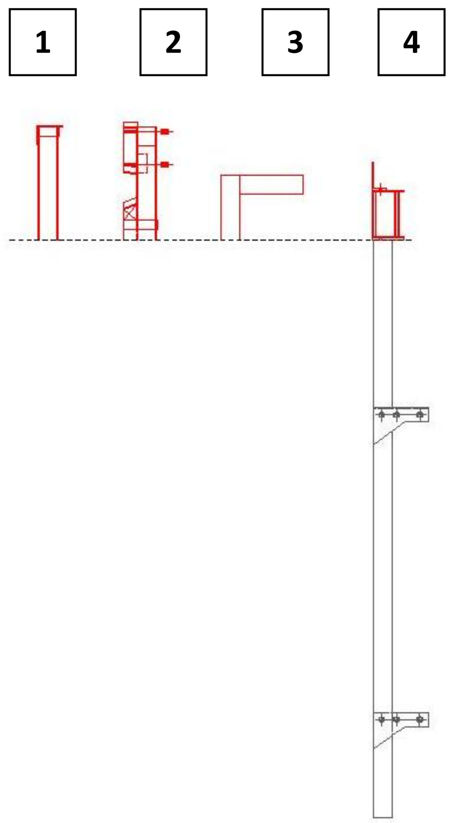
The construction of the 'endstop' can be defined as the platform. This lower part of the 'endstop' doesn't change. Instead of different fastening points, one is selected.



Top elements

The differences at the top of the 'end stop' are analyzed. At the top four different types are used in the 25 projects. In the analyzed projects the types show some small changes in breadth and height. So the elements must be made stretchable. The types are called:

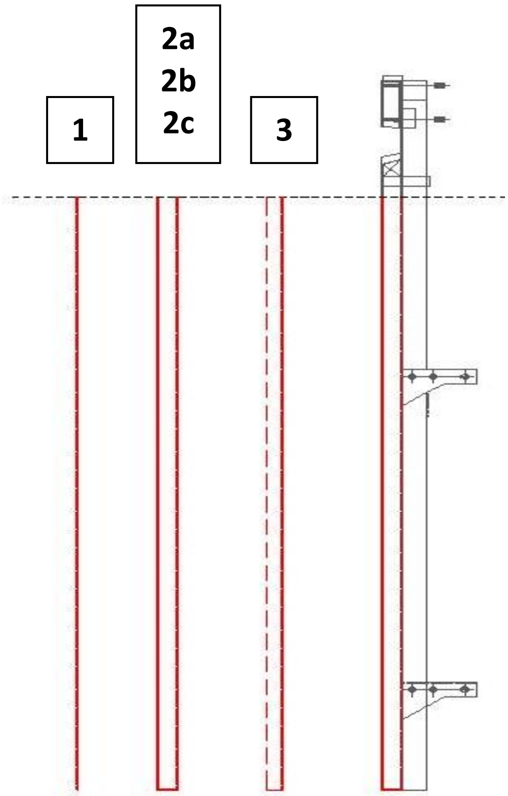
1. Top element flat
2. Top element spared
3. Top element spared for prefabricated concrete
4. Special



Face elements

At the face side of the product are five different face elements used. The elements showed in the analyzis some small changes in breadth. The types are called:

1	Face element flat
2a	Face element groove left
2b	Face element groove right
2c	Face element two sided groove
3	Face elemnt with a slope



Appendix 8: Taken steps in this research

Step	Description
Create the current state map	The First step is to create an overview of the current processes. The overview must have process step included with an time indication and the steps must be marked as value added or non value added.
Create future state map	The second step is to delete the process steps which are marked as non value added. A process line with only value adding steps is the result. This is the goal for the company to change the current process to the created future process.
Creating a list of process steps to improve	The process parts which are deleted can be ranked in a list. On top of the list is the biggest non value added process step placed. This will be the first process part to improve.
Explore biggest non value added process step	The process parts which are deleted can be ranked in a list. On top of the list is the biggest non value added process step placed. This will be the first process part to improve.
Analyze the product of the explored activity	The process part to improve must be further investigated. For this part all activities must be placed in order and a time indication must be add to it. Also the documents and products in this step must be investigated. The activity where the most time Is spend will be improved
Pile up all products	The idea is to save time in the preparation phase when the product is standardized. Therefore the first step is to investigate the product and pile up all used drawings of the product.
Count the parts that differ	When all drawings are piled up the part that differ are visible. Investigate the differences and group them.
Count the commonality parts	When the drawings of the product are piled up the commonalty parts of the product become visible. This part of the product will be the platform of the product.
Improve the activity step to use only standardized elements and processes	A standardized product can be combined with a fast standardized preparation process. No complex production drawings or unknown products are used.