



Master's degree thesis

LOG950 Logistics

**Root cause analysis of walking at the shipyard at
Ulstein Verft AS; A Lean Perspective**

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Number of pages including this page: 175

Molde, 25.05.2012



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Acknowledgements

This master thesis is a mandatory part of the Master of Science in Logistics program at Molde University College. The work with the thesis started January and extended through May, 2012. The authors would like to express our gratitude to the following people:

Bjørn Guvåg: For being an advisor that has given the authors highly appreciated guidance and feedback, interesting discussions and motivation through the writing process.

Karolis Dugnas: For being a valuable co-advisor that has given the authors professional guidance, feedback, inspiring discussion and motivation through the writing process.

Runar Toftesund: For interesting discussions and for the information you provided.

Odd Sverre Volle: For all the help providing the authors with information, professional feedback and suggestions through the writing process. Further for providing the authors with equipment, office and apartment during the stays in Ulsteinvik.

The foremen at Ulstein Verft AS: For a warm welcoming and for providing the authors with valuable information. Further for providing the authors with equipment and help during the studies.

The operators at Ulstein Verft AS: For being open minded and providing the authors with valuable information during the conduction of the personal interview/ survey.

Odd I. Larsen: For guidance regarding the observation study and the calculation method.

The student group: For giving the authors highly appreciated feedback and motivation. Further for giving the authors valuable and interesting discussions through the process.

Malin Engeset, Ole-Petter Vinjevoll, Julianne Hovden and Hanna Aadland: For reading the thesis and give valuable feedback.

Our families and friends: For all your love and support.

Abstract

The Norwegian shipbuilding industry has through the last years struggled to remain competitive and profitable. This is partly due to the financial crisis and the increased competition from shipyards in low-cost countries. Lean principles can be used to address these challenges.

Ulstein Verft AS started to focus on implementing Lean tools and methods already back in 2006 through the project *Lean Shipbuilding- Innovative shipbuilding in a Norwegian context*. A master thesis written by two students from Molde University College was a part of the project. The thesis revealed that 73 % of the working time at the shipyard in Ulstein is spent on non-value adding (NVA) and non-value adding but necessary (NNVA) activities. Therefore the aim of this master thesis was to find solutions on how to reduce the share of non-value adding activities by focusing on *walking* in the shipyard at Ulstein Verft AS.

This thesis uses Lean theory as a framework in order to reveal how much time which was spent at NVA and NNVA walking and further to find the root causes of the walking by using the 5 Why method. A case study of Ulstein Verft AS was carried out by using two data collection methods: an observation study and a personal interview/ survey. A calculation method which normally is used in transportation planning problems was used to reveal the walking patterns.

The findings showed that 2902 employees spent in total 20 hours on NVA and NNVA walking between 17 destinations during one working day. The main storage is one of the destinations which employees spend much time walking to; 150 employees spend in total 2 hours and 10 minutes walking between door 1 (the main door in the dock) and the main storage during one working day (7.5 hours). Further the results showed that each employee in average spend 2 hours per day on walking to get tools and materials.

The conclusion suggests that Ulstein Verft AS should implement smart devices in their production and in their communication. Further they should continue to focus on Lean tools like the 5 S and on Kaizen in their daily work. The master thesis has also showed that a transportation method could be a helpful tool in identifying walking patterns at a shipyard.

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List of abbreviations and acronyms

UPS – Ulstein Production System

R&D- Research and Development

TPS – Toyota Production System

LP – Lean Production

LC – Lean Construction

LS – Lean Shipbuilding

VSM – Value Stream Mapping

VA – Value adding

NVA – Non value adding

NNVA – Necessary non value adding

1 Introduction

This chapter presents the background for the research and gives an introduction to Ulstein Verft AS. Further the purpose of the study and the research problem are presented.

1.1 Background

Shipbuilding has been and will continue to be an important part of the maritime industry in Norway (Ulstein Verft AS 2005). Norwegian shipyards have advantages through short lead time, total project accomplishment and right-on-time delivery of highly complex ships (Hervik, Aslesen and Oterhals 2005).

However, the Norwegian shipbuilding industry has through the last years struggled to remain competitive and profitable. There are two main reasons for this. Firstly, the industry experienced an order boom of shipbuilding contracts from 2000-2007, which resulted in problems for the shipyards to finish projects on time due to lack of capacity. This resulted in expensive delays and thus low margins for the shipyards (Aslesen 2007) (Ulstein Verft AS 2005) (Hervik, Otherhals, et al. 2011). Secondly, the financial crisis which started in 2007 led to a decrease in orders for new ships. In addition, the Norwegian shipbuilding market experienced an increased competition from shipyards in low-cost countries due to this crisis (Hervik, Oterhals, et al. 2010).

The future prospect for the Norwegian shipbuilding industry appears mixed. Hervik et. al. reported in 2011 an increase in both order levels and margins for the shipyards located in the Norwegian county Møre and Romsdal. Hervik further stated that most shipbuilding companies were optimists with regards to market developments for the future. They expected a high and rising oil price and growth in contracts regarding vessels for “deep waters operations”. The oil leak at an oil platform in the Mexico gulf in 2010 lead to stricter requirements regarding quality and safety on demanding offshore operations, and it is in this field the Norwegian shipbuilding industry has a strong competitive position. However the current economic climate regarding the debt crisis of several EU countries, the USA and Japan gives uncertainty regarding funding of new ships. This means that the Norwegian shipbuilding’s cost competitiveness will be tested (Hervik, Otherhals, et al. 2011).

The challenge for the Norwegian shipyards is to maintain the quality and innovation advantage while reducing costs and lead time for producing ships. This is due to the fact that the industry is characterized by frequent change orders, global supply chains and increased competition from shipyards in low-cost countries. Shipyards in low-cost countries have in addition to providing cheaper ships also started to investigate the possibility to construct the same types of ships as the Norwegian shipyards (Hervik, Oterhals, et al. 2010) (Hervik, Otherhals, et al. 2011). According to Aslesen (2007) Lean Thinking can be used to strengthen Norwegian shipyards competition abilities. However Lean must be adjusted to the shipbuilding productions peculiarities (Aslesen 2007). Dugnas and Otherhals (2008) agrees with Aslesen and states that one way for shipbuilders to address the competitive challenge is through the adaption of Lean principles (Dugnas and Oterhals 2008).

In order to address these challenges, Ulstein Verft AS (which is presented in section 1.1.1) has in cooperation with the Norwegian research council's innovative program MAROFF, the shipyards STX Europe, Kleven Maritime as well as Møreforskning Molde and Molde University College engaged in an research- and development project. The project title was *Lean Shipbuilding- Innovative shipbuilding in a Norwegian context* and lasted from 2006-2009. The project was inspired by the concept of Lean Construction and the goal was to tailor Lean Thinking to the project-based production of the Norwegian shipbuilding industry. This ought to be done by increasing the understanding about the Norwegian shipbuilding industry in a Lean context, as well as developing Lean methods and tools to fit the industry (Ulstein Verft AS 2005).

In 2011 Ulstein Verft AS wanted to continue with this research and established a project titled *Lean Shipbuilding part II*, in cooperation with Møre Research, Fafo and Molde University College. The project goal is to increase productivity and lower the cost connected to the production of ships in Norway. The project has two main focus areas (Ulstein Group ASA 2011):

- Project logistics: The concept is developed as a part of the project to emphasize that the production has its own logistics that requires specific adjustments concerning both the physical flow and the organizational aspect in a value chain perspective.

- Social logistics: The concept has been used to emphasize the social cooperation required between activities and functions in a production setting.

This master thesis is a part of the Lean Shipbuilding part II research project and can be categorized within the project logistics focus area. For a better understanding of the research background Ulstein Verft AS is presented in the section below. Further this chapter presents the purpose of the study and the thesis research problem.

1.1.1 Ulstein Verft AS

This section is based on information from Ulstein Groups ASA's official website and information from Runar Toftesund, Ulstein Verfts manager in the planning department.

Ulstein Verft AS is one of Ulstein Group ASA's subsidiaries and the company represents the shipbuilding subdivision in Ulstein Group ASA. The company employs around 380 people and in addition they also hire extra workers for projects. Their main yard for shipbuilding is based in Ulsteinvik, Norway. However the company also has a department in Vanylven, Norway, where steel sections are built. In addition Ulstein Verft AS cooperates with Maritime-Shipyard in Poland and Zaliv Shipyard in Ukraine regarding delivery of ship hulls. Ulstein Verft AS roughly produces three vessels per year and was the most profitable shipyard in Norway in 2009. The figure below shows an overview over Ulstein Verft AS's shipyard area (Toftesund 2009) (Ulstein Group ASA 2011). The company will further in the thesis be referred to as Ulstein.



Figure 1: Ulstein Verft AS map

(Sunnmorskart u.d.)

1.2 Purpose of the study

In connection with the project *Lean Shipbuilding- Innovative shipbuilding in a Norwegian context* two students from Molde University College wrote a master thesis titled *A study of; Work-time utilization and root causes hindering work flow at Ulstein Verft AS*. The master thesis revealed that only 27% of the working time used in the production at the shipyard at Ulstein was spent on value adding activities (VA) (Ugland and Gjerstad 2010). Value adding activities are those activities which can be defined as transforming the product into something the customer wants (Liker and Lamb 2000). This means that 73 % of the work time is used on non-value adding activities (NVA) and on non-value adding but necessary activities (NNVA). Non-value added but necessary activities create no value but seem unavoidable with current settings. Non-value added activities create no value and are immediately avoidable (Womack and Jones 2003).

From 2006 to 2010 Ulstein's material purchasing costs accounted for approximately 60% of the company's total costs. Further 40% of the total costs were connected to work (Emblemsvåg 2012). This is illustrated in the pie chart to the left in figure 3. In addition, figure 3 illustrates that the work cost is further divided into value adding activities (27%) and non-value adding activities (73%). Ulstein's ongoing project, *Lean Shipbuilding part II*, aims at increasing the productivity and lower the costs connected to production (Ulstein Verft AS 2010). Thus the focus of this master thesis is to find solutions on how to reduce the share of non-value adding activities by using the concepts of Lean Thinking.

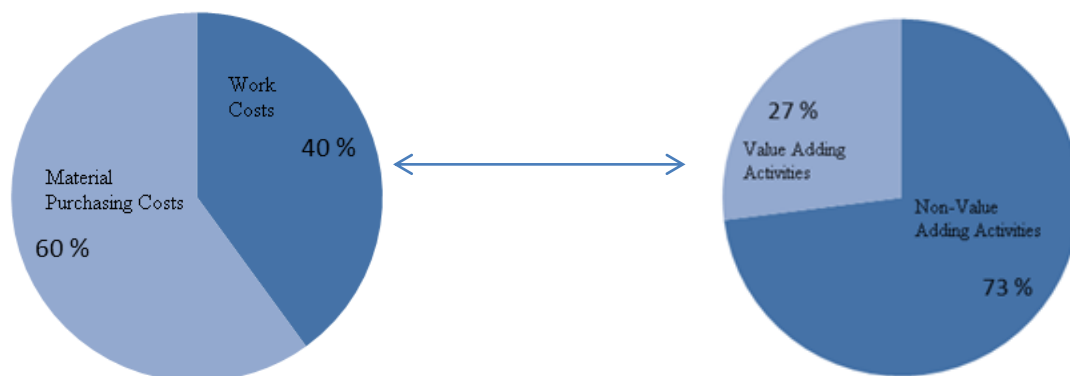


Figure 2: Division of cost and division of value/ non-value adding activities

1.3 Research problem

Ugland and Gjerstad (2010) further discovered in their master thesis that unnecessary walking in the shipyard was one of the reasons to the high share of NVA activities at Ulstein (Ugland and Gjerstad 2010). Based on these findings, Ulstein wanted to carry out a study of non-value adding (NVA) and non-value adding but necessary (NNVA) walking at the shipyard. Thus the master thesis focus is to find solutions on how to reduce NVA and NNVA walking and thus indirect create a higher percentage of value adding activities.

Two research questions are developed in order to provide guidance in the search for solutions to reduce the NVA and NNVA walking.

The master thesis answers the following research questions:

- 1) How much time do the employees working on ship #293 spend at non-value adding and non-value adding but necessary walking at the shipyard?*
- 2) What are the root causes of the NVA and NNVA walking and how can Ulstein counteract them?*

1.4 Structure of the thesis

Chapter 1: Introduction.

This chapter presents the background for the research and gives an introduction to Ulstein Verft AS. Further the purpose of the study and the research problem are presented.

Chapter 2: Theoretical Framework.

This chapter presents theories that are relevant to solve the master thesis research questions. Further the theory is used as a base for the research methodology, the analysis and in the discussion chapter. The thesis solves the research questions by using Lean Thinking theory. The Lean Thinking theory is split into four main sections. The first section presents Kaizen, the second section presents Lean Production theory, the third section present Lean Construction theory and the forth section present Lean Shipbuilding theory. The chapter ends with a theoretical summary.

Chapter 3: Research Methodology

In this chapter the research approach is described in terms of research design and data collection methods. The case study method and the action research model are explained in section 3.1. Further the direct observation method and the personal interview/ survey method are presented in section 3.2.

Chapter 4: Analysis

In this chapter the results from the observation study and the survey/ personal interview are presented.

Chapter 5: Discussion

The discussion chapter is divided into two main sections, one for each research question. Each section will use the earlier presented Lean literature and findings from the observation- and the personal interview/ survey study to discuss the research questions.

Chapter 6: Conclusion and recommendations

This chapter presents the master thesis conclusions based on the findings in the analysis and discussion chapters. The chapter further presents suggestions for future research.

The master thesis' disposition is presented in the figure below:

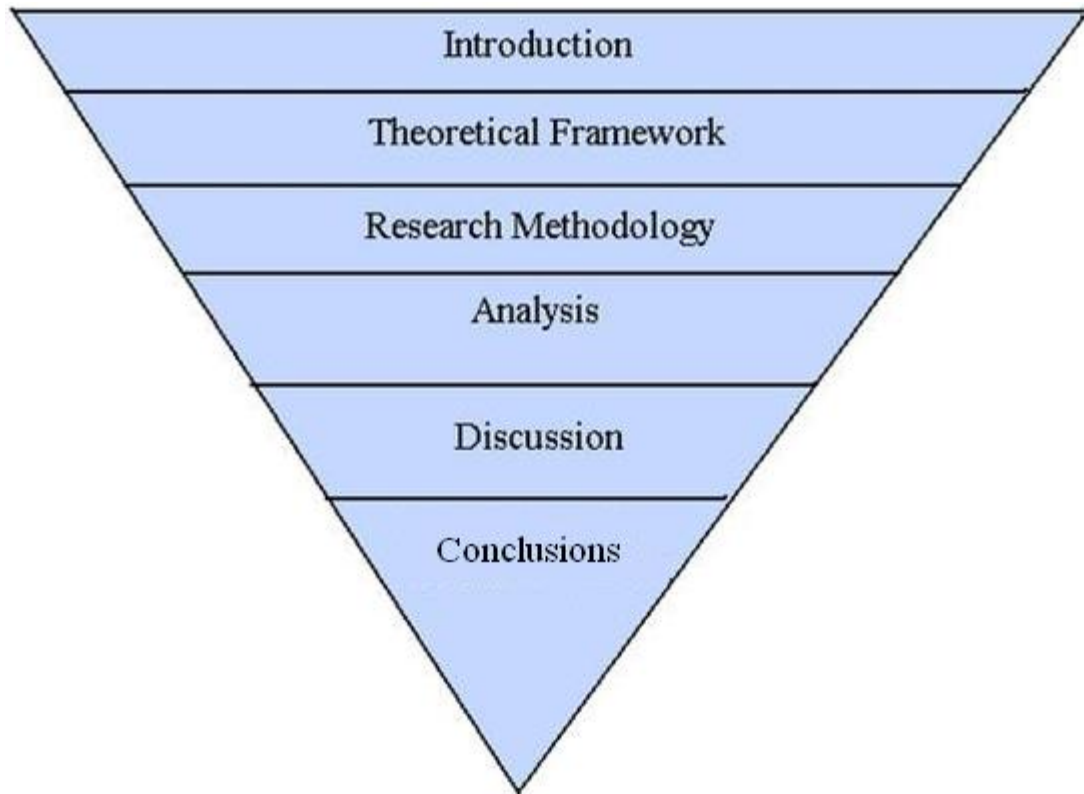


Figure 3: The thesis disposition

2 Theoretical Framework

This chapter presents theories that are relevant to solve the master thesis research questions. Further the theory is used as a base for the research methodology, the analysis and in the discussion chapter. The thesis solves the research questions by using Lean Thinking theory. The Lean Thinking theory is split into four main sections. The first section presents Kaizen, the second section presents Lean Production theory, the third section present Lean Construction theory and the forth section present Lean Shipbuilding theory. The chapter ends with a theoretical summary.

2.1 *Lean Thinking*

Lean Thinking is a fundamental mindset, and Yuji Yamamoto and Monica Bellgran (2010) have defined it as:

Lean Thinking definition:

[...] occasionally by force, create a situation where people have no choice (or little choice) but to feel the need of improvement. The situation is such that it brings different wastes and problems up to surface. Through letting people solving the wastes and problems one by one, the performance of the operation as well as the capability of individual and organizational learning are improved (Yamamoto and Bellgran 2010).

The word Lean is defined as *slim, efficient or/and optimal*. The road to a Lean organization involves a journey that includes useful techniques and tools, and creating a management that can generate a sustained and consistently evolving organization (Lean Consulting n.d.). Womack and Jones (2003) state that Lean Thinking is *Lean* because it provides a way to do more and more with less and less. An organization will use less equipment, less time, less human effort and less space. In addition an organization will manage to come closer to provide the customers with exactly what they want to pay for. Further, Lean Thinking provides a way to make the work more satisfying. This is done by giving immediate on efforts in order to convert waste into value (Womack and Jones 2003).

Lean Thinking can be seen as a general term for a business philosophy, and it contains specific terms like Lean Production, Lean Construction and Lean Shipbuilding (Ugland and Gjerstad 2010). These terms will be presented in respectively section 2.1.2, 2.1.3 and 2.1.4. Further, an important aspect in Lean Thinking is continuous improvement. The term Kaizen will be presented below.

2.1.1 Kaizen

Continuous improvement is also called *Kaizen*, which is a Japanese word. In business, *Kaizen* can be defined as “*The process of gradual and incremental improvement in pursuit of perfection of business activities*”. Continuous improvement is considered to be everybody’s job in an organization. Hence any employee must do their job and strive to improve it (Womack and Jones 2003) (Smadi 2009).

Kaizen is a strategy which is the single most essential concept in Japan’s competitive success. Many systems have been developed to make managers and workers Kaizen-conscious. Kaizen is the underlying thread running through the philosophy, the systems and problem-solving tools developed in Japan, such as Lean philosophy. It is important that organizations working with the Kaizen concept seek to satisfy the customer and serve the customer needs. Improvement regarding quality, cost and scheduling is crucial. All activities should lead to improved customer satisfaction (Imai 1986).

The management in an organization has two major focus areas they must concentrate on. These are maintenance and improvement. Maintenance is those activities that are involved when maintaining current technological, managerial and operating standards. Operation standards under maintenance means that management must first establish policies, rules, directives and procedures for all major operations and then see to that everybody follow these. Thus when people in the workplace come across a problem it is analyzed, the causes are identified and solutions are suggested (Imai 1986). This is done by using the steps in the PDCA-cycle, which will be further introduced in section 2.1.2.6. If the suggestion is found to be an improvement, it is adopted as a new standard. Improvement is referred to as the activities involved to improve current standards. Improvement can be broken down to two classifications, Kaizen and Innovation. Kaizen is here referred to as small

significant improvements in the status quo as a result of continuous improvement. Innovation contains an extreme improvement change that is a result of investments in technology and/or equipment (Imai 1986).

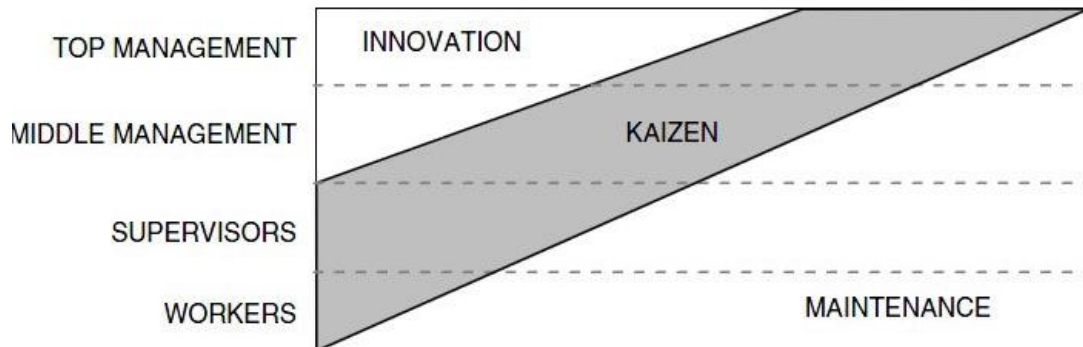


Figure 4: Japanese perception of job functions

Improvement in Kaizen is as already mentioned a continuing process and involves everyone in the organization. As illustrated in figure 5, a top manager should use approximately 50% of his/her working time on Kaizen. A worker should in contrast use little time of his/her working day on Kaizen, and focus mostly on maintenance. However the employee is still involved in Kaizen activities. The figure below shows the hierarchy of Kaizen involvement (Imai 1986).

| Top Management | Middle Management and Staff | Supervisors | Workers |
|--|---|---|---|
| Be determined to introduce KAIZEN as a corporate strategy | Deploy and implement KAIZEN goals as directed by top management through policy deployment and cross-functional management | Use KAIZEN in functional roles | Engage in KAIZEN through the suggestion system and small-group activities |
| Provide support and direction for KAIZEN by allocating resources | Use KAIZEN in functional capabilities | Formulate plans for KAIZEN and provide guidance to workers | Practice discipline in the workshop |
| Establish policy for KAIZEN and cross-functional goals | Establish, maintain, and upgrade standards | Improve communication with works and sustain high morale | Engage in continuous self-development to become better problem solvers |
| Realize KAIZEN goals through policy deployment and audits | Make employees KAIZEN-conscious through intensive training programs | Support small-group activities (such as quality circles) and the individual suggestion system | Enhance skills and job-performance expertise with cross-education |
| Build systems, procedures, and structures conducive to KAIZEN | Help employees develop skills and tools for problem solving | Introduce discipline in the workshop | |
| | Help employees develop skills and tools for problem solving | | |

Table 1: Hierarchy of Kaizen involvement

According to Rother and Shook (2003) there are two kinds of Kaizen;

- *Flow Kaizen*: Focuses on value-stream improvement regarding material and information flow. Flow Kaizen is management doing Kaizen.
- *Process-level Kaizen*: Focuses on elimination of waste at the shop floor team level regarding people and process flow.

(Rother and Shook 2003)

2.1.2 Lean production

Lean Production is one of the main terms in Lean Thinking, aligned with Lean Construction and Lean Shipbuilding. The section first presents conventional production vs. Lean production. Further Lean processes, value and waste and principles of Lean are presented. Last, the section presents tools that are relevant to solve the master thesis research problem.

2.1.2.1 Conventional Production vs. Lean Production

There have been two predominant production systems in the 20th century. This is the Conventional Production and a new production philosophy namely Lean Production (Koskela 1993). According to Womack and Jones (1996) a conventional process are broken down to a series of activities all converting input to output. This production system historically uses what is called batch and queue theory (Womack and Jones 1996). However the view of production as a series of conversions is fundamentally different from the new production philosophy. The new production philosophy views manufacturing as a flow model. Hence this is one of the core ideas of Lean Production (Koskela 1992). This flow process focuses on the elimination of the large buffers which are found within the Conventional Production. This is done by emphasizing the constant movement of components from one value adding activity to the next (Womack and Jones 1996).

Koskela (1993) has summarized the differences between the Conventional Production philosophy and the new production philosophy, Lean Production, in table 2 below (Koskela 1993).

| | Conventional Production Philosophy | New Production Philosophy |
|-------------------------------------|--|--|
| Conceptulation of production | Production consists of conversions (activities); all activities are value-adding | Production consists of conversions and flows; there are value-adding and non-value adding activities |
| Focus of control | Cost of activities | Cost, time and value flows |
| Focus of improvement | Increase of efficiency by implementing new technology | Elimination or suppression of non-value adding activities, increase of efficiency of value adding activities through continuous improvement and new technology |

Table 2: Conventional Production Philosophy versus New Production Philosophy

In Lean Production the emphasis is explicitly on the non-value adding activities. This is because it is possible to reduce the costs related to non-value adding activities considerably. This can be made through measurements and the application of the principles for flow control and improvement. Further, value adding activities are first improved through internal continuous improvement and fine tuning of existing machinery. The implementation of new technology is easier in Lean Production than in Conventional Production. This is because fewer investments are needed and the production is better controlled. Thus after the initial phase, Lean Production should have more rapid increase of efficiency of value adding activities than in Conventional Production (Koskela 1993).

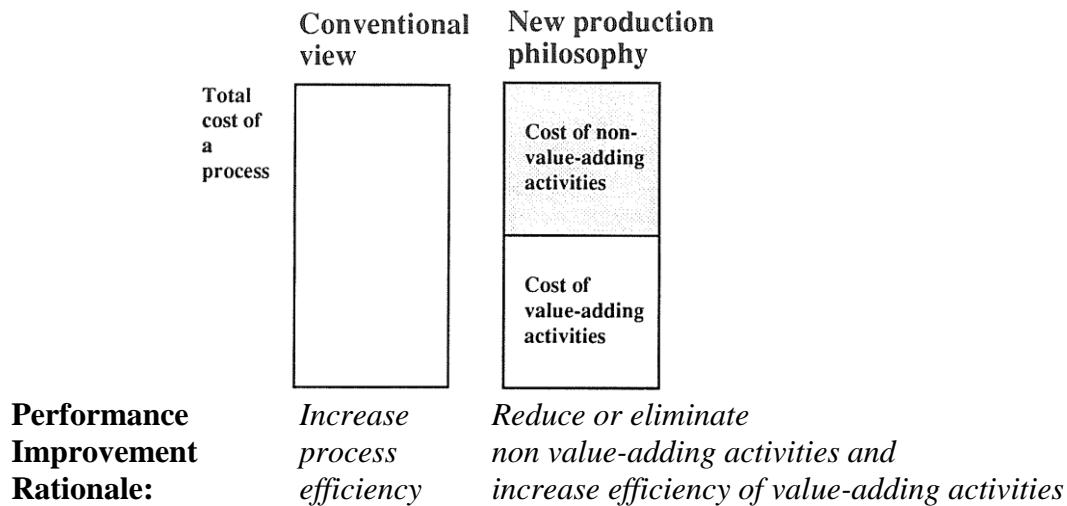


Figure 5: Conventional Production versus Lean Production (Koskela 1992)

Koskela's (1992) figure above summarizes the major differences in the cost aspect between the two predominant production theories of the 20th century. The Conventional Production focus on the total cost of a process, while the new production philosophy split the cost in to non-value and value adding activities. The goal of the new production philosophy is to reduce or eliminate non-value adding activities and increase efficiency of value-adding activities. The Conventional Production's goal is in contrast to increase process efficiency (Koskela 1992).

Lean Production History

The history of Lean Production (also known as Lean Manufacturing or the new production philosophy) started in the first half of the 20th century. This happened with Henry Ford and his invention of the mass production system (the focus on the production flow) at the Ford Company. There was nevertheless a problem with the system; its inability to provide variety. Kiichiro Toyoda, Taiichi Ohno, and others at Toyota Company looked into this problem, and they believed that a series of simple innovations could solve it. They therefore used Ford's original idea on the mass production system and invented the Toyota Production System (TPS) (Binder and Rae n.d.) (Lean Enterprise Institute n.d.).

TPS

The Toyota Production System (TPS) has since the last half of the 20th century been seen as the source to Toyota's exceptional performance as an automobile manufacturer. The system has been the competitive advantage for the company. The TPS is as mentioned a manufacturing system which is formed as a philosophy where the focus is on a total elimination of waste. It focuses on adding value or reduce waste in all the production activities. This is in order to satisfy the end customer's needs (Spear and Bowen 1999). The goal is to produce the highest quality, at the lowest cost, in the shortest lead time and to respond to change flexibility (Franz and Liker 2011).

Toyota developed a TPS house figure to easier explain and teach the system to their employees. The TPS house is illustrated in figure 7. This figure has become an important figure in modern manufacturing. The figure illustrates that the system is a structural system, which means that all the parts in the house (representing the system) must be strong or the house (system) will collapse. Due to this the roof represent the focus on best quality, lowest cost, shortest lead time, best safety and high morale all these focus on reducing the waste. The roof symbolizes the goals of the Toyota Company (J. K. Liker 2011).

In the center, represented by the pillars in the figure, the focus is on four areas. One pillar represents the people (the employees) in the company, and the interaction they have in teamwork. Another is on JIT, which focuses on having the right part, at the right amount at the right time. Then there is the waste reduction attention, which consists of for instance the 5 Why's which will be represented in section 2.1.2.6. The last pillar represents Jidoka, which is to make problems visible in order to solve them directly and secure optimal product quality anytime. Then there is the foundation of the house, which represents the need for standardized, stable, reliable processes and Heijunka (level production).

Continuous improvement (Kaizen) is located in the center of the figure, and is the core of the TPS system. If one link in the system is weakened the whole system will be affected. It is just like a house, if one of the links is weak the house may collapse (J. K. Liker 2011).

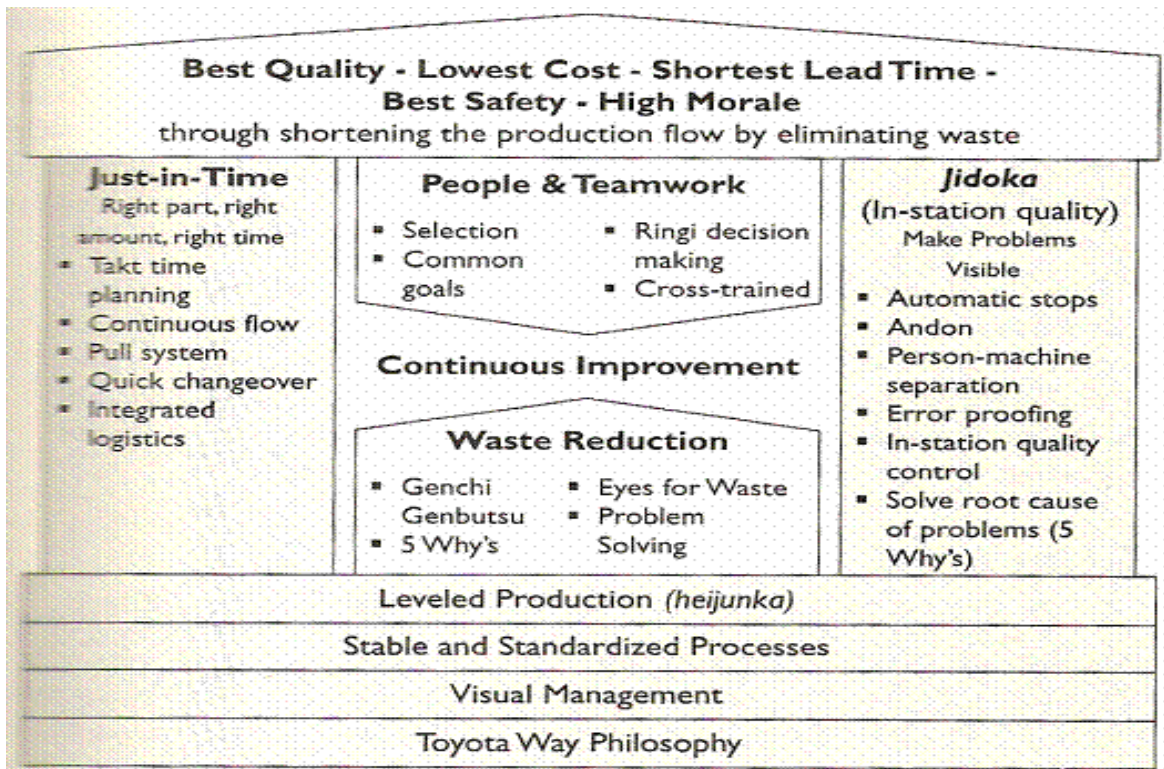


Figure 6: The TPS House (J. K. Liker 2011)

2.1.2.2 Lean Processes

In Lean Thinking there will be a continuous focus on improving the work processes. The processes are the heart in every organization. This is where a product is produced to the customer. If an organization manages to increase the value in the work that is done, this will give value to both the customer and the organization. If not, it will be characterized as waste (Lean Consulting n.d.).

Production is a network consisting of processes and operations. Figure 8 illustrates how a process, which is to transform material into product, is accomplished through a series of operations. Shigeo Shingo (1988) believed that production is a network made by intersecting axes of process (the y-axis) and operation (the x-axis). The figure below also illustrates this. The axes are mutually dependent on each other. Processes lies along the y-axis representing the flow from raw materials to finished goods. Operations on the other hand lie on the x-axis representing the flow where a succession of workers works on the items (Shingo 1988).

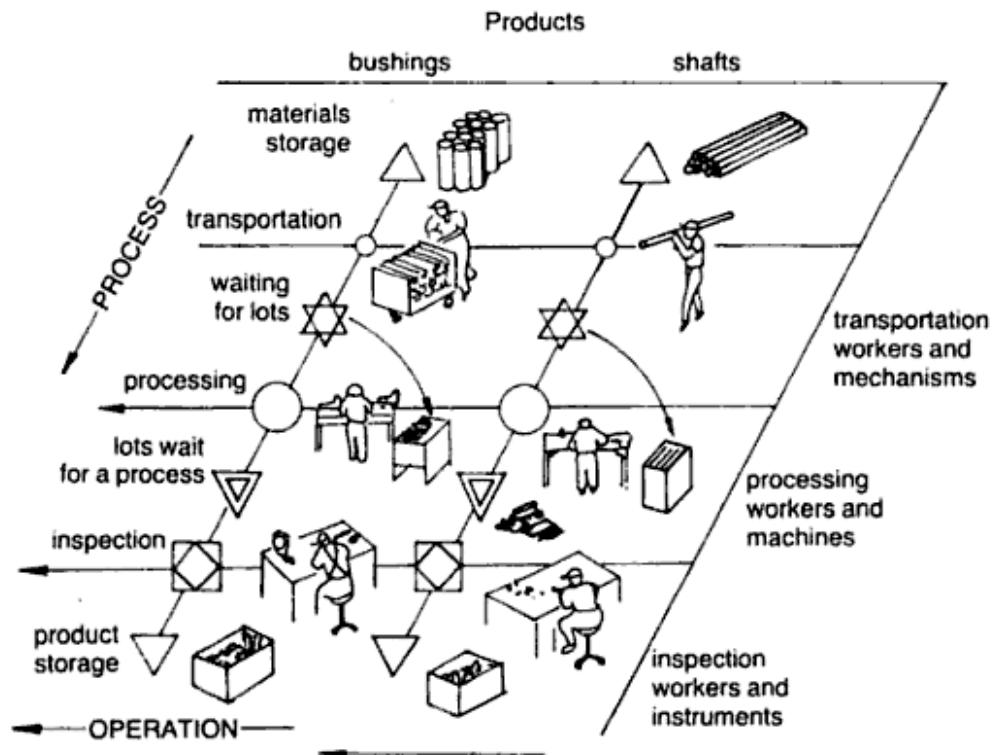


Figure 7: Two Streams of Production (Shingo 1988)

People have often focused on *operational* improvements in order to raise the processes productivity. However Shingo (1988) wants organizations to focus on *process* improvements to raise the processes productivity. He states that the process improvements are of first order, while the operational improvements are secondary (Shingo 1988).

2.1.2.3 Value and Waste

To put it simply; the main idea behind Lean is to *maximize customer value while minimizing waste*. The ultimate goal, which is very hard and almost impossible to achieve, is to provide perfect value to the customer. This can be achieved by having a perfect value creation process with zero waste (Lean Enterprise Institute 2009). This section presents the concepts of value and waste.

Value

Womack and Jones (1996) states that value only can be defined by the ultimate end customer. They also claim that value is the critical starting point for Lean Thinking (Womack and Jones, Lean Thinking 1996). Two definitions are presented below:

Value creation definitions:

Value is a capability provided to customer at the right time at an appropriate price, as defined in each case by the customer (Womack and Jones 1996).

Value creation is those activities which can be defined as transforming the product into something the customer wants (Liker and Lamb 2000).

Womack and Jones (1996) suggest that the purpose of an organization is to create and deliver value to customers, shown in the first “Lean principles” presented in section 2.1.2.4 (Womack and Jones 1996).

Further, Ballard, Koskela, et al note (2001) states that: *Products have value only to the extent that they can be used to fulfill purposes. A product may be said to be more valuable either if it allows greater fulfillment of purpose or fulfills purpose at less cost. A product that does not fulfill purpose has no value regardless of its cost. The cost of products is what must be sacrificed in exchange for their use and can be divided between costs to acquire and cost to use* (Ballard, Koskela, et al. 2001).

Firms often have problems in defining value. One reason why firms may find it hard to get the value definition right can be that while value creation normally flows through many firms, each of them tends to define value in their own way to suit their own needs. Hence, when these different definitions are added up, they often do not match. Once the product is defined the most important task in specifying value to determine a target cost takes place. This should be done based on the amount of resource and effort required to make a product of given capabilities and specifications, if all the currently visible muda (waste) have been removed from the process. This is the key to squeeze out waste. Muda, or waste, is central in Lean Thinking and is presented below (Womack and Jones 2003).

Waste

Muda is a Japanese word which means “waste”. There is no absolute definition of waste in Lean theory; however Womack and Jones (2003) have defined waste as:

Waste definition:

Any human activity that absorbs resources but creates no value (Womack and Jones 2003)

This can for example be mistakes which require rectification or/and production of goods that no one wants. This results in piled up inventories or movement of employees and transport of goods without any purpose (Womack and Jones 2003). According to Alan Mossman (2009) waste is anything that creates no value for the owner/client/end-user. He emphasizes that waste is defined in terms of value. Hence one can only know waste by knowing value first (Mossman 2009).

Taiichi Ohno (1988), Toyota’s Chief Engineer, developed a tool to categorize waste. This tool is known as “The seven wastes”. To be able to eliminate waste it is vital to understand what waste is and where it exists. The seven wastes are (EMS Consulting Group 2003) (Ohno 1988):

- Overproduction
- Waiting
- Transporting
- Inappropriate processing
- Unnecessary inventory
- Unnecessary/ excess motion
- Defects

1) *Overproduction*

Overproduction is to manufacture the item before it is required. It is very costly due to the fact that it prohibits the smooth flow of materials and degrades quality and productivity. The solution to overproduction can be to turn off the tap; this requires a lot of courage since the problems that overproduction is hiding will be revealed.

2) *Waiting*

The waste of waiting occur whenever goods are not moving or being processed. Much of the products lead time is tied up in waiting for the next operation. This is often due to poor material flow, too long production runs or too long distances between work centers. One way to reduce waiting dramatically is by linking process together so that one feeds directly into the next.

3) *Transporting*

Transportation of products between processes adds no value to the product. Transportation can often be difficult to reduce due to the perceived costs of moving equipment and processes closer together. In addition, it is often hard to determine which processes should be next to each other. Mapping the product flows is a good way to make this easier to visualize.

4) *Inappropriate processing*

Often, organizations use expensive high precision equipment where simpler tools would be enough. This can result in poor plant layout because operations are located too far apart. The waste of inappropriate processing can be reduced by for

instance investing in smaller, more flexible equipment where possible or creating manufacturing cells.

5) *Unnecessary inventory*

Unnecessary inventory usually hide problems on the plant floor, which must be identified and resolved in order to improve operation performance. Excess inventory normally leads to increased lead times, delays the identification of problems, inhibits communication and consumes productive floor space. To improve this element it is important to achieve a seamless flow between work centers.

6) *Unnecessary/ Excess Motion*

This type of waste is seen in all instances of for instance bending, walking, lifting and so on. It is related to ergonomics and is also a health and safety issue. It is important to redesign and analyze jobs with excessive motion, and this should be done with the involvement of plant personnel.

7) *Defects*

Quality defects are a huge cost to organizations since it normally results in rework or scrap. The total cost of defects is often a significant percentage of total manufacturing cost in many organizations. However there is a great opportunity to reduce defects through employee involvement and continuous process improvement.

(EMS Consulting Group 2003) (Ohno 1988)

It is important to remember that not even Ohno's seven wastes are absolutes. According to Alan Mossman (2009), some overproduction has value; for instance when a process is not yet capable of switching between products virtually instantly and yet customers want instant delivery. Hence overproduction creates a temporarily necessary buffer; even though customers do not value transportation between work stations in the factory, many of them value transportation to their door (Mossman 2009).

In addition to Taijchi Ohno's (1988) seven wastes, Alan Mossman (2009) has listed some other activities which do not add value from the customer's point of view. Among these are *behavioral waste* – human behaviors that add no value and therefore can be eliminated, excess information, not taking advantage of people's thoughts (wasting good ideas), not using people's talents and not speaking, not listening (Mossman 2009). Further, Womack and Jones have added an eighth waste to Ohno's original seven wastes in their book "Lean Thinking" from 2003. This waste is called *Underutilization of Employees*. It emphasizes that organizations should capitalize on employees' creativity. It is the employees who are closest to the processes and hence they are in a great position to come up with suggestions for improvements. Organizations can thus eliminate the other seven wastes and continuously improve their performance (EMS Consulting Group 2003) (Womack and Jones 2003).

A step to achieve the ultimate goal (maximize customer value while minimizing waste) is to not eliminate waste at isolating points but in the entire value stream. This will help to create a process which needs less human effort, less capital, less space and less time to make product and services compared with old traditional business systems. Hence, companies who implement Lean are more able to respond to changing customer needs with high quality and low cost, and with fast throughput times (Lean Enterprise Institute 2009).

In order to achieve this main idea behind Lean a company must also distinguish between value-added steps (VA), non-value added steps (NVA) and non-value adding but necessary (NNVA) steps in a process, together with eliminating waste. By doing this, ultimately every step adds value to the process (Womack, Byrne and Fiume, 2005). The VA operations regards the conversion or processing of semi-finished products or raw materials through the use of manual labor. Further, the NVA involves unnecessary actions which should be eliminated completely and is hence pure waste. The NNVA operations may be wasteful but are necessary under the current operating procedures (Hines and Rich 1997).

2.1.2.4 Principles of Lean

Womack and Jones (2003) have developed five Lean principles which is useful when implementing Lean Thinking. The principles of Lean can be described as a five-step process of Lean techniques. These five steps are easy to remember, however not always that easy to achieve. These are as follow (Lean Enterprise Institute 2009) (Womack and Jones 2003):

- 1) Specify value from the standpoint of the end customer by product family.
- 2) Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
- 3) Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
- 4) As flow is introduced, let customers pull value from the next upstream activity.
- 5) As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste.

Instead of reinventing business models constantly, Lean thinkers instead go back to basics and ask what the customers really perceives as value. Value is only meaningful when it is expressed in the terms of a specific product which meets the customers need at a specific time and at a specific price. This is reflected in the first step. Further the second step is to line up the activities which creates value and eliminate those who do not add value in the value stream. When the value stream is identified it helps to establish when and how decisions should be made. Third, Lean thinkers creates a flow condition. When the value flow is made a Lean thinker should see that the value development and product components is in constant motion. This supports the complimentary goals of maximum throughput and zero stores. The next step, a pull of the customer, means to make only what is sold (Lean Enterprise Institute 2009) (Womack and Jones 2003).

Once the “pull step” is implemented, the cycle of improvement is speeded up in pursuit of perfection. The cycle is repeated and ensure continous improvement (Kaizen) which is a crucial factor to succeed in implementing Lean Thinking (Womack and Jones 2003) (Smadi 2009).

The cycle is illustrated in figure 8:



Figure 8: The Lean implementation steps (Lean Enterprise Institute 2009).

Even though these Lean principles have been very useful when implementing Lean Thinking in production (and construction), their validity have been discussed. Sven Bertelsen (2002) states that the principles only focus on waste in the form of waiting, instead of focusing on minimizing waste in all its forms. He also points out that waiting is not always bad; buffers may be needed in order to optimize the output. In addition, the workable backlog in the Last Planner System (a tool presented in section 2.1.3.4) represents waiting (Bertelsen 2002).

In addition to these five Lean principles, there exist 14 management principles in Lean Thinking. These are developed by Jeffery K Liker (2004) and are presented in the section below.

2.1.2.5 The Toyota Way: 14 Management Principles

In the book «The Toyota Way: 14 Management Principles» Jeffrey K. Liker (2004) states that Toyota's success comes from their business philosophy, which is based on its understanding of people and human motivation. The success is a result of cultivate leadership, teams and culture and developing strategies that builds supplier relationships and focus on maintaining a learning organization. This business philosophy is called the "Toyota Way", and he presents 14 principles that represent this philosophy. The philosophy is defined by Liker (2004) as: "The Toyota Way - a system designed to provide the tools for people to continually improve their work". These 14 principles are the foundation of TPS. The principles are divided into four categories for a better overview. The figure below illustrates the four categories and the 14 principles of the "Toyota Way", but first the four categories are presented:

- 1) *Philosophy*- a long-term philosophy
- 2) *Process*- the right process will produce the right results
- 3) *People/Partners*- add value to the organization by developing your people
- 4) *Problem Solving*- continuously solving root problems drives organizational learning

(J. K. Liker 2004)

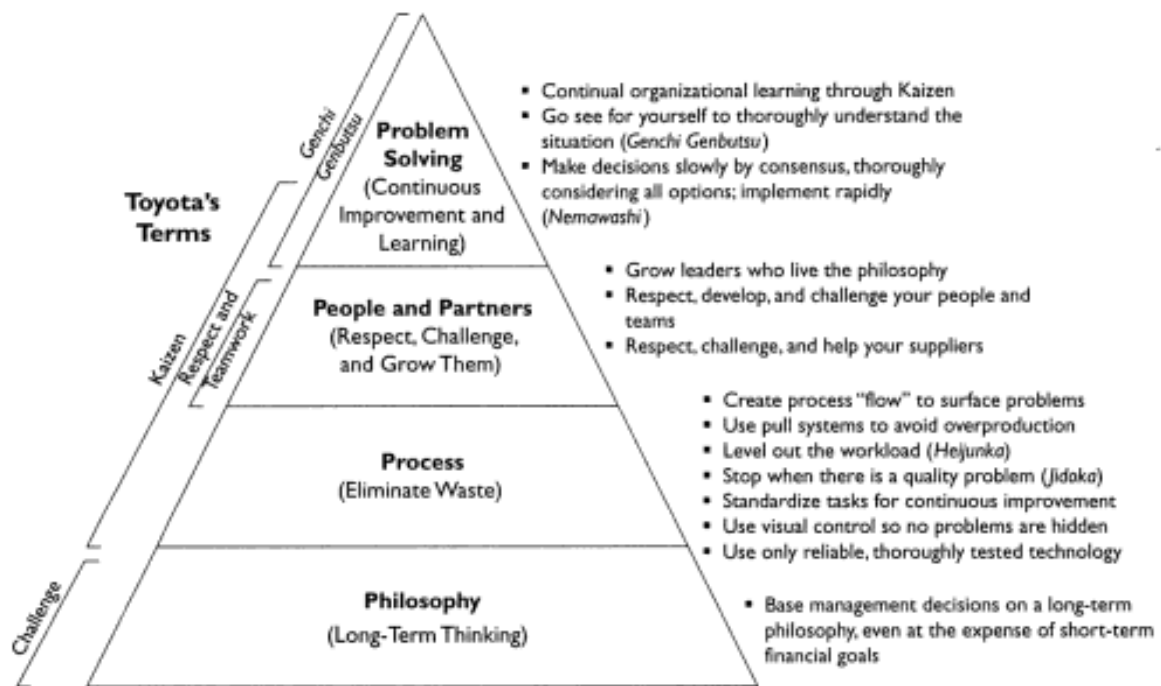


Figure 9: A “4P” model of the Toyota Way (J. K. Liker 2004)

According to Liker (2004) it is quite possible to use a variety of TPS tools and still be following only a few of the Toyota Way principles. The results of this will be short-term jumps on performance measures, which will not be sustainable. However Liker (2004) stated that an organization that practices all the 14 principles would be following the TPS. The organization will then be on its way to develop a sustainable competitive advantage (J. K. Liker 2004).

It is important to highlight that Lean is not about imitating the tool used by Toyota, but it is about developing principles that are right for each individual organization. An organization must diligently practice them in order to achieve high performance that will add value to the customers and the society. This will give an organization competitive and profitable advantage (J. K. Liker 2004). Nevertheless the Lean principles made by Toyota are not always adapted to their fullest extent. Organizations all over the world have been unable or unwilling to do this for various reasons (Cusumano 1994).

2.1.2.6 Lean Production Tools

There exist several useful tools in Lean Production. This section starts with a description of value stream mapping, before introducing PDCA, the 5'S framework, the four M', the 5 whys, motion studies and Gemba. These tools are used in chapter 4, 5 and 6, when performing an analysis, discussion and presenting the conclusion.

Value Stream Mapping

Whenever a product (or service) is made for a customer, there exists a value stream. The problem is to see it. Shiego Shingo (1988) and other developers of the TPS and Lean principles have underlined the importance of mapping out the entire production process. They have emphasized that this will give valuable knowledge for organizations. Mapping the production process will help an organization to see and eliminate steps that are not required (Shingo 1988), (Lian and Van Landeghem 2002), (Franz and Liker 2011).

Mike Rother and John Shook stated in their book (2003) that many organizations are having problems with implementing Lean. They believed that the Value Stream Mapping (VSM) tool could help organizations with this, in order to find a real progress toward becoming Lean (Rother and Shook 2003).

An organization can after defining "value" explore the value stream, as explained in section 2.1.2.3. The value stream is all the activities, which are both value-added and non-value added, that are currently required to bring the product from being a raw material to becoming an end product for the customer (Lian and Van Landeghem 2002). Hence the tool is used to describe supply chain networks. It maps not only the material processing steps, but also the information flow that signal and control the material processing steps. In addition VSM must be developed with respect for people. However this does not mean that an organization should have respect for old habits. An organization must also have in mind that developing Lean value streams can be difficult, since it exposes sources of waste. This means that people in all business functions risks the possibility to change habits (Rother and Shook 2003), (Manos 2006), (Lian and Van Landeghem 2002).

Mike Rother and John Shook (2003) have presented four phases of making a VSM:

- 1) *Preperation (getting started)*: Establish boundary conditions and priorities
- 2) *Current-state map*: The current production situation must be made clear by drawing the material and information flows. Sources of wast must be highlighted and eliminated by going to step 3).
- 3) *Future-state map*: The alternative setup that suits the company's goals best must be selected. This will be achievable within a short period of time.
- 4) *Achieving the future state*: First step 2) and step 3) are compared. Then a list of improvement activities must be made. It is important to consider practical issues and suitable/ available tools. Remember that value stream improvement is the management's job.

(Rother and Shook 2003)

VSM should be a day-to-day management in any organization where a product (or service) is made for an end customer. It has been discovered that when you remove sources of waste you will detect more waste which can be eliminated. The job of Lean managers and their teams is to keep this cycle happening every day (Rother and Shook 2003).

PDCA (Plan-do-check-adjust)

PDCA is a method for problem solving, which was taught to Toyota by Dr.W.Edwards. According to Jefferey K. Liker and James K. Franz (2011) PDCA problem are solving the core of Lean Thinking. Further they state that “*the PDCA way of thinking recognizes that life and busines are dynamic and drives people to develop a disciplined method for identifying, defining and solving problems as they occur, ideally one by one*” (Franz and Liker 2011). An illustration of PDCA is shown in the figure below:



Figure 10: PDCA-Cycle (PDCA Security 2010)

In figure 10 the term Act is used for the A, but Liker and Franz (2011) uses the term Adjust in their book “The Toyota Way to Continuous Improvement.” This is because the term adjust reflects the dynamic of learning. The different terms are explained below (Franz and Liker 2011):

Plan:

- Identify gap to target
- Analyze root cause
- Formulate countermeasure

Do:

- Develop implementation plan
- Communicate plan
- Execute plan

Check:

- Monitor progress of implementation plan
- Modify plan if necessary
- Monitor results

Adjust:

- Evaluate results (reflect)
- Standardize effective countermeasures
- Identify further improvement projects
- Spread best practices
- Start PDCA again

According to Franz & Liker (2011) the PDCA should be implemented as a way of thinking in organizations. This is in order to:

- Question deeply every process; problems are brought up to the surface and carefully defined.
- Understand the root cause.
- Develop countermeasures that are viewed as provisional until proven.
- Plan implementation in great detail (all plan to this point).
- Run the experiment (do).
- Closely monitor and analyze what is going on in the experiment (check).
- Learn from what happens and turn that into further action (adjust).

(Franz and Liker 2011)

The PDCA loop should be repeated over and over (continuous improvement). Then companies can see that employees and the organization learn, operational excellence grow,

and further connect that capability to a well-planned and well-executed business strategy. When an organization implements PDCA thinking it starts to become a learning organization. Projects become a continuous stream of learning opportunities on the road to excellence (Franz and Liker 2011).

The 5 S framework

The 5 S framework is developed by Hiroyuki Hirano. The 5 S tool can help to improve the work environment consistent with the tenets of Lean manufacturing systems. The concept focuses on how the visual workplace can be utilized to drive inefficiencies out of the manufacturing process. Further the 5 S also improves workplace safety, which makes it attractive to businesses. Hirano also claims that other Lean manufacturing tools are likely to fail without the organization and discipline provided by successfully implementing the 5Ss (Shil, Nikhil 2009).

The 5 S are (Shil, Nikhil 2009):

1) Sort (Seiri) – Sort is closely related to the JIT philosophy and it requires strict tagging of all items that are unnecessary and unwanted. In order to stand out, these tags are colored red. The red-tags ask three questions of any item:

- a. Is the item needed?
- b. If it is needed, is it needed in this quantity?
- c. If it is needed, does it need to be located here?

Occasionally, unneeded items are discarded while used items are moved to a more organized storage location outside of the work area. Hence, sorting is a good way to free up valuable floor space and eliminate such things as broken tools and excess raw material.

2) Set in Order (Seiton) – Set in order focuses on efficient and effective storage methods. When all the unnecessary items have been removed, the remaining items can be arranged efficiently so that they can be accessed or retrieved quickly and returned to their home

rapidly. Seiton focuses on that there should be a place for everything and everything in its place. Hence, effective strategies to follow Seiton are among others to outline work areas and locations, painting floors and shadow boards.

An important principle of Seiton is motion economy, which focuses on the removal of human motion waste. This is the removal of time, energy and effort from a process by the intelligent location of equipment and parts, so that all movement is absolutely necessary to perform a given operation.

According to the author Nikhil Shil (2009), Seiton has many benefits to the organization:

- a. It eliminates motion waste as items are strategically located;
- b. It eliminates searching waste and waste due to difficulty in returning items as items have a clearly identified location; and
- c. Easy retrieval of items saves time and reduces employee frustration.

In most situations the first two elements of the 5 S activities (Sort and Set in Order) are implemented together since they normally complement each other.

3) *Shine (Seiso)* – Shine consists of keeping equipment clean and regularly cleaning of the workplace. Hence, it is important to make a good first impression from an external point of view. To implement cleanliness as a routine, a daily five minute cleaning exercise is suitable. To make this successful it is extremely important that management is involved as resistance to cleaning easily can build up.

Shine has many benefits:

- a. Creating a more comfortable and safe working environment;
- b. Greater visibility, which reduces searching time;
- c. Not having to disrupt production every time there is a plant tour; and

d. Simplification of maintenance activities as cleaning can also be used as a form of inspection. Problems such as oil leaks become instantly visible before they have the opportunity to affect performance

4) *Standardize (Seiketsu)* – After the first three of the S's has been implemented, it is important to standardize best practice in the work area. Seiketsu focuses on that the processes and procedures are in place so that mistakes are more difficult to make. This could include a set time each week to practice the first three elements, for instance a ten minute clean-up. It is important to allow the employees to be a part of the development of such standards. They are often an overlooked source of information regarding their work.

5) *Sustain (Shitsuke)* – Sustain makes sure that the productivity increases continuously. This without moving forward with the 5 S improvements could make a company gradually lose ground.

(Shil, Nikhil 2009)

Sustain is the most difficult element to achieve. Leadership is a crucial factor for success. It is vital that senior management realize that 5 S is a part of the organizational culture. Further they must communicate the benefits of 5 S to the employees and encourage them to use their training to take action. The management must remember that human nature is resistance to change. Hence the ability to mobilize and motivate people is required to ensure that 5 S becomes and stays a part of the organizational culture (Shil, Nikhil 2009).

The greatest benefits of successfully implement the 5 S are that it can increase efficiency in an organization, increase work morale and create positive impressions on customers. In addition the effect on continuous improvement can lead to better quality, less waste and faster lead times (Shil, Nikhil 2009). The 5 S is illustrated below.



Figure 11: 5 S (TPF Europe n.d.)

Four M

The tool was developed by Kaoru Ishikawa and it is also famous under the names Ishikawa diagram, fish bone diagram and the Cause & Effect diagram. The Four M is a simple diagram which helps to easily identify and discuss all potential causes of an effect.

The tool emphasizes on team efforts on the Manpower (people/staff), Machines (equipment), Material, and Methods (processes). These are issues of a value-added process analysis. The Four M are used when addressing problems appearing in the manufacturing industry (Perry, Michael S 2006).

It is impossible for a person to know everything about a problem or a solution and not at least the causes of an effect. The four M enables a group to contribute with their knowledge and together see the problem as a whole, which creates new discussions and new understandings. The group should consist off all affected personnel who can contribute positively (National Research Council 2004).

The tool has a five step procedure according to Michael S. Perry (2006) and The National Resource Council Canada (2004):

- 1) In order to find the causes, you first have to make a clear statement of the problem that you want to examine.
- 2) Identify potential cause categories.
- 3) Draw the fishbone figure similar to figure 14 below.
- 4) Then the team has to brainstorm to find potential causes by each category, and attach ideas to the potential causes.
- 5) The team should then together discuss and identify the factors that have the strongest impact on the effect. The team should try to find the factor that, once addressed, will solve (or eliminate) the problem. The problem can be addressed by using the Five S, the Five why or other methods.

(National Research Council 2004) (Perry, Michael S 2006)

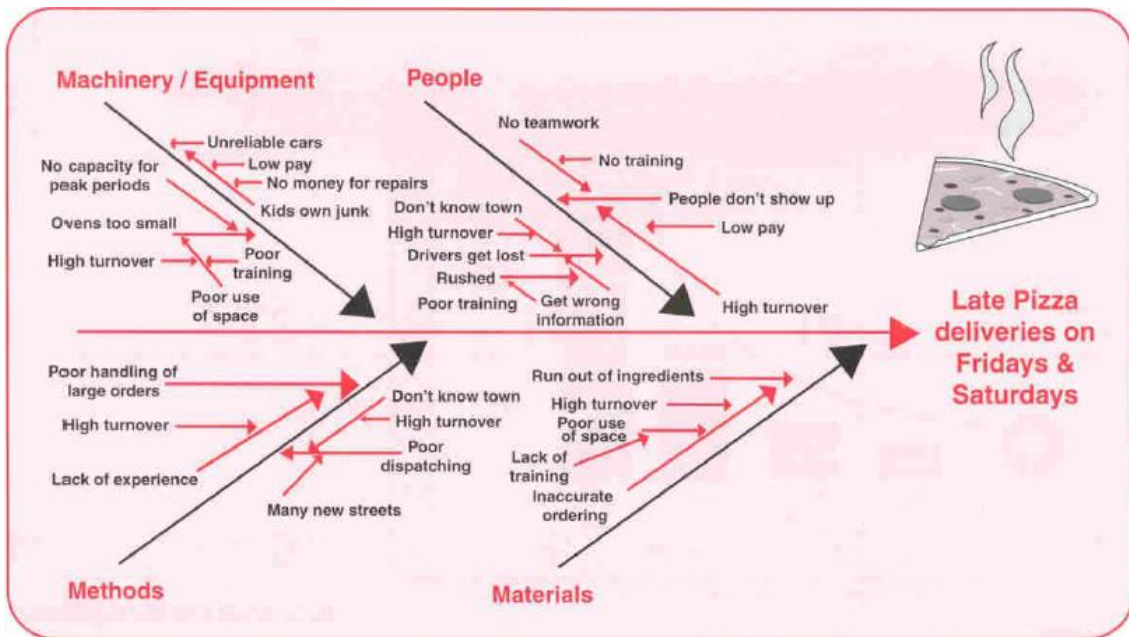


Figure 12: Fishbone diagram (National Research Council 2004)

5 Why

The 5 Why analysis is used to conduct a root cause analysis to find reasons for waste, and to formulate and implement actions to solve the problem. This analysis is frequently used by managers when Lean Manufacturing problems arrives (Murugaiah, et al. 2010).

The analysis involves looking at the problems that arise and ask the question “Why?” five times (or more if necessary), to find the root cause to the problem. The methods starts with gathering a team and in agreement develop a problem statement. When this is done it must be decided whether more people are needed to solve the problem. Then the team asks the first why. If there are several answers all must be included to the next step. Then we must meet the answer(s) we found with another why. This will continue until why has been asked five times. Then the team must settle on the most probable root cause of the problem and develop actions that will solve the root cause. Figure 14 illustrates how the five why worksheet could look like. The methodology tries to find the underlying problem instead of just fixing the overlying issues. The method helps an organization to find and truly eliminate the root cause to a problem, so the same problems do not return in the future (Murugaiah, et al. 2010) (Serrat 2009).

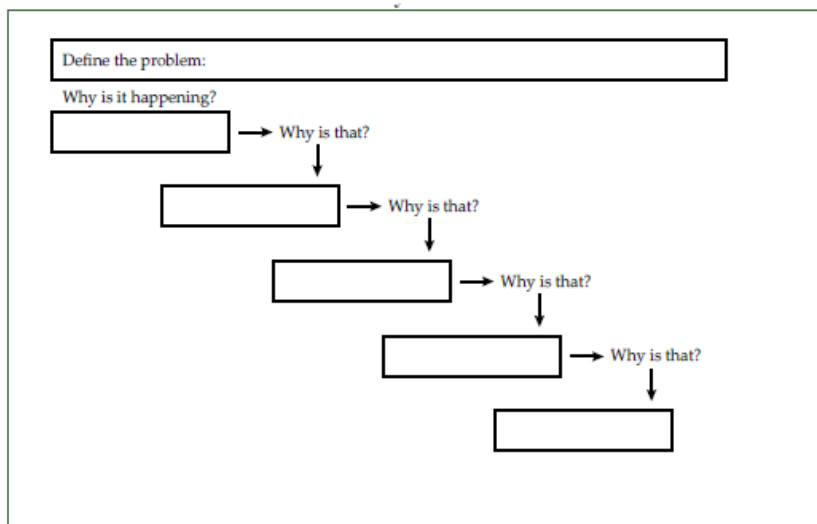


Figure 13: A Five Why Worksheet

The analysis has been criticized to be employee subjective. The method is based only on opinions and observations from the people that are doing the tasks. If several employees who are doing the same tasks are asked, the root cause of the problem can be different. In

addition if a manager asks an employee why a problem happened, the employee can feel threatened and may give wrong answers. Due to this the end result of the analysis may be totally wrong (Murugaiah, et al. 2010). Another obstacle can be that people can have the attitude “it is not my problem to solve”. Since this is a team task and the result of working together is essential this will create big problem with the execution of the method (Pojasek 2000).

The 5 why method and the Four M method are very simple and useful methods for problem solving. In order to create a Lean culture one of the first steps will be to turn every employee into a problem solver. The first step in achieving this should begin with teaching the employees the use of the 5 why on a regular basis (EMS Consulting Group 2006).

Motion studies

Frank B. and Lillian M. Gilbreth studied ways to improve the efficiency of human motion and developed what is called motion study in the 1980's. They emphasized the need to improve motion if the time factor were to be improved and to improve work conditions if motion were to be improved. Improving the motions means studying the characteristics common to all people and designing jobs accordingly (Shingo 1988).

According to the Gilbreths, motion analysis should be performed by breaking up the status quo into elemental units of motions called therbligs. Then the purpose of each therblig should be identified and further find the one best way using techniques that accord with those purposes (Shingo 1988).

The system consists of 18 different therbligs. These are presented in table 3. Shingo (1988) have further divided them into four classes:

- *Class 1:* These therbligs represent the essence of an operation. Generally, they have the highest value.
- *Class 2:* These are preparatory motions for or follow up motions to class one. These therbligs have a secondary importance.

- *Class 3:* These therbligs are incidental to class 2 motions and they make a lower contribution to the task than class 2 therbligs.
- *Class 4:* These make an even lower contribution than class 3 and hence they should be eliminated to the extent possible.

The division of motion studies into four classes leads to the uncovering of waste. This is a major advantage of motion studies (Shingo 1988).

Therbligs

| Class | No. | Name | Symbol | Description |
|-------|-----|---|--------|--|
| 1 | 1 | Assemble | ≡ | Shape of combined rods |
| | 2 | Disassemble | ≡ | One rod removed from a combined shape |
| | 3 | Deform (use) | ∪ | U for "use," or a cup placed upright |
| 2 | 4 | Transport empty (extending or retracting your hand) | ∪ | Shape of palm opened up |
| | 5 | Grab | ∩ | Shape of hand grabbing |
| | 6 | Transport | ∪ | Shape of object being transported with hand |
| | 7 | Release | ∩ | Shape of object with hand facing down |
| 3 | 8 | Search | ◉ | Symbol of searching eye |
| | 9 | Find | ◉ | Symbol of eye having located object after search |
| | 10 | Select | → | Symbol of finger pointing at selected object |
| | 11 | Inspect | ◉ | Shape of a lens |
| | 12 | Regrasp (reposition) | 9 | Symbol of regrasping object held by finger tips |
| | 13 | Hold | ∩ | Shape of rod held with hand |
| | 14 | Prepare | 8 | Shape of a cuestick standing erect |
| 4 | 15 | Think | 8 | Shape of a thinking person with hand by head |
| | 16 | Rest | 8 | Shape of a person sitting on chair |
| | 17 | Unavoidable delay | ∩ | Shape of tripped person on ground |
| | 18 | Avoidable delay | ∩ | Shape of person lying down |

Table 3: Therbligs (Shingo 1988)

The therbligs relevant for this master thesis is explained below:

Search: The search motion starts when the eyes and/or the hand start to seek the object needed and ends just as the object is located. One way to reduce search is to arrange tools and parts in a physical sequence of use. Further contrasting colors, shapes or embossed symbols can reduce the search function.

Transport loaded: The main objective of this Therblig is to reduce the distance and subsequent time involved for transport.

Transport empty/ unloaded: This is the motion of moving the unloaded hand from the point of Release Load, to the next function within the sequence. It can also be considered the hand motions involved between Select and Grasp, where the eye identifies the object and the hand moves towards it to grasp. This Therblig is a non-productive one, and as such, should be kept to a minimum.

Rest: This Therblig is actually a lack of motion and is only found where the rest is prescribed by the job or taken by the worker. In the Gilbreths' scheme of Fatigue Reduction, after you had eliminated all unnecessary motions and made necessary ones as least fatiguing as possible, there would still be the need to rest.

(Ferguson 2000)

Gemba

Gemba “the real place” is a philosophy that reminds the employees working on the offices to go out of their offices and spend time in the plant floor. The plant floor is the place where the real action occurs in the organization. The tool encourages the office workers to get a deep and thorough understanding of the production process, and the problems they are facing by first-hand experience. The office workers will have the opportunity to observe and talking with the plant floor workers (Leanproduction.com 2011).

2.1.2.7 Lean Production Challenges

Many companies often fail to implement Lean Production in their organizations. This is due to the fact that Lean Production often is complicated and hence difficult to implement. In this section some common mistakes when implementing Lean will be presented (Scherrer, Boyle and Deflorin 2009).

When looking at the literature there is several common mistakes when implementing Lean. One mistake is that companies implement individual Lean tools without seeking to understand the whole system in which they are a part of. This is often hard to avoid, since many of the Lean tools, like 5S, gives immediate payoffs. However the true gains come from changing the way the whole organization runs. This can be done by changing the whole culture of the business and adapting Lean as a system. Further, one of the hardest challenges when implementing Lean is the degree to which individual Lean successes always will uncover new problems and greater challenges. Hence, it is important to be aware of how difficult this work will be (Scherrer, Boyle and Deflorin 2009).

Organizations also need to be aware of resistance to change when implementing Lean. This can happen at any level within the organization. One way to overcome it can be to use time to fully explain benefits of Lean to any individuals challenging its effectiveness. In addition, it is important that the employees not only generate improvement ideas but that they are a part of the team that solves them. This can mean to work through a structured “Plan-Do-Check-Act” approach with support and guidance, see section 2.1.2.6. Personal guidance is often needed to identify and implement the best approach for an individual organization and Lean needs to be adjusted to each company (Lean Enterprise Institute 2009) (D'Souza 2011).

2.1.3 Lean Construction

In this section the term Lean Construction is presented and explained. First the Lean Construction concept is outlined, before the characteristics of Lean Construction are introduced. Further, Lean Construction principles, the Last Planner system and Lean Construction limitations are presented.

2.1.3.1 What is Lean Construction

Even though Lean Production was highly successful in the car manufacturing industry, many believed that it would not be applicable in the construction industry. The construction industry is compared to the car industry highly dynamic and complex. The construction industry operates in a highly uncertain environment. Furthermore, the industry has a great schedule and time pressure which makes it fundamentally different from the car industry (Dugnas and Oterhals 2008).

Lean Construction (LC) is a production management-based approach to project delivery and the industry usually delivers products which are one-of-a-kind. Lean Construction emphasizes effectiveness measured by defection rate, cycle time and completion of planned work per week. Further the goal is to eliminate non value adding activities. This is done by organizing interdependence, improving reliability, reducing uncertainty and integrating production management (Dugnas and Oterhals 2008). According to the Lean Construction Institute, Lean Construction is especially useful in complex, uncertain and quick projects. However it challenges the belief that there always must be a trade between cost, time and quality. In Lean Construction it is more important to manage and improve performance aimed at improving total project performance rather than reducing cost or increase the speed of activity (Lean Construction Institute 2011) (Cusumano 1994).

Managing construction under Lean is different from typical contemporary practice because Lean Construction (Howell 1999):

- Has a clear set of objectives for the delivery process,
- Is aimed at maximizing performance for the customer at the project level,
- Designs concurrently product and process, and
- Applies production control throughout the life of the project.

On the contrary, the current form of production management in construction derived from the same activity centered approach found in project management and mass production. It aims to optimize the project activity by activity, assuming customer value has been identified in design (Howell 1999).

LC is extended from the objectives of a Lean Production system; to maximize value and minimize waste (Lean Construction Institute 2011). The elimination of waste is a core focus both in Lean Production and Lean Construction. “Making-do” has later been added as an eighth type of waste, in addition to the seven wastes mentioned in chapter 2.1.2.3. “Making-do” indicates that a construction task is started without its standard inputs being in place. Further, tasks are normally started too early in order to maintain a high utilization rate or to avoid schedule slippage. According to Kalsaas (2010) most part on-site production is not a matter of serial production in construction. Hence, overproduction may be the most problematic of the different waste types. Overproduction in construction is interpreted as “*overbuilding a particular aspect of a project, either because it was overengineered or a process was started before it was really needed*” (Kalsaas 2010).

2.1.3.2 Characteristics of Lean Construction

Lauri Koskela (2000) has listed three differentiating characteristics of Lean Construction in his publication “An exploration towards production theory and its application to construction”. These are: *one of a kind nature of projects, site production and temporary multi-organizations* (Koskela 2000).

The one-of-a-kind nature of projects in construction is due to different needs and priorities of the customer, different sites and surroundings and different views of designers on the best design solution. The materials, skills and components needed are usually similar or the same. One-of-a-kind production is further characterized by two issues. The first issue is that product design is an integral part of production. In addition, there is uncertainty. This is critical especially in regard to customer order acceptance (Koskela 2000).

The second characteristic of Lean Construction is “site production”. This means that production in construction is normally carried out at the final site of the product. The site production is a feature that few other industries share. In construction, the site production concept refers to a bundle of features (Koskela 2000):

- * *Site as a resource*: the site is a necessary input resource for production;
- * *Lack of shelter*: there is usually little protection against elements or intrusion;
- * *Local resources and conditions*: local material and labor input often have to be used, potentially adding to uncertainty; other areas of uncertainty include site geology and other environmental factors;
- * *Creating the production infrastructure*: the production infrastructure (machines, manpower, etc.) has to be planned, procured and set up on site;
- * *Space needed by production (workstations move on the product)*: the spatial flow of workstations (teams), have to be coordinated (in contrast to a factory, where only material flow through workstations is planned)

According to Koskela (2000) it is evident that these characteristics of site production add complexity and uncertainty to construction compared to stationary production (Koskela 2000).

The third characteristic of Lean Construction is “temporary multi-organizations”. This means that a construction project organization normally is a temporary organization which is designed and assembled for the purpose of a particular project. The project is made up for different companies and design practices, that have not necessarily worked together before. In addition they are often tied to the project by means of varying contractual arrangements. The work force in a temporary multi-organization is normally employed for a particular project rather than permanently. This also reflects the one-of-a-kind nature of a construction project, namely that several alternative materials can be used, each requiring specialist expertise in installation and design (Koskela 2000).

2.1.3.3 Lean Construction principles

According to Lauri Koskela (1997) a number of heuristic principles for flow process design, control and improvement in various fields for the new production philosophy has evolved. Further, there is ample evidence that the efficiency of flow processes in production activities can be considerably and rapidly improved through the 11 principles presented below. The principles implicitly define flow process problems such as segmented control, in-transparency or complexity. They can also be applied both to the total flow process and to its sub-processes. The 11 principles are (Koskela 1997)

- 1) Reduce the share of non-value adding activities
- 2) Increase output value through systematic consideration of customer requirements;
- 3) Reduce variability;
- 4) Reduce cycle times;
- 5) Simplify by minimizing number of steps, parts and linkages;
- 6) Increase output flexibility;
- 7) Increase process transparency;
- 8) Focus control on the complete process;
- 9) Build continuous improvement into the process;
- 10) Balance flow improvement with conversion improvement;
- 11) Benchmark

Experience shows that these principles apply both to purely physical production and to informational production. Hence the principles are universal (Koskela 1997). According to Lauri Koskela (2000) the principles also seem to apply both to mass production and one-of-a-kind production. Thus they are crucial to Lean Construction but they do also apply to Lean Manufacturing (Koskela 2000).

2.1.3.4 Last Planner System

Glenn Ballard introduced the Last Planner approach to the planning and management of the construction process in 1993 (Ballard 1993). In 1997 the Last Planner system was a complete tool and ready to be introduced in the construction process (Bertelsen 2002).

Last Planner refers to:

The hierarchical chain of planners, where the last planner acts as the interface to execution (Koskela and Howell 2002).

Hence the Last Planner method concentrates on the detailed planning just before the execution, instead of focusing on the whole planning process (Koskela and Howell 2002). The main idea behind this system is that a weekly work planning and a careful monitoring of the plan performance are needed in order to obtain an even workflow. Hence the Last Planner is mainly a tool for obtaining an even workflow. However it may also be more than that. Bertelsen (2002) states that several other strategies in making the construction process more efficient and smooth seem to lead to the Last Planner principle, for instance managing the flow of information seems to give rise to tools like Last Planner (Bertelsen 2002).

Looking at the Last Planner in light of the three different views presented by Koskela (Koskela 2000); *one of a kind nature of projects, site production and temporary multi-organizations* may lead to a deeper understanding of why the system is useful in practice. First, the one-of-a-kind nature of the project can make it hard to establish a reliable production schedule. Many factors are uncertain, and these add up along the chain of activities. However the short horizon for the planning is an excellent way of overcoming this uncertainty aspect. Further, complex systems often have a high sensitivity to initial conditions making them in practice unpredictable for more than a few steps into the future. In a chaotic situation, the Last Planner system can be seen as the establishment of a local window of order. Last, the system can be viewed upon as a means for establishing a co-operation between equal parties at the construction site. The planning process executed as action learning brings mutual understanding of the importance of an even workflow and it supports the cross trade cooperation (Bertelsen 2002).

Ballard and Howell (1999) have presented some Last Planner Principles. As a starting point they claim that “*All plans are forecasts and all forecasts are wrong. The longer the forecast, the more wrong it is. The more detailed the forecast, the more wrong it is.*” The principles are presented below.

- Plan in greater detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make reliable promises.
- Learn from breakdowns

(Ballard og Howell 1999)

The Last Planner are divided into five elements (Ballard og Howell 1999) (Lean Construction Institute 2012):

- *Master Scheduling* – set milestones and strategy, identify long lead times;
- *Phase “Pull” planning* – specify handoffs and identify operational conflicts;
- *Make Work Ready Planning* - look ahead planning to ensure that work is made ready for installation. Re-planning may be needed;
- *Weekly Work Planning* – commitment to perform work in a certain manner and a certain sequence; and
- *Learning* - measuring percent of plan complete (PPC), deep dive into reasons for failure, developing and implementing lessons learned.

The Last Planner method has turned out to be a very useful tool for the management of the construction process. Further, continuous monitoring of the planning efficiency gives rise to an ongoing improvement. This often ensures a steady stabilizing of the workflow and an improvement in the productivity (Bertelsen 2002).

2.1.3.5 Lean Construction Limitations

Lean Construction is a rather new concept and the overall diffusion of the Lean Philosophy is limited (Koskela 1997). Koskela (1997) have answered why the diffusion of the new production philosophy has been so slow in construction. Barriers to implementation are presented below:

- Cases and concepts commonly presented to teach about and diffuse the new approach have often been specific to certain types of manufacturing, and thus not easy to internalize and generalize from the point of view of construction.
- Relative lack of international competition in construction.
- Lagging response by academic institutions.

(Koskela 1997)

It seems like these barriers are of temporary nature. However they can be an explanation of the limitations and slow development of Lean Construction (Koskela 1997).

A characteristic feature regarding the literature on Lean Construction is that there is a lack of a commonly used definition. Researchers have found that there are a wide range of definitions and interpretations of the term Lean Construction. The lack of a clear definition gives different point of views, which again is a challenge when implementing Lean Construction. It is clear that Lean Manufacturing is much more developed than Lean Construction when comparing the research literature. Thus there are challenges regarding information accessibility on the philosophy (Jørgensen and Emmitt 2008).

2.1.4 Lean Shipbuilding

In this section Lean Shipbuilding (LS) is presented and explained. Lean Shipbuilding is also a part of Lean Thinking and is a result of LP and LC adapted to fit the shipbuilding industry. Nevertheless, the worldwide research on Lean Shipbuilding is limited. There are two main reasons for this: firstly that the term itself has not yet become a concept with a solid theoretical base. Secondly, the term is quite similar to Lean Construction (Dugnas and Oterhals 2008) (Liker and Lamb 2000).

2.1.4.1 What is Lean Shipbuilding

Lean Shipbuilding is an outcome of LP and LC and has a lot of similarities with these two philosophies. All three philosophies have focus on satisfying customer needs with a short lead time by eliminating waste in every process. However Lean Shipbuilding is most similar to LC. As mentioned, the construction industry is also project-driven and usually delivers products which are one-of-a-kind. The table below illustrates some important differences and similarities between Lean Shipbuilding, Lean Construction and Lean Production (Dugnas and Oterhals 2008) (Liker and Lamb 2000).

| Manufacturing | Lean Shipbuilding | Lean Construction |
|---|--|---|
| <ul style="list-style-type: none"> • High volume | <ul style="list-style-type: none"> • Low volume | <ul style="list-style-type: none"> • Projects can be everything from mass production of prefabricated housing to a unique bridge |
| <ul style="list-style-type: none"> • Standardized and repetitive products | <ul style="list-style-type: none"> • Complex, non-repetitive on product level | <ul style="list-style-type: none"> • Complex projects in uncertain environment |
| <ul style="list-style-type: none"> • Integrated production system | <ul style="list-style-type: none"> • Production in loose network | <ul style="list-style-type: none"> • Varies from project to project |
| <ul style="list-style-type: none"> • Automated processes | <ul style="list-style-type: none"> • Handcraft | <ul style="list-style-type: none"> • A combination of handcraft & automated processes |
| <ul style="list-style-type: none"> • Short through-put time | <ul style="list-style-type: none"> • Long through-put time | <ul style="list-style-type: none"> • Covers a spectrum ranging from slow, certain, and simple projects on one end to quick, uncertain, and complex projects on the other. |
| <ul style="list-style-type: none"> • No customization | <ul style="list-style-type: none"> • Customization | <ul style="list-style-type: none"> • The uniqueness of projects extends from mass production of prefabricated housing on one end of the spectrum a unique bridge on the other. |
| <ul style="list-style-type: none"> • No design and engineering changes are allowed | <ul style="list-style-type: none"> • Product is partly designed and engineered to order | <ul style="list-style-type: none"> • Product should meeting the unique requirements of a customer |

Table 4: Differences and similarities between Lean Production, Lean Construction and Lean Shipbuilding (Toftesund 2009), (Ballard and Howell 1998) (Liker and Lamb 2000)

There are also some other differences between Lean Shipbuilding and Lean Construction are explained. In LC the focus is to simplify by minimizing number of steps, parts and linkages in a product, while in LS the focus is on the entire material or information flow. Another difference is that in LC output value is increased through systematic consideration of customer requirements. In LS the consideration of customer requirements is continuous (Dugnas and Oterhals 2008).

2.1.4.2 A Model of Lean Shipbuilding

In section 2.1.2.1 the Toyota Production System house were presented. Liker and Lamb (2000) have used this model as a base and developed it in to a shipbuilding model. This model is shown in figure 14 below. The model includes all the elements of the TPS house. However it is presented as a shipyard model by using a ship in the dry-dock as centerpiece. The shipyard model has however one weakness compared to the TPS house. The TPS house clearly depicts a system and shows that if one element is missing, the house will collapse. The shipyard model does not reflect this as clearly as a house. Remember that Lean is a system and elements illustrated in the figure cannot be picked one at the time (Liker and Lamb 2000).

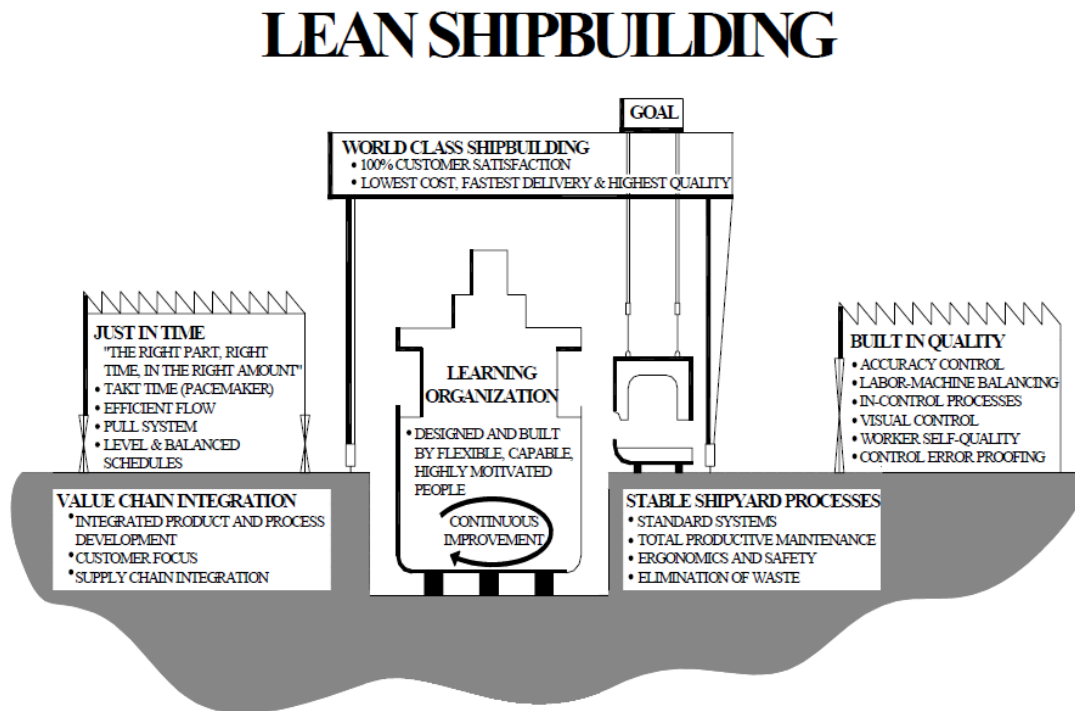


Figure 14: Lean Shipbuilding model (Liker and Lamb 2000)

2.2 Theoretical summary

This chapter has presented the theoretical concepts which are relevant in order to answer the master thesis' two research questions. First, the term Kaizen was introduced and explained. Further, Lean Production and Lean Construction were presented, looking deeper into the relevant principles and tools. Last, Lean Shipbuilding was introduced and compared to Lean Production and Lean Construction.

Theory regarding Lean Production explains the relationship between value and waste (with the seven types of waste) and the difference between NVA and NNVA activities. Together with motion studies these theoretical concepts helps to define the terms NVA and NNVA walking. The Four M and the 5 Why were applied to reveal root causes to the NVA and NNVA walking at Ulstein. Further the Lean Production tools Five S and Gemba and the Lean Construction tool Last Planner were used in order to find suggestions for improvement.

The term Kaizen means continuous improvement and is central in Lean philosophy. Kaizen runs as a red thread through the master thesis and is especially important in order to undermine the suggestions for improvement.

3 Research Methodology

In this chapter the research approach is described in terms of research design and data collection methods. The case study method and the action research model are explained in section 3.1. Further the direct observation method and the personal interview/ survey method are presented in section 3.2.

3.1 Research Design

Robert K. Yin (2009) has defined research design as:

Research design definition:

A logical plan for getting from here to there, where here may be designed as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions (Yin 2009).

The research designs purpose is to avoid situations where the evidences do not address the original research questions. Yin (2009) presented five components that are essential in a research design (Yin 2009):

- 1) *Study Question:* These questions illustrate what type of research that is going to be applied in the study. The questions should NOT already been answered completely by others. The questions should be formulated with “who”, “what”, “where”, “how” and “why”. The master thesis’ study questions are presented in the research problem in section 1.4.1.
- 2) *Study Propositions:* The propositions are made as a supplement to the study questions. The propositions will help to reflect important theoretical issues and help the writer deciding where to find evidence for this. The master thesis’ propositions are introduced in section 3.2.1.1.

- 3) *Unit of analysis*: The case subject is defined. Selection of the appropriate unit of analysis will occur after the study questions are made. The unit of analysis is described in the research problem in section 1.4.1.

- 4) *Linking data to propositions and criteria for interpreting the findings*: Tools and techniques are here used to analyze the data. This will give a solid foundation for the analysis. This is done in chapter 4 and chapter 5.

- 5) *Criteria for interpreting a study's findings*: This can be done in several ways; one of them is to use statistical criteria. However it can also be about identifying and discussing other explanations that do not support the explanation for the results. This is done in chapter 4 and chapter 5.

The master thesis used a case study method of Ulstein and an action research method. These methods will be more thoroughly explained in section 3.1.1 and 3.1.2.

3.1.1 Case Study Method

There is no standard definition of a case study (Benbasat, Goldstein and Mead 1987).

However Yin (2009) has defined case study as:

Case Study definition:

An empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 2009).

A case study can be conducted with the help of several methods and tools which are often used to collect data from a number of units by a direct observer(s) in a single and normal setting. It is important that there is no experimental control or manipulations that can influence the data collection result. In order to conduct a case study both quantitative and qualitative methods and tools can be used. The goal is to really understand the phenomenon that has been studied in a real life context, which in this research is the walking pattern at Ulstein Shipyard. At the same time it is important to make sure that the accumulation of multiple entities as supporting sources of evidence to ensure that data collected are correct and truthful (Meredith 1988). Hence an observation study and personal interviews/ survey are conducted and the results are crosschecked in order to ensure correct and truthful data.

However the case study research method has some disadvantages. These are for instance the requirements that are needed to conduct the method like the cost, use of time, access to information obstacles and the need for using several methods and entities for triangulation (Meredith 1988). These disadvantages were taken into consideration before conducting the personal interview/ survey and the observation study.

Angerer (2005) has described the case study method as an iterative process between theory and empiricism. He has illustrated the methods process in the figure below. In addition he emphasizes the fact that the closure between the collected data and the developed theory is achieved when the difference between them are small (Angerer 2005).

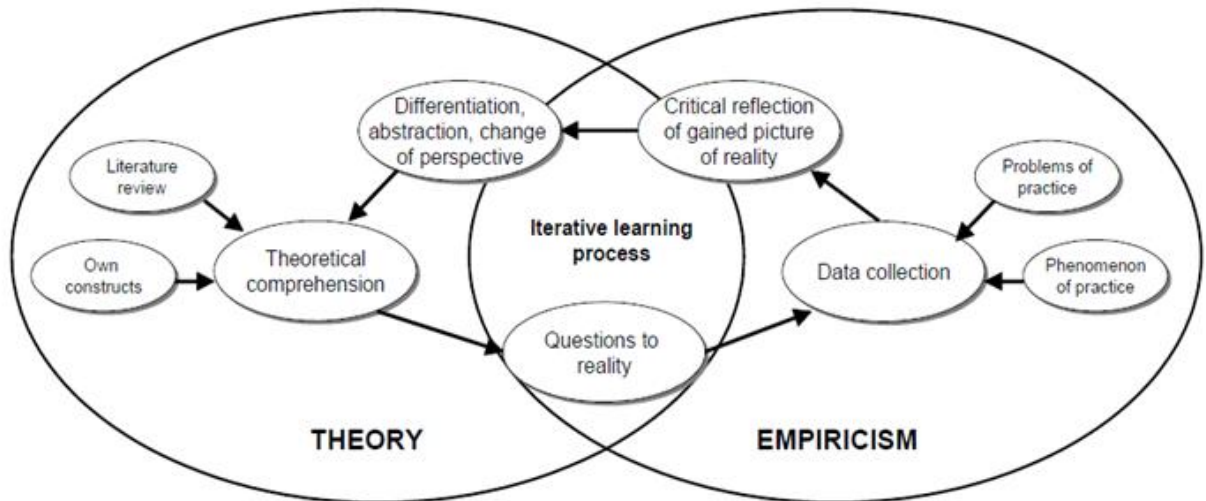


Figure 15: The case study method: An iterative process between theory and empiricism (Angerer 2005)

3.1.2 Action Research Method

Action research, also known as participatory action research, has no universally accepted definition (Koshy, Koshy and Waterman 2011). However Fisher (2006) has defined action research as:

Action research definition:

A process in which a group of people with a shared issue of concern collaboratively, systematically and deliberately plan, implement and evaluate actions. Action research combines action and investigation. The investigation informs action and the researchers learn from critical reflection on the action (Fisher 2006).

Research is about generating knowledge. Action research creates knowledge based on examination of precise and practical situations (Koshy, Koshy and Waterman 2011). The practical situation which is going to be examined in this master thesis is the walking-pattern in Ulstein's shipyard.

The action research method is frequently used for improving conditions and practices. The method involves the practitioners to conduct systematic examinations in order to help them improve their own practices. The goal is to improve their working environment and the working environment of the people that is a part of it (Koshy, Koshy and Waterman 2011). In the master thesis the participants are defined as the management at Ulstein and the employees working on ship #293. The master thesis' goal is to improve the employees own practices regarding the activity *walking*. The thesis will use knowledge gained from the employees and from observations as foundation for the research.

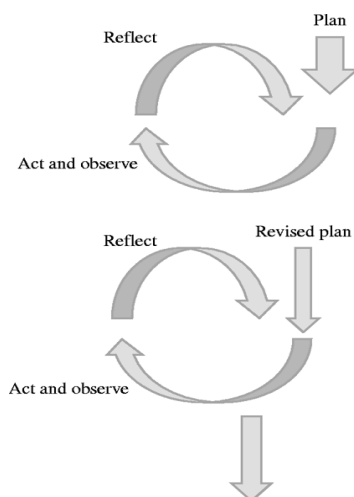


Figure 16: Action research cycle (Kemmis and McTaggart 2005)

The action research method is often presented as a cyclical process with repeated cycles of planning, action, evaluation and re-planning. This is illustrated in figure 16 above (Kemmis and McTaggart 2005). Bridget Somekh (2005) explained the cycle as an integration of research and action in several cycles of data collection, analysis and interpretation, planning and introduction of action strategies, and evaluation of these strategies through further data collection. The process continues in cycles until someone decides to stop it. The final results could then be seen and presented (Somekh 2006). The method is a group activity where researchers and participants involved do research on issues or problems that are identified by the practitioners themselves. The researchers and the practitioners will then cooperate with each other to find a future-oriented conclusion on the issues or problem through the cyclical process (Koshy, Koshy and Waterman 2011) (Guiffrida, et al. 2011).

The thesis research problem is identified by Ulstein through Ugland and Gjerstad (2010)'s master thesis (Ugland and Gjerstad 2010). However the problem is well-known by the practitioners (both management at Ulstein and the employees), and the practitioners are eager to find better practices to reduce the time spent on walking. The thesis has not been addressed as a group activity between the participants and the researchers. However the researchers have been in regular contact with Ulstein in order to gain knowledge and secure the information. In addition a personal interview/ survey has been used to get knowledge regarding employees thoughts and solutions to reduce the walking.

The research method involves using researchers that are outside the established research group that do not have advanced degrees as professionals and doctor-level researchers (Guiffrida, et al. 2011). The thesis is written by master students and not professional researchers which fit to the characteristic of writing an action research paper.

3.2 Data Collection

When a researcher is collecting data, he/she can select in a wide range of data collection methods. These methods can be divided into two categories; primary data and secondary data.

Primary data definition:

Data collected for the specific research problem at hand, using procedures that fit the research problem best.

Secondary data definition:

Data originally collected for a different purpose and reused for another research question.

(Hox and Boeije 2005)

Both primary and secondary data can be divided into two categories: qualitative data and quantitative data (Hox and Boeije 2005). The table below presents a list of primary data collection techniques:

| | Solicited | Spontaneous |
|---------------------|--|---|
| Quantitative | <ul style="list-style-type: none"> • Experiment • Interview survey • Mail survey • Structure diary • Web survey | <ul style="list-style-type: none"> • (Passive) observation • Monitoring • Administrative records (e.g., statistical records, databases, internet archives) |
| Qualitative | <ul style="list-style-type: none"> • Open interview • Focus group • Unstructured diary | <ul style="list-style-type: none"> • (Participant) observation • Existing records (e.g., ego-documents, images, sounds, news archives) |

Table 5: Primary Data (Hox and Boeije 2005)

Primary research data is more expensive to collect and more time consuming than secondary data. However it will give better results (Gratton og Jones 2010). Hence the research has used two primary data collection methods in the research: an observation study and a personal interview/ survey. In addition, some secondary data have been used in

order to solve the research problem. The table below presents the different data collection methods used in the thesis.

| | Primary | Secondary |
|---------------------|---|---|
| Quantitative | - Personal interview/ survey - Direct observation | - Research paper by Ugland and Gjerstad (2010) -General information |
| Qualitative | - General information from Ulstein | - Literature - Background information from website - Earlier research papers -Annual reports |

Table 6: Data collection methods used in the master thesis

As mentioned, two methods have been used in order to collect the primary data for the research. First a direct observation study was performed. Further a personal interview/survey was conducted based on the observation results, general information from Ulstein and Lean theory. General information from Ulstein includes information from meetings with our supervisors at Ulstein and information presented by Ulstein on email. The observation method and personal interview/survey method will be described in more depth in section 3.2.1.3 and 3.2.1.4.

The secondary data collection in the thesis is literature, background information from websites, general information (email), a research paper by Ugland and Gjerstad (2010) and annual reports. Three problems could occur when selecting and finding secondary data. The first problem is that it may be difficult to find data that can be used in the research. The second problem is that the researcher must be able to collect all the data needed. The third problem is the importance of evaluating the quality of the information collected (Hox and Boeijs 2005). The data collection methods are used to collect information in order to answer the master thesis research questions. Further the data collection methods will be used to answer the master thesis' propositions. Propositions are used by researchers to

state their expected research results (Cooper and Schindler 2003). The propositions are presented in section 3.2.1.1.

3.2.1 Data Collection Methods

In this chapter the master thesis propositions are presented. In addition, definitions on NVA and NNVA walking, the observation study method and personal interview/survey method are presented.

3.2.1.1 Propositions

Direct observation propositions

The direct observation propositions help to answer the thesis' first research question:

“How much time do the employees working on ship #293 spend at non-value adding and non-value adding but necessary walking at the shipyard?” Further the propositions gives additional information to the research problem.

- When leaving the gangway on ship #293 operators will spend more time on NNVA walking than NVA walking.
- When leaving door 1 (the main door in the dock) operators will spend more time on NNVA walking than NVA walking.
- No time is spent on walking to the cafeteria during the observation study. (Since the observation study was not conducted during lunch time or when employees arrived/ left work).
- Operators spend much time on walking between ship #293 and the outfitting hall.
- There will be little time spent on walking to the main storage outside the dock. (Since the tool-storage and the prop-stock are much used, little time should be used walking to the main storage).

These propositions are based on findings from the pilot study. The observation study is used to find answer to these propositions.

Personal interview/ survey propositions

The personal interview/ survey proposition help to answer the thesis' second research question: "*What are the root causes of the NVA and NNVA walking and how can Ulstein counteract them?*" Further they will also contribute to information regarding the first research question and they will be used to crosscheck the results from the observation study.

- Not optimal access to inventory is the main reason for walking.
- Walking to the outfitting hall and the tool storage are the main reasons for leaving the gangway on ship #293 during a working day.
- The destinations which are most frequently walked to are the outfitting hall and the tool storage.
- The layout in the dock is not optimal.
- Lean /Ulstein Production System is fully implemented in the dock. In addition, the employees know the meaning of the term.
- There is lack of information between foremen and operators.

The propositions are based on the results from the direct observation, general information from Ulstein and Lean literature.

3.2.1.2 Definitions

Before introducing the observation and personal interview/ survey methods some important definitions are explained. First a map of the different destinations used in the observation study is introduced. Further the master thesis' research problem distinguishes between non- value adding (NVA) and non-value adding but necessary (NNVA) walking. Hence these terms will be defined. In addition the thesis will use the term employees when referring to both the foremen and the operators working on ship #293.

Map over the destinations in the shipyard

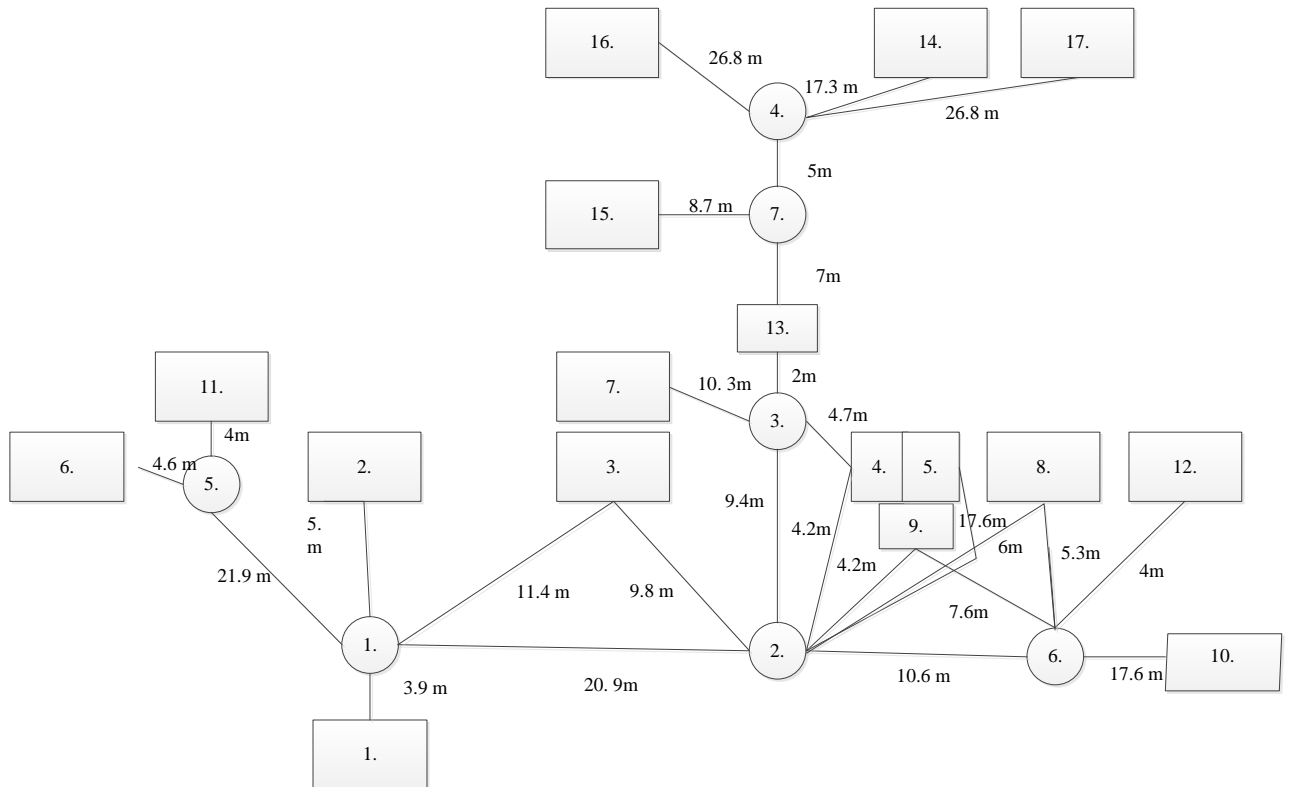


Figure 17: Destinations and nodes which are used in the observation study.

In the figure, the squares indicate different destinations while the circles are nodes. The nodes are points on the network map where the walking patterns from destinations to other destinations are connected. The areas are as follows:

- | | |
|---------------------|------------------------|
| 1. Gangway | 10. Door 2 |
| 2. Prop-stock | 11. Outfitting hall, 1 |
| 3. Tool storage | 12. Tool storage 2 |
| 4. Men toilet | 13. Door 1 |
| 5. Woman toilet | 14. Cafeteria |
| 6. Toilet | 15. Outfitting hall, 2 |
| 7. Foremen's office | 16. Workshop |
| 8. Soda machine | 17. Storage |
| 9. Coffee machine | |

Gangway on ship #293: The entrance to ship #293 which is located in the dock.

Prop-stock: The storage for consumption products, like for instance screws, bolts etc.

Tool-storage: This includes the counter to the tool-storage as well as a rack with tools and props outside the tool storage.

Foremen's office: Located at the second floor inside the dock.

Door 2: Located at the end of the dock.

Outfitting hall: The hall where pipes and other items are adjusted to fit the ship.

Prop stock 2: A second prop stock where tools etc. are stored in the dock.

Door 1: The main door in the dock. The last day of the observation week was used to observe the activities in the area outside this door.

Outfitting hall- 2: The entrance to the outfitting hall from the area outside the dock.

Workshop: This is the area where small corrections on items are done.

Storage: The main storage for Ulstein Verft AS.

Non-value adding walking vs. non-value adding but necessary walking

Activities (in this case walking) can in general be divided between value adding (VA), non-value adding (NVA) and non-value adding but necessary (NNVA). This division is important due to the fact that it is the walking which does not add value which is important to focus on in order to reduce waste (Liker and Lamb 2000).

The results from the observation study and the personal interview/ survey are presented based on whether the walking to the different destinations are classified as non-value adding walking (NVA) or non-value adding but necessary walking (NNVA). The reason why none of the walking is classified as value creation is that walking does not transform the product into something the customer wants and hence it is waste due to Lean theory (Liker and Lamb 2000).

The NVA and NNVA walking are defined based on theory regarding therbligs and the seven wastes. Therbligs is originally intended for analyzing the motions involved in performing a given task. The focus is to identify individual motions, like for instance to lift the hand to reach an object and further grasp the object (Ferguson 2000). However in this research therbligs has been used to analyze walking at the shipyard, which means that the theory has been expanded to count for larger distances and motions.

Non-value adding walking:

Waste is defined as “*..any human activity that absorbs resources but creates no value.*” (Womack and Jones 2003). Hence, walking which do not add value is waste and should be eliminated. NVA walking at the shipyard can be characterized as the therbligs *transport unloaded* and *rest*. Further NVA walking is classified as *excess motion*, which is one of the seven wastes. Walking to the following destinations is classified as NVA walking:

- Walk to soda machine
- Walk to coffee machine
- Walk to door 2
- Walk to cafeteria

Walking from ship #293 to any of these destinations can be classified as *transport unloaded*. This is because when the operators returned back to ship #293 from these destinations they walked onboard the ship without transporting anything. This was noticed during the observation study.

Excess motion is highly related to *transport unloaded* since it refers to the unnecessary movement of people. Walking to the soda machine, coffee machine, door 2 and the cafeteria is *excess motion* and should be completely eliminated. Further, walking to these destinations can be characterized as *rest*. According to the observation study employees perform this type of walking in order to take a break from work. *Rest* is according to Shingo (1988) a part of class 4 and should hence be eliminated to the extent possible. This will also count as one of the seven wastes, namely *waiting*. There should be no reason for operators working on ship #293 to walk to these destinations during a working day except during lunchtime (Shingo 1988).

The figure below shows NVA walking from the gangway on ship #293 to the following destinations: cafeteria, coffee machine, soda machine and door 2.

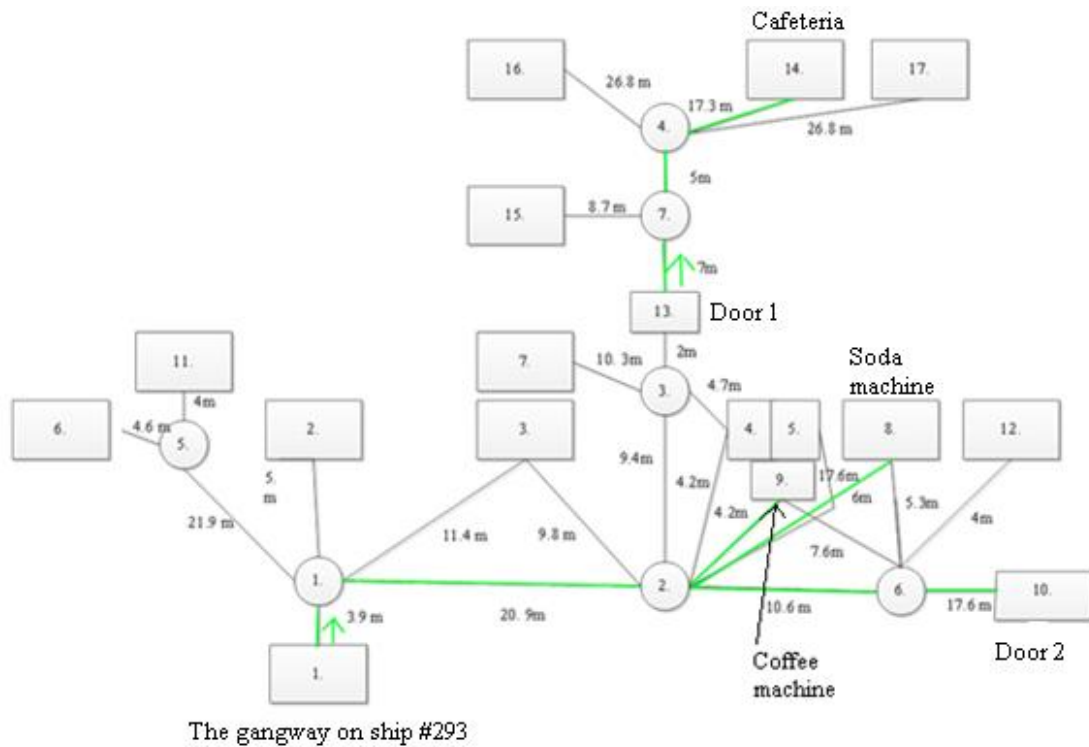


Figure 18: NVA walking

Non-value adding but necessary walking:

Walking to the destinations mentioned below does not add value to the final product. However they are to some extent necessary for finishing ship #293. Some of the walking can be classified as the *therblig prepare* while some is classified as *transport loaded* or *searching*.

- Walk to toilet
- Walk to women's toilet
- Walk to men's toilet
- Walk to prop stock
- Walk to tool storage
- Walk to counter
- Walk to foremen's office
- Walk to outfitting hall
- Walk to prop stock 2
- Walk to door 1
- Walk to main storage
- Walk to workshop

Walking to the prop stock, tool storage, outfitting hall, prop stock 2, main storage and workshop is classified as NNVA walking due to the fact that most employees came back to gangway on ship #293 carrying tools or materials. Hence the walking is classified as *transport loaded*. Transport is one of the seven wastes; however material handling and transport necessitated by the relocation of work are unavoidable in construction (Diekmann, et al. 2004). Transport is a central part of building a vessel like ship #293. All the parts needed to perform the work needs to be transported onboard the ship. However the walking to these destinations is in some cases classified as *search*. Searching for tools or materials often leads to NNVA walking and *excess motion*. It is hard to know which walking that can be categorized as *search*. However it is reasonable to assume that when employees are walking between the different storages they are not finding what they are looking for. Hence employees perform NNVA walking due to searching for tools or materials.

Further walking to the foremen's office is classified as the *therblig prepare*. Operators walk to the foremen's office when they need to get information on how to perform their work, hence walking to get information can be classified as preparing for executing the work. Walking to this destination is therefore characterized as NNVA.

Walking to door 1 is also classified as NNVA since most of the employees came back through door 1 carrying tools or materials from the main storage outside the dock. Further walking to the toilet is classified as NNVA walking. It is necessary to go to the toilet during one working day, but it is not necessary to use much time walking to toilets. Our supervisor at Ulstein agrees that walking to the toilet should be classified as NNVA. It will be impossible to eliminate walking to this destination, however the time spent walking to it should be minimized.

The NNVA walking may be wasteful but is necessary under the current operating procedures at ship #293. In order to reduce waste, the distance to these destinations and number of times walking to these destinations should be minimized to the extent possible. The figure below shows NNVA walking from the gangway on ship #293 to the following destinations: toilet, outfitting hall, prop stock, tool storage, foremen's office, men's toilet, women's toilet, prop stock 2, door 1, outfitting hall (entrance 2), workshop and main storage.

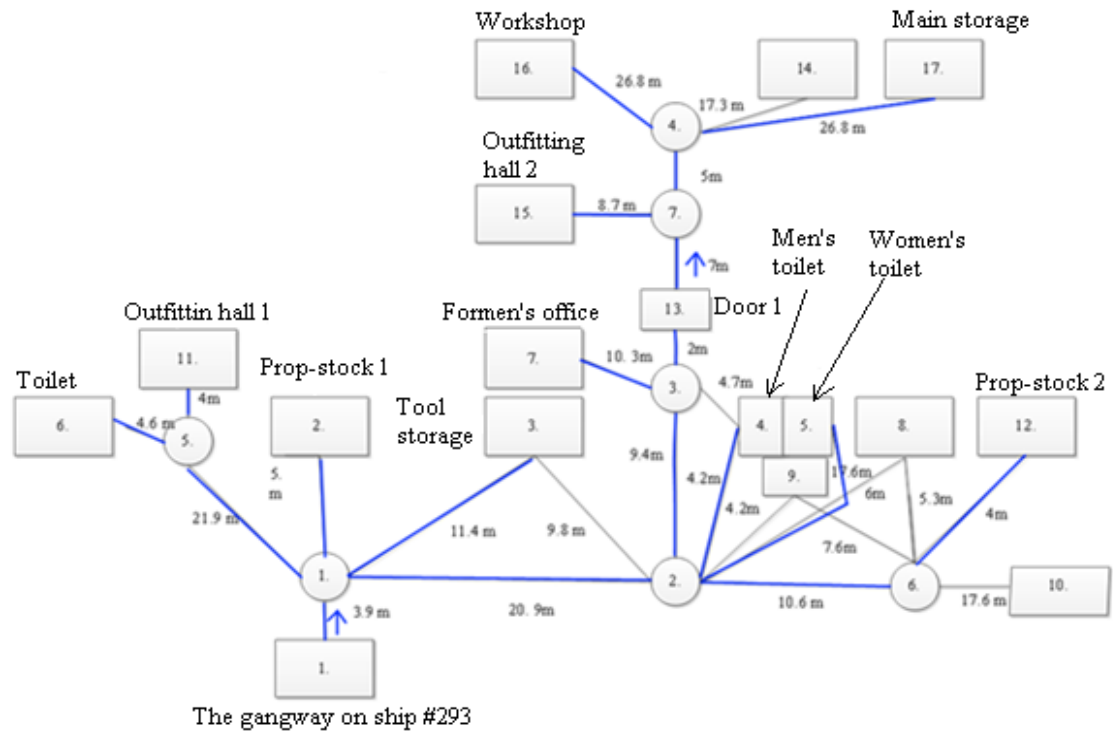


Figure 19: NNVA walking

3.2.1.3 Direct observation

The thesis has used a direct observation method. The observation study was performed in order to answer the first research question: “*How much time do the employees working on ship #293 spend at non-value adding and non-value adding but necessary walking at the shipyard?*”

Observation definition:

The systematic description of events, behaviors, and artifacts in the social setting chosen for study (Kawulich 2005).

One of the advantages of this method is that the people observed can be observed in the environment where the system is normally used. The reliability of the observations increases with the number of observations (Yin 2009).

Observation method

The direct observation study was planned executed during one week. The first day was used to perform a pilot study. The pilot study was used to ensure that the walking-pattern in the dock was similar to what the authors believed in beforehand. The outfitting hall seemed to be more frequently used than first assumed; hence this destination was added to the original destination map. The pilot study was also used to find the best way to conduct the observation study. The best solution was to perform the observation study from the top of ship #293. This way the walking pattern in the dock would not be disturbed.

The observation study was conducted three days inside the dock and one day outside the dock. The observations inside were conducted from Tuesday 07.02.2012 to Thursday 09.02.2012. Further Friday 10.02.2012 was used to observe outside the dock. The total results show 13 hours and 30 minutes of observation inside the dock, which is approximately two working days. In order to make the results reliable for one working day the number of observations is divided by 13.5 hours and then multiplied with 7.5 hours. This is based on the assumption that one working day contains 7.5 hours (Larsen 2012).

Outside the dock the observation study lasted for 4 hours and 30 minutes. The number of observations is also here divided by 4.5 hours and then multiplied with 7.5 hours in order to make the results reliable for one working day. All observations were conducted from 08.45-11.00 and from 12.30-14.45. It was emphasized to observe the exact same time each day in order to make the results comparable.

This research paper used a calculation method which normally is used in transportation planning problems. The places the employees walk to are called destinations while nodes are used to simplify measure and draw the network. As mentioned, the nodes are points on the network map where the walking patterns from destinations to other destinations are connected. The observation study includes 17 observation destinations and 7 nodes. The destinations are showed in figure 20 below and more deeply explained under definitions in section 3.1.3. The observation results are based on an assumption that the employees walk 5 km/h (Larsen 2012).

The different destinations and nodes are shown in the figure below.

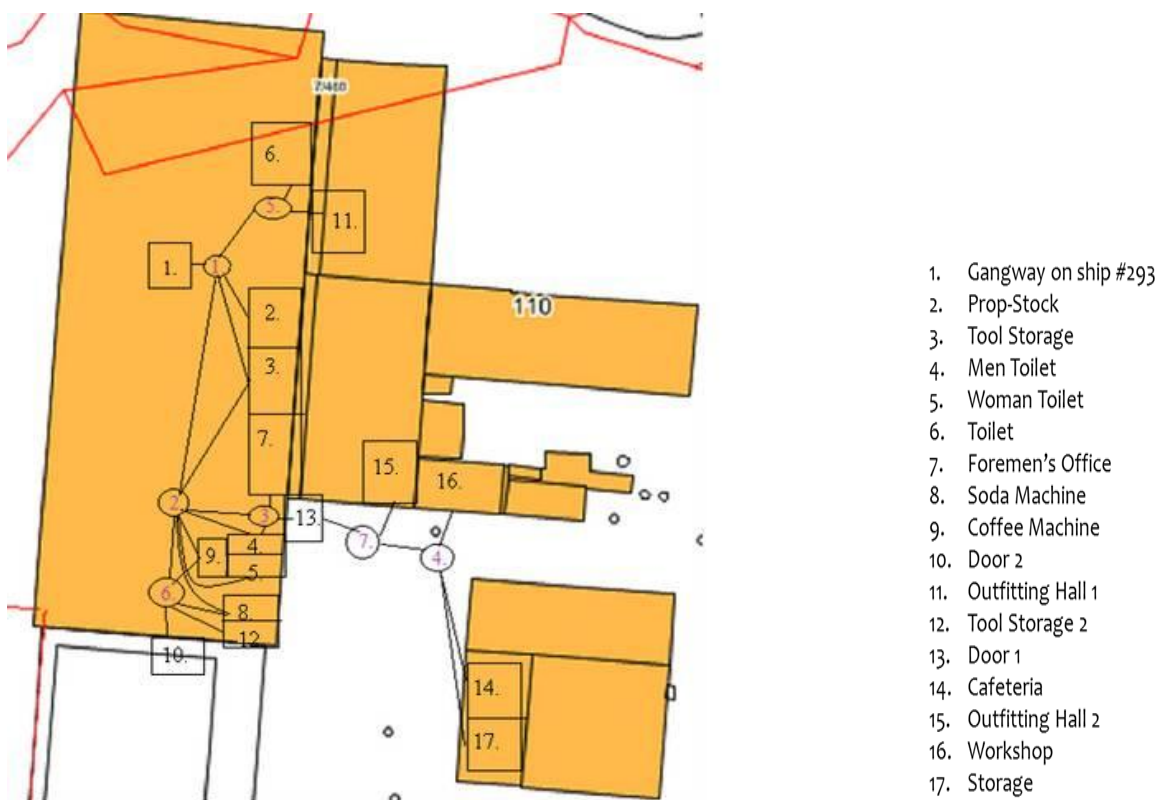


Figure 20: An overview over the shipyard area and the dock (Sunmorskart u.d.)

When the observation study was completed, all the observations were assembled in two matrixes. One matrix was made for the observations inside the dock and one was made for the observations outside the dock. These matrixes gave the authors a certain amount of information. However it was not the same number of employees walking to a destination as the number of employees walking back from a destination. This means that the employees will start to accumulate in certain destinations over time. Hence a “correct” matrix should give the same number of employees walking to a destination as the number of employees walking back from the destination (Larsen 2012). Thus in order to secure this, two biproportional balanced matrixes were made, see appendix 8.2.1 and 8.2.2. From appendix 8.2.1 one could see that the same number of employees is walking to for instance the prop-stock as walking back from the prop-stock, namely 280 observations.

Creating an balanced matrix is a complex and time consuming process to do by hand, thus the balanced matrix was made through the advanced mathematical and statistical computer program GAUSS. See appendix 8.3 for more information about the calculations.

Observation limitations

The first limitation is that it was impossible to observe all the destinations at the same time, which would be the optimal conduction of the observation. There had to be two observers in order to see all the destinations inside the dock. Thus in order to manage to cover all the destinations (both inside and outside the dock) the ideal situation would be to have three persons executing the observation. If there were three observers a walkie-talkie could be used to communicate. This would give an opportunity to see where the employees went when they left the dock through door 1, and where they came from when they entered the dock through door 1.

The next limitation is that neither the operators nor the foremen were informed about the observation study in beforehand. Ulstein was supposed to inform the employees about the observation study; however this had not been done. This mistake was discovered on the first observation day and Ulstein immediately sent a mail to inform the foremen. The mail contained information to the foremen and operators regarding the observation. Further it is important to inform the foremen and the operators since the Norwegian Working Environment Act and the Personal Data Act had to be taken into consideration. Act §9-1 (1) in the WEA states that: “The employer may only implement control measures in

relation to employees when such measures are objectively justified by circumstances relating to the undertaking and it does not involve undue strain on the employees.” Further, §9-1 (2) states that: “The Personal Data Act shall apply to the employer’s handling of information concerning employees in connection with control measures unless otherwise provided by this Act or another Act.” Employees need to be informed about the control measures according to WEA §9-2 where it is stated that employees have the right to know the purpose of the control measures and also practical consequences of these and the assumed duration of the control measures (Personal Data Act 2000) (Working Environmental Act 2005).

Another limitation is that while doing the observation inside the dock the authors wore red jackets and yellow helmets, which are different from what the operators and foremen use. Hence the workers easily noticed that they did not belong there. This might have disturbed some of the results. However the observation study was conducted from the top of ship #293 in order to be as little visible as possible. This seemed to work very well.

It was also considered using video surveillance in the observation study. This could have given the possibility to observe without disturbing the results. In addition this could also give the opportunity to have an overview over all the activities both inside and outside the dock, which would be the optimal solution. However, according to §38 in the Personal Data Act “Video surveillance of a place which is regularly frequented by a limited group of people is only permitted if there is a special need for such surveillance in the interests of the said activities.” Hence, video surveillance was not an option (Personal Data Act 2000) (Working Environmental Act 2005).

Another limitation is that there were only selected 17 destinations in the observation survey. This means that employees walking from or to destinations that were not included in the survey were not taken accounted for. Hence there are even more walking to and from destinations in the shipyard than the observation results present.

3.2.1.4 Personal interview/ survey

The personal interview/ survey was performed to help answer the second research question: *“What are the root causes of the NVA and NNVA walking and how can Ulstein counteract them?”*

The personal interview/ survey is two different methods (a structured personal interview and a survey) which are used to complement each other and to crosscheck the results with the observation study. A questioner with 22 questions was made (See appendix 8.1). Two of the questions had “open answers” while there were different alternative answers regarding rest of the questions. The questioner was made both in Norwegian and English, since some of the workers only know one of these languages.

First a structured personal interview was conducted. Secondly the same survey was handed out to random respondents in the dock. The two different methods will be explained in this section. Since the exact same questions are answered in the structured personal interview and the survey, the results will be presented together in chapter 4.

Structured personal interview method

A structured personal interview was used in order to get more in depth answers from the respondents. According to Gripsrud, Olsson and Silkoset (2008) the benefits of using this type of interview are that the interviewer can convince the respondent to answer all questions and also observe reactions that the respondent might have. In addition, this secured that the respondents understood the questions and hence misunderstandings were avoided (Gripsrud, Olsson and Silkoset 2008).

Further there are five aspects of interviewer behavior which is important to emphasize in a structured personal interview (Fowler 2009):

1. *Presenting the study.* A good interviewing staff will give all respondents similar orientation to the project so that the context of the interview is as constant as possible.
2. *Asking the questions.* Survey questions are supposed to be asked exactly the way they are written, with no variation or word changes.
3. *Probing.* If a respondent does not answer a question fully, the interviewer must ask some kind of follow-up question to get a better answer.
4. *Recoding the answers.* When an open-ended question is asked, the interviewers are expected to record answers exactly in the words that the respondent uses.
5. *Interpersonal relations.* The interpersonal aspects of an interview are to be managed in a standardized way. Behaviors that communicate the personal characteristics of the interviewer are to be avoided because they will vary across interviewers.

All these aspects were taken into consideration when the authors performed the structured personal interviews. However when the interviewer and the respondent come from different background in society the communication may not go as free and easy as when backgrounds are similar. Interviewers who take steps to ease communication in such situations may be able to produce a more effective interview (Fowler 2009). Hence, chocolate was served in order to make the respondents feel comfortable and create a relaxed atmosphere. This strategy seemed to work very well. In addition, a meeting-room in the dock was used when conducting the structured personal interviews. The reason why

the meeting-room in the dock was used was because the operators and foremen were comfortable there. In addition they did not have to spend much time walking to the office in the administration building. The respondents had a printed version of the survey in front of them, so they easily could see the questions and the answer options.

The personal interviews were conducted 27.02.2012 and 28.02.2012. In total 22 respondents were interviewed; 5 foremen and 17 employees working on ship #293. The personal interviews lasted for approximately 30 minutes per respondent. When choosing respondents a random sample was used. In a random sample each element has in the population the same probability of being selected (Gripsrud, Olsson and Silkoset 2008). Odd-Sverre Volle at Ulstein pre sent lists over employees and the respondents were chosen randomly (every second name) from these lists.

Personal interview limitations

There will always be limitations when having a structured personal interview. The first limitation is that the respondents may not answer honestly due to the interviewers' presence. Further, this kind of interview often takes long time and can have relatively high costs (Gripsrud, Olsson and Silkoset 2008). Each interview lasted for approximately 30 minutes and hence 30 minutes of each respondent's working time was used. This is the reason why only 22 employees were interviewed. Thus in order to get more respondents the questioner was handed out to 18 random respondents. This method is described below.

Survey method

The survey was used to cross check the results from the structured personal interview and hence get more respondents in order to secure the reliability. The term reliability is explained in more depth in section 3.2.1.5. Benefits from handing out the survey and let the respondents answer themselves is that the cost is low and it is easier to answer honestly since nobody can see what they answer. Further the respondents are not so easily stressed since they can use the time they need (Gripsrud, Olsson and Silkoset 2008).

The survey was conducted 29.02.2012 and 30.02.2012. It was handed out to 18 random respondents working on ship #293; hence a random sample was used. The survey was handed out randomly to every second employee in the dock until 18 respondents had answered. Many of the respondents chose not to answer due to language problems. The respondents could choose to answer the survey in English or Norwegian. Further the respondents were offered a chocolate before answering the survey and this created a good atmosphere between the interviewers and the respondents.

Survey limitations

When handing out the survey to random respondents one limitation could be that the respondent misunderstood one or more of the questions (Gripsrud, Olsson and Silkoset 2008). However the authors tried to minimize misunderstandings by being available so that the respondents could ask them if they did not understand the questions. In addition, language problems could occur since a lot of the workers on ship #293 were polish and not very good in English. Another disadvantage by using this method is that open questions usually are not useful (Fowler 2009).

A limitation in the questioner is that the last question did not measure what it was intended to measure and hence it weakens the validity. The validity of the data collection methods are further explained in section 3.2.1.5. The question was intended to measure if the employees had power to make decisions and changes in the production. However a lot of the respondents signalized that they misunderstood the question. Therefore this question (q 23 – see appendix 8.1) will not be used in the results and in the discussion chapter.

3.2.1.5 Quality of the research

It is important to consider the validity and the reliability of the observation study and the personal interview/ survey in order to evaluate the quality of the measurement procedure. Validity and reliability are often used when deciding how well one or more phenomena are measured (Gripsrud, Olsson and Silkoset 2008).

In order to measure how much time which was spent on walking between the 17 destinations at the shipyard, the authors found an observations study as an appropriate method to use. Both the thesis' supervisors and the contact persons at Ulstein supported this decision. By using this method the authors observed what was intended to observe, namely how much time which was spent on NVA and NNVA walking at the shipyard in Ulstein.

In addition, using multiple sources of evidence is a tactic to increase validity when doing case studies (Yin 2003). This master thesis used multiple sources of evidence: observation study, personal interview/ survey and other documents/literature in order to increase the validity.

The authors have also presented the results for Ulstein, where the head of planning, the storage chief and 10 others were present. They expressed that the root causes behind the NVA and NNVA walking was something they have noticed themselves and that the solutions presented were good solutions which will be taken into further consideration. This is also a factor which secures the validity.

Reliability concerns the extent to which one can trust that the results are reliable and if the measurement will give the same result if repeated many times with the same or with other methods. (Gripsrud, Olsson and Silkoset 2008). The goal of reliability is to minimize the errors and biases in a study (Yin 2003). Hence the high number of observations secures the reliability of the observation study and in the personal interview/ survey. Further the pilot study also helped in improving reliability.

4 Analysis

In this chapter the results from the observation study and the survey/ personal interview are presented.

4.1 Results

First, the results from the observation study are presented, before introducing the results from the personal interview/ survey.

4.1.1 Observation study

The findings from the observation study answer the first of the two research questions:

How much time do the employees working on ship #293 spend at non-value adding and non-value adding but necessary walking at the shipyard?

Further, the observation results answer the following propositions:

- When leaving the gangway on ship #293 operators will spend more time on NNVA walking than NVA walking.
- When leaving door 1 (the main door in the dock) operators will spend more time on NNVA walking than NVA walking.
- No time is spent on walking to the cafeteria during the observation study. (Since the observation study was not conducted during lunch time or when employees arrived/ left work).
- Operators spend much time on walking between ship #293 and the outfitting hall.
- There will be little time spent on walking to the main storage outside the dock. (Since the tool-storage and the prop-stock are much used, little time should be used walking to the main storage).

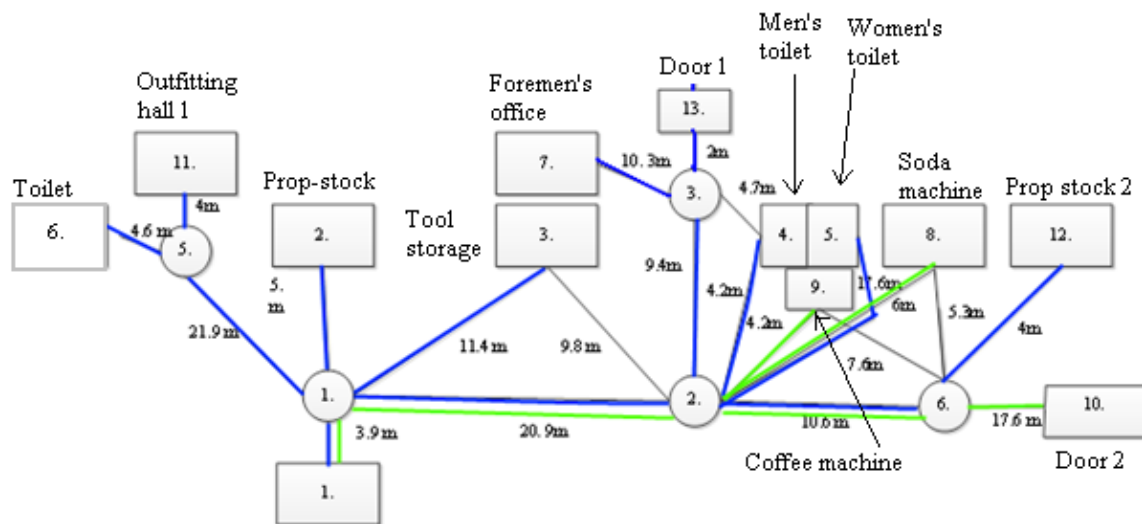
4.1.1.1 Introduction to the observation results

As mentioned in the research problem, Ugland and Gjerstad (2010) discovered that unnecessary walking in the shipyard was one of the reasons to the high share of NVA activities at Ulstein (Ugland and Gjerstad 2010). Further they stated that there was much walking back and forth from the gangway on ship #287 (Ugland and Gjerstad 2010). Hence the results focus on how much time which is spent on NVA and NNVA walking after leaving the gangway.

Data was collected through an observation inside the dock. A total of 3361 observations were collected during a period of 13 hours and 30 minutes.

The results are presented for one working day at Ulstein. See appendix 8.2 for the balanced matrixes and calculations regarding results for one month and one year. In order to make the results reliable for one working day (7.5 hours) the number of observations made inside the dock was divided by 13.5 hours and then multiplied with 7.5 hours (Larsen 2012).

The figure below shows which destinations that is included in the observation results when employees leave the gangway on ship #293. The gangway is marked 1 in the figure.



The gangway on ship # 293

Figure 21: Destinations included in the observation results inside the dock

The blue lines represent NNVA while the green line represents NVA walking. The pie-chart below illustrates the percent of total time spent on NVA and NNVA walking from the gangway on ship #293 during one working day. The green area in figure 23 represents NVA walking, while the blue area represents NNVA walking.

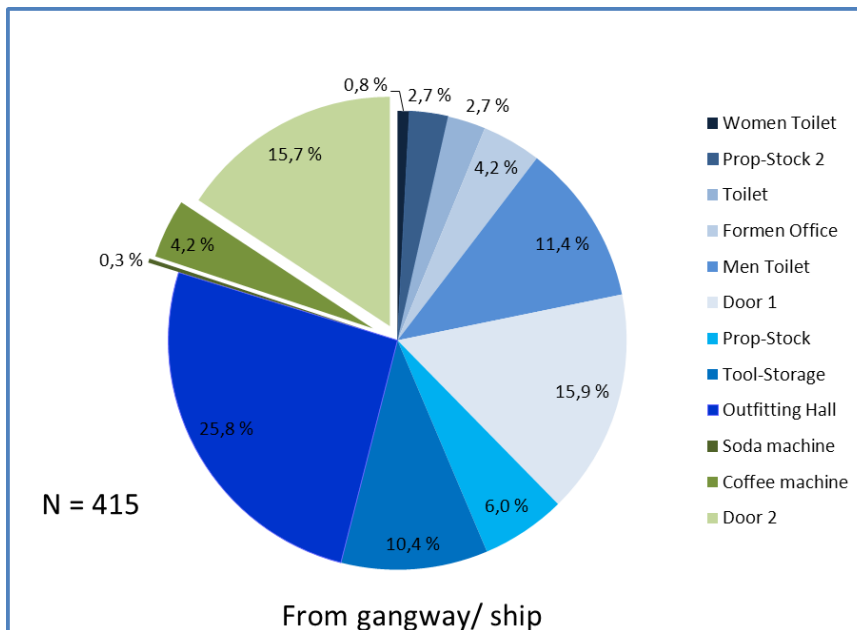


Figure 22: Percent of total time spent on NVA and NNVA walking from the gangway on ship #293

This figure answers the first proposition “*When leaving the gangway on ship #293 operators will spend more time on NNVA walking than NVA walking.*” According to the pie chart, as much as 80 % of the time spent walking from the gangway on ship #293 is spent on NNVA walking during a working day. This means that 20 % of the time spent walking from the gangway on ship #293 is spent on NVA walking.

Further it was noticed during the observation that many of the employees which left the gangway walked through door 1, which is the main door in the dock. Since the main storage and the cafeteria are located outside the dock, it was interesting to investigate whether any NVA and NNVA walking was performed also here. Therefore the results also present how much time which was spent on NVA and NNVA walking after leaving door 1.

Data was collected through an observation outside the dock. A total of 621 observations were collected during a period of 4.5 hours. In order to make the observations valid for one working day, the number of observations outside the dock was divided by 4.5 and then multiplied with 7.5 hours (Larsen 2012).

The figure below shows which destinations that are included in the observation results when employees leave door 1.

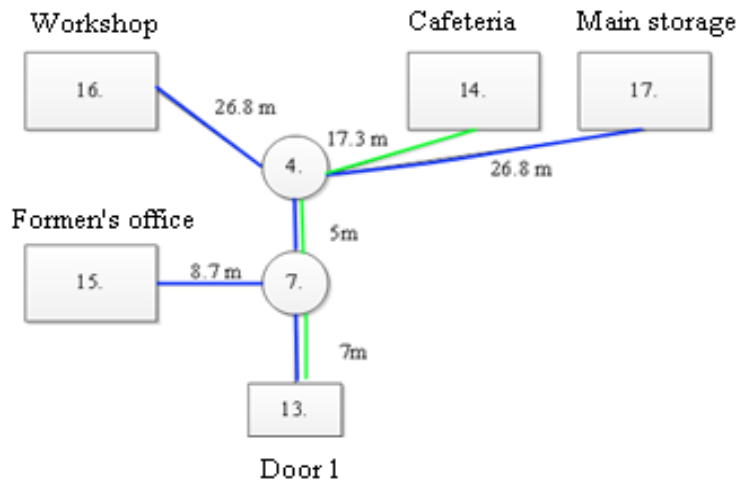


Figure 23: Destinations included in the observation results outside the dock

The NNVA walking is marked with a blue line, while the NVA walking is marked with a green line. The pie chart below illustrates the percent of total time spent on NVA and NNVA walking from door 1 during one working day.

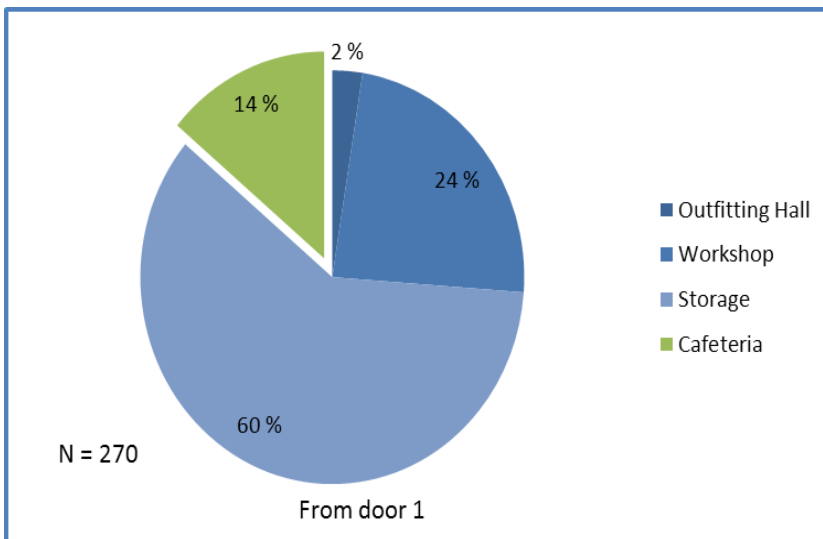


Figure 24: The percent of total time spent on NVA and NNVA destinations from door 1

The figure above answers the second proposition “When leaving door 1 (the main door in the dock) operators will spend more time on NNVA walking than NVA walking”.

According to the pie chart, as much as 86 % is NNVA walking from door 1 to the destinations outside the dock. Hence 14 % is spent at NVA walking when leaving door 1.

4.1.1.2 Findings

This section looks deeper into how much time which is spent at NVA and NNVA walking after employees leave the gangway on ship #293 and door 1. In addition the time spent on NVA and NNVA walking between all 17 destinations are presented.

4.1.1.2.1 NVA WALKING

NVA Walking from the gangway on ship #293

The observation regarding NVA walking from the gangway on ship #293 includes walking to the soda machine, coffee machine and door 2. As mentioned, 20 % of the time spent on walking when leaving the gangway is NVA. According to Lean theory much of the time spent on NVA activities should be possible to eliminate.

The table below shows number of observations walking from ship #293 to the 3 destinations and time spent per observation. Further the table shows time spent in total (number of observations x time spent per observation), assuming a normal working day of 7.5 hours.

| NVA walking per one day (7.5 hours) | | | |
|--|------------------------|-----------------------------------|---|
| <i>* From the gangway on ship #293</i> | <i># Observations</i> | <i>Time spent per observation</i> | <i>Time spent in total for all observations</i> |
| To the Soda machine | 1 observation | 24 sec | 24 sec |
| To the Coffee machine | 16 observations | 18 sec | 5 min 30 sec |
| To Door 2 | 33 observations | 36 sec | 20 min 54 sec |
| Total | 50 observations | 1 min 24 sec | 26 min 54 sec |

Table 7: Time spent on NVA walking from ship #293

Table 7 shows that only one person walks from ship #293 to the soda machine during one working day. This is a very small observation and hence the results may not be reliable for one month and one year. If one extra person walk to the soda machine during one day this will lead to a 100 % increase in total time spent walking to the destination.

Door 2 is the most frequent used destination regarding NVA walking when leaving the gangway on ship #293. According to table 7, 33 observations walked to door 2 during one working day. These use over 20 minutes to walk from ship #293 to door 2, hence if they also walk the same distance back to the ship, over 40 minutes are spent on walking between ship #293 and door 2 during one working day. The door leads out to the sister ship outside the dock and it should ideally not be necessary for an employee working on ship #293 to go out this door during a working day.

During one working day 50 employees are performing NVA walking when leaving ship #293. Whether 50 employees are a high number depends on how many persons who work on ship #293 during one day. If for instance 100 persons work on ship #293 at the same time, 50 is a rather high number.

NVA Walking from door 1

The observation regarding NVA walking outside the dock regards the cafeteria.

The table below shows number of observations walking from door 1 to the cafeteria and time spent per observation. Further the table shows time spent in total (number of observations x time spent per observation), also here assuming a normal working day of 7.5 hours.

| NVA walking per one day (7.5 hours) | | | |
|-------------------------------------|------------------------|-----------------------------------|---|
| <i>* From door 1</i> | <i># Observations</i> | <i>Time spent per observation</i> | <i>Time spent in total for all observations</i> |
| Cafeteria | 46 observations | 24 sec | 16 min 6 sec |
| Total | 46 observations | 24 sec | 16 min 6 sec |

Table 8: Time spent on NVA walking from door 1

Figure 25 shows that 14 % of the time employees use to walk from door 1 is spent on walking to the cafeteria. 14 % is quite much, especially since the observation study was not conducted during lunch-time or when the employees arrived or left work. However

there is also a toilet and a wardrobe located in the same building as the cafeteria. This may have affected the results and is not taken into account. This means that some of the time spent walking to the cafeteria can be time spent walking to the toilet or to the wardrobe located in the same area as the cafeteria.

During one working day (7.5 hours) 46 observations are walking from door 1 to the cafeteria (see table 8). Assuming that the employees also walk back to door 1 after leaving the cafeteria, 32 minutes is spent on walking back and forth between door 1 and the cafeteria during one working day. The third proposition stated that: *“No time is spent on walking to the cafeteria during the observation study.”* This is not in accordance to the findings, as explained above.

Summary NVA Walking

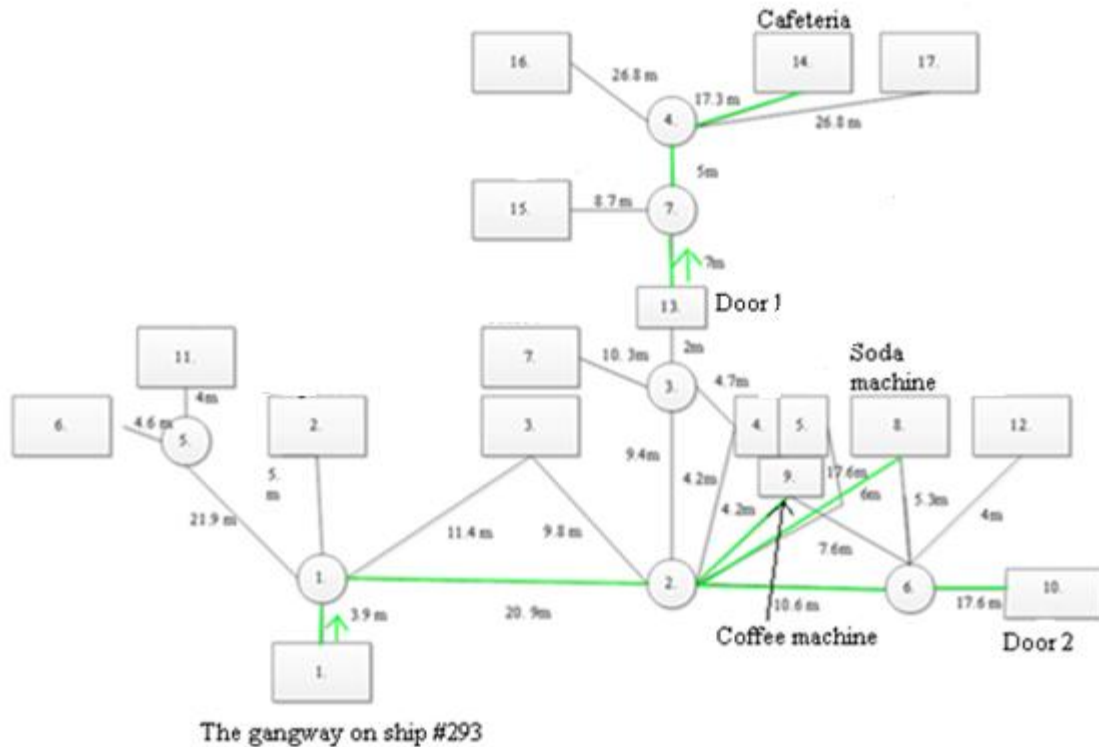


Figure 25: NVA walking performed from ship #293 (1) and from door 1 (13)

NVA walking is performed from ship #293 to the coffee machine, soda machine and door 2, and from door 1 to the cafeteria, see figure 26. In total, 43 minutes is spent on NVA walking from the gangway on ship #293 and from door 1 performed by 96 observations during one working day, see table 9 below.

According to Lean theory, walking is classified as waste; it creates no value and hence it should be eliminated. During the observation it was noticed that some of the employees who walk to these destinations returned to ship #293 without carrying anything. Hence the walking can be defined as *transport unloaded*. Since the employees do not carry anything which can be used to add value to the product, the NVA walking can also be classified as *excess motion*. As mentioned, this is one of the seven wastes and undermines the fact that the NVA walking should be eliminated.

The table below summarizes the NVA walking per day performed by employees when leaving the gangway on ship #293 or door 1.

| <i>NVA walking per one day</i> | <i># Observations</i> | <i>Time spent in total for all the observations</i> |
|----------------------------------|------------------------|---|
| From door 1 | 46 observations | 16 min 6 sec |
| From gangway on ship #293 | 50 observations | 26 min 54 sec |
| Total | 96 observations | 43 min |

Table 9: Summary of total NVA walking from ship #293 and door 1

4.1.1.2.2 NNVA WALKING

NNVA Walking from the gangway on ship #293

The observation regarding NNVA walking from the gangway on ship #293 regards walking to the toilet, women’s toilet, men’s toilet, prop stock, tool storage, foremen’s office, outfitting hall, prop stock 2 and door 1.

The table below shows number of observations walking from ship #293 to the 9 destinations and time spent per observation. Further the table shows time spent in total (number of observations x time spent per observation), assuming a normal working day of 7.5 hours.

| NNVA walking per one day (7.5 hours) | | | |
|--|-------------------------|-----------------------------------|---|
| <i>* From the gangway on ship #293</i> | <i># Observations</i> | <i>Time spent per observation</i> | <i>Time spent in total for all observations</i> |
| To women's toilet | 2 observations | 30 sec | 1 min 6 sec |
| To prop-stock 2 | 8 observations | 30 sec | 3 min 36 sec |
| To toilet | 10 observations | 24 sec | 3 min 36 sec |
| To foremen's office | 10 observations | 30 sec | 5 min 30 sec |
| To men's toilet | 44 observations | 18 sec | 15 min 6 sec |
| To door 1 | 49 observations | 24 sec | 21 min 6 sec |
| To prop-stock | 72 observations | 6 sec | 7 min 54 sec |
| To tool storage | 75 observations | 12 sec | 13 min 48 sec |
| To outfitting hall | 96 observations | 24 sec | 34 min 18 sec |
| Total | 365 observations | 3 min 18 sec | 1 hour 46 min |

Table 10: Time spent on NNVA walking from ship #293

Table 10 shows that most workers walk to the prop stock (72 observations), the tool storage (75 observations) and the outfitting hall (96 observations) from ship #293 during one working day. This undermines the forth proposition, namely that: “*Operators spend much time on walking between ship #293 and the outfitting hall.*” The 96 observations use approximately 35 minutes on NNVA walking to the outfitting hall. Assuming that the 96 employees walk the same way back to ship #293, approximately 1 hour and 10 min is spent on walking back and forth from the gangway on ship #293 to the outfitting hall

during one working day. Remember that this is only the time spent on *walking* to the destination, not the time spent at the destination itself.

NNVA Walking from door 1

The observation regarding NNVA walking from door 1 regards the outfitting hall, workshop and the storage.

The table below shows number of observations walking from ship #293 to the 3 destinations and time spent per observation. Further the table shows time spent in total (number of observations x time spent per observation), also here assuming a normal working day of 7.5 hours.

| NNVA walking per one day (7.5 hours) | | | |
|---|-------------------------|-----------------------------------|---|
| * From door 1 | # Observations | Time spent per observation | Time spent in total for all observations |
| To outfitting hall | 16 observations | 12 sec | 2 min 54 sec |
| To workshop | 59 observations | 30 sec | 27 min 30 sec |
| To storage | 150 observations | 30 sec | 1 hour 9 min 36 sec |
| Total | 224 observations | 1 min 6 sec | 1 hour 35 min |

Table 11: Time spent on NNVA walking from door 1

The table above shows that the main storage outside the dock is frequently used. 150 employees walk from door 1 to the storage during one working day. The 150 employees spend in total 2 hour and 20 min on walking back and forth between door 1 and the main storage.

The fifth proposition stated that: *“There will be little time spent on walking to the main storage outside the dock.”* However table 11 shows that much time is spent walking to the main storage during one working day. A reason for this can be that the workers do not find what they are looking for in the tool storage or the prop stock, and thus have to walk to the main storage outside the dock. Another reason can be that the planning is not optimal. This is further discussed in chapter 5.

Summary NNVA walking

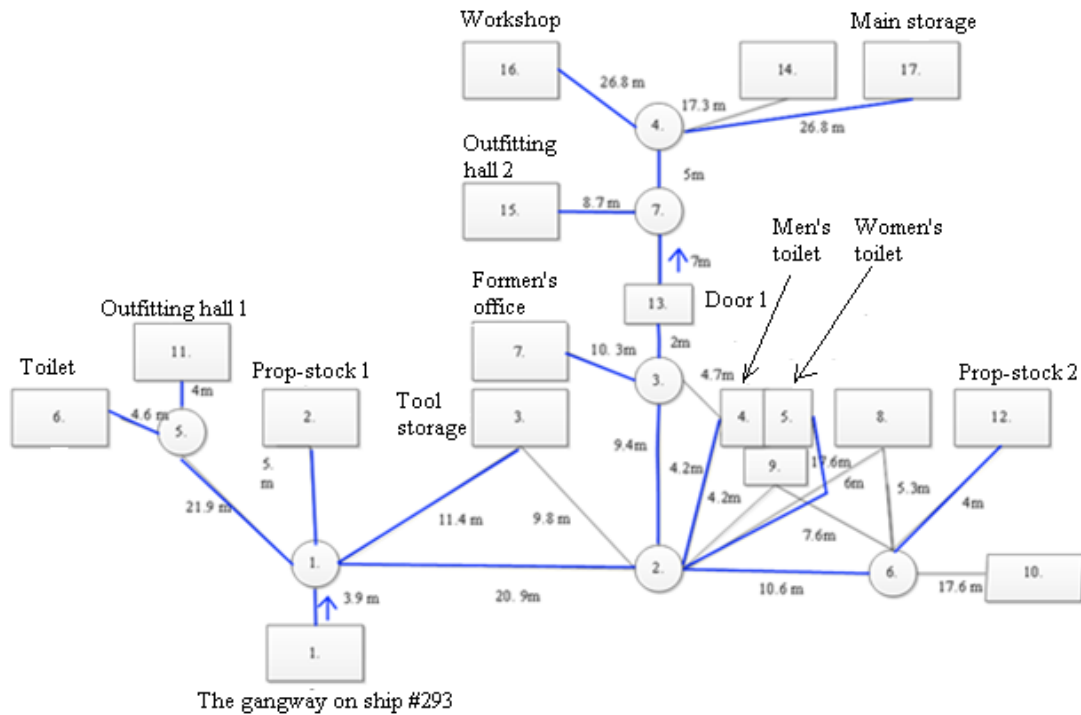


Figure 26: NNVA walking performed from ship #293 (1) and door 1 (13).

In total, 3 hours and 21 minutes is spent on NNVA walking performed by 589 employees leaving ship #293 or door 1 during one working day (see table 12 below). The walking to the above destinations is classified as NNVA due to the fact that the employees are carrying tools or materials when they are returning to the gangway on ship #293 or returning through door 1. This is according to Lean theory classified as *transport loaded*. One exception is when the employees walk to the toilet. However as stated in section 3.2.1.2 walking to the toilet is classified as NNVA since it will be impossible to eliminate the walking to this destination. Hence the walking is in most cases necessary, however the time spent walking to the destinations and number of times walking to the destinations should be reduced.

The table below summarizes the NNVA walking per day performed by employees when leaving the gangway on ship #293 or door 1.

| <i>NNVA walking per one day</i> | <i># Observations</i> | <i>Time spent in total for all the observations</i> |
|----------------------------------|-------------------------|---|
| From door 1 | 224 observations | 1 hour 35 min |
| From gangway on ship #293 | 365 observations | 1 hour 46 min |
| Total | 589 observations | 3 hours 21 min |

Table 12: Summary of total NNVA walking from ship #293 and door 1

NVA and NNVA Walking between all destinations

The structure of the results above is based on the findings in Uglund and Gjerstad (2010)'s master thesis, namely that there were a lot of walking on and off the gangway on ship #293. Further the authors noticed that a lot of the employees who left the ship went to door 1 (15, 9 %) and hence the results is also based on how much time which is spent on NVA and NNVA walking outside the dock after leaving door 1.

However, during the observation study it was noticed that a lot of the walking also was performed from other destinations than the gangway on ship #293 and door 1. There is also a lot of walking traffic between the 17 destinations. Figure 28 below shows which walking patterns that are most used. These are marked with a black line in the figure.

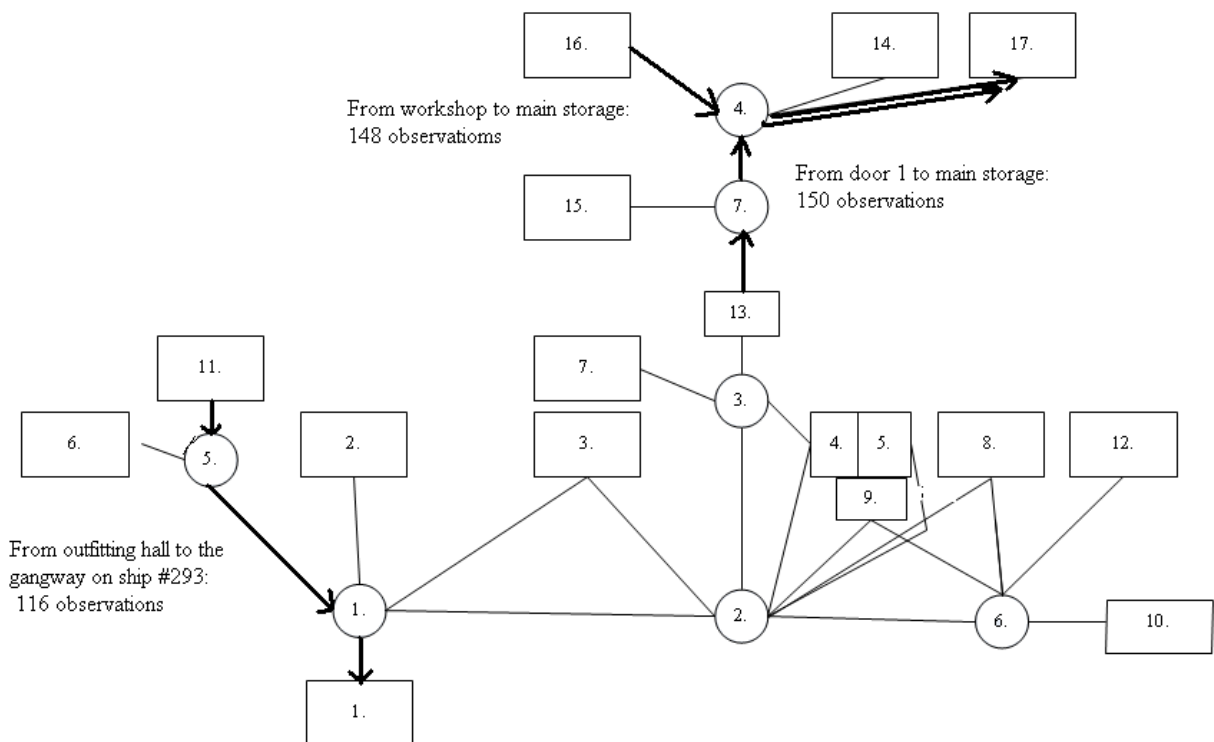


Figure 27: The black line illustrates the walking patterns which are most frequently used during one working day (7.5 hours)

The figure illustrates that 150 employees walk from door 1 to the main storage during one working day. Further, 146 employees walk from the workshop to the main storage, while 116 employees walk from the outfitting hall to the gangway on ship #293 during one working day.

The observation study further revealed that:

- 11 hours and 38 minutes is spent on walking between the destinations inside the dock performed by 1867 employees during one working day.
- 8 hours and 35 minutes is spent on walking between the destinations outside the dock performed by 1035 employees during one working day.
- Hence, a total of 20 hours and 13 minutes is spent on NVA and NNVA walking performed by 2902 employees between the 17 destinations during one working day.

See appendix 8.2 for calculations.

4.1.1.3 Summary

The findings from the observation study answered the first of the two research questions:

“How much time do the employees spend at non-value adding and non-value adding but necessary walking at the shipyard“

Main findings from the results presented above:

NVA walking:

- Approximately 32 minutes is spent on NVA walking during one working day back and forth from door 1 to the cafeteria (based on 46 observations).
- Approximately 54 minutes is spent on NVA walking during one working day back and forth from ship #293 to the coffee machine, soda machine and door 2 (based on 50 observations).
- Hence, approximately 1 hour and 26 minutes is spent on NVA walking back and forth from door 1 and ship #293 during one working day to 4 destinations (based on 96 observations).

NNVA walking:

- Approximately 3 hours and 10 minutes is spent on NNVA walking during one working day back and forth from door 1 to the outfitting hall, workshop and main storage (based on 224 observations).
- Approximately 3 hours and 12 minutes is spent on NNVA walking during one working day back and forth from ship #293 to the women’s toilet, prop stock 2, toilet, men’s toilet, door 1, prop stock, tool storage and the outfitting hall (based on 365 observations).
- Hence, approximately 6 hours and 22 minutes is spent on NNVA walking back and forth from door 1 and ship #293 to 11 destinations during one working day (based on 589 observations).

NVA and NNVA walking:

- A total of 20 hours and 13 minutes is spent on NVA and NNVA walking between the 17 destinations during one working day (based on 2902 observations).

4.1.2 Personal interview/ survey

4.1.2.1 Introduction to the personal interview/ survey results

The personal interview/ survey were used to reveal the root causes of the NVA and NNVA walking. In order to find the root causes, the 5 Why method was used in the conduction of the personal interviews. Thus when a respondent expressed a problem related to walking the authors followed up by asking why. The authors asked why as many times as they thought it was necessary. To find the root cause of the walking is helpful in order to find suggestions for eliminate or reduce the waste. Hence the results from the personal interview/ survey help to answer the last research problem:

What is the root causes of the NVA and NNVA walking and how can Ulstein counteract them?

The results will answer the following propositions:

- Not optimal access to inventory is the main reason for walking.
- Walking to the outfitting hall and the tool storage are the main reasons for leaving the gangway on ship #293 during a working day.
- The destinations which are most often walked to are the outfitting hall and the tool storage.
- The layout in the dock is not optimal.
- Lean /Ulstein Production System is fully implemented in the dock. In addition, the employees know the meaning of the term.
- There is lack of information between foremen and operators.

The main findings from the personal interviews/ survey will be presented together in this chapter, while the rest of the information will be taken further in the discussion part.

4.1.2.2 Findings

Main reason for walking

The results from the personal interview/ survey showed that “not optimal access to inventory” is the main reason why employees spend much time on NVA and NNVA walking. In addition 23 % of the respondents answered that the “other”-category was the main reason for walking. See figure 28.

When the employees answered “other”, they mentioned several times that there was a lot of waiting, and hence walking, due to the crane capacity. The employees also believed that time spent on walking varied with regard to working area; the welder would for instance walk much less than a mechanic. However there does not exist any significant correlation between these two factors to back up the statements.

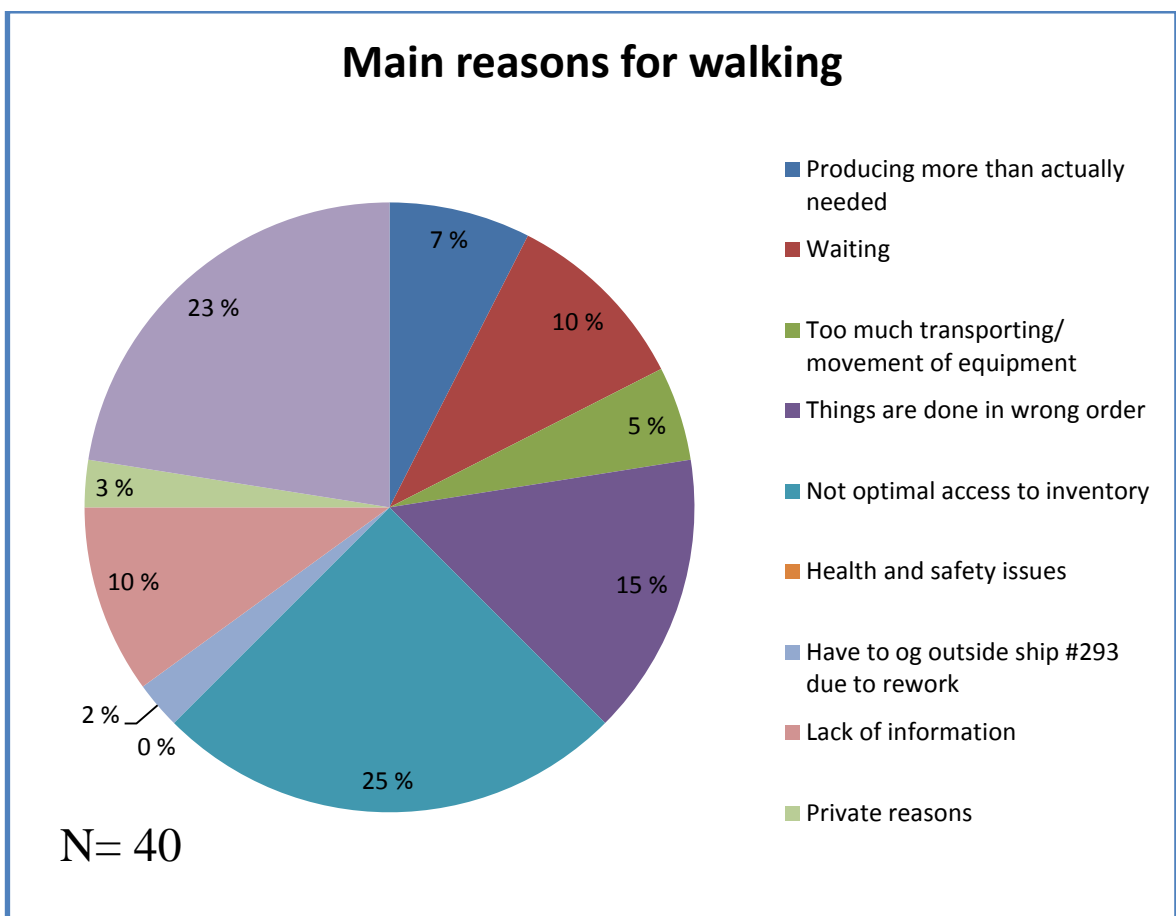


Figure 28: Main reasons for walking

This finding answer the first proposition: “*Not optimal access to inventory is the main reason for walking.*” According to the pie chart above, this statement is correct.

Main findings:

- Not optimal access to inventory is the main reason for walking.

Main reasons for leaving the gangway on ship #293

The statistics showed that the toilet and the tool storage are the two main reasons why employees leave ship #293. Table 13 below shows that there is a significant difference between toilet and foremen’s office (which is the third most used reason). Hence it is 99 % certain that the toilet and the tool storage are the most frequent reasons for leaving the gangway on ship #293.

| Paired Samples Correlations | | | |
|-----------------------------|-------------------------------|----|------|
| | | N | Sig. |
| Pair 1 | # Toilet & # Foremen's office | 40 | .001 |

Table 13: Significant difference between toilet and foremen’s office

The respondents were told to choose three main reasons why employees leave ship #293 during a working day. The results were as follows:

| | Descriptive Statistics | |
|------------------------|------------------------|------|
| | N | Mean |
| # Tool storage | 40 | .70 |
| # Toilet | 40 | .63 |
| # Foremen's office | 40 | .35 |
| # Prop stock | 40 | .30 |
| # Coffe machine | 40 | .28 |
| # Waiting | 40 | .20 |
| # Work shop | 40 | .18 |
| # Storage outside dock | 40 | .18 |
| # Outfitting hall | 40 | .10 |
| # Cafeteria | 40 | .03 |
| # Prop stock 2 | 40 | .03 |
| # Soda machine | 40 | .05 |

Table 14: Reasons for leaving ship #293

Table 14 shows that 70 % of the 40 respondents think that the tool storage is one (out of three) of the main reasons for leaving the gangway on ship #293. Further, 63 % of the 40 respondents answered the toilet as one of the main reasons.

Proposition 2 stated that “*Walking to the outfitting hall and the tool storage are the main reasons for leaving the gangway on ship #293 during a working day*”. This statement is

based on findings from the observation study. The observation study namely showed that most workers walked to the outfitting hall (96 observations during one day) and secondly to the tool storage (75 observations during one day) when leaving ship #293. Hence the results from the personal interview/ survey correspond to a certain degree to the observation study. The result seems to indicate a tendency towards how the workers see their own walking-pattern; the observation study undermines that the tool storage is frequently used. However the outfitting hall is much more used than what the workers tend to believe. Actually, only 10 % of the 40 respondents answered the outfitting hall as one of the main reasons for leaving the gangway on ship #293 while in reality it is the most frequent used destination.

Main findings:

- The personal interview/ survey results show that the toilet and the tool storage are the most frequent reasons for leaving the gangway on ship #293.

Number of times walking to different destinations

The table below shows how many times (in average) an employee walks to the different destinations during one working day.

| Descriptive Statistics | Mean |
|------------------------|------|
| # Outfitting hall | 3,4 |
| # Door 1 | 3,1 |
| # Foremen's office | 3,1 |
| # Tool storage | 3,1 |
| # Toilet | 1,9 |
| # Prop stock | 1,6 |
| # Door 2 | 1,5 |
| # Prop stock 2 | 0,6 |
| # Soda machine | 0,5 |
| # Other | 0,5 |
| # Coffe machine | 0,4 |

Table 15: Number of times walking to different destinations

It is statistically significant that the outfitting hall, door 1, foremen's office and the tool storage are the destinations which are most frequently walked to during one working day (paired sample correlation, sig 0,025). The fact that one person walks in average 3.4 times to the outfitting hall during one working day undermines that a lot of NNVA walking is performed when walking to this destination. This corresponds to the results from the observation study, where most NNVA walking was performed when walking to the outfitting hall and the tool storage.

A restriction is however that the descriptive statistics above do not say anything about which destinations the employees walk from. Hence they can come from any of the destinations inside or outside the dock and not just from the gangway on ship #293. However both the results from the observation study and the survey points in the same direction; namely that the outfitting hall and the tool storage is frequently walked to. Hence the proposition *"The destinations which are most often walked to are the outfitting hall and tool storage"* is correctly based on the result shown in table 15 and the result from the observation study.

Main findings:

- The personal interview/ survey shows that it is statistically significant that the outfitting hall, door 1, foremen's office and the tool storage are the destinations which are most often walked to during one working day. This correspond to:
- The observation shows that the outfitting hall and the tool storage are the destinations which are most frequently walked to from the gangway on ship #293.

Layout in the dock

One reason why the employees spend much time on NVA and NNVA walking could be that the layout not was optimal. However the findings show that 75 % of the 40 respondents believe that the layout in the dock is optimal.

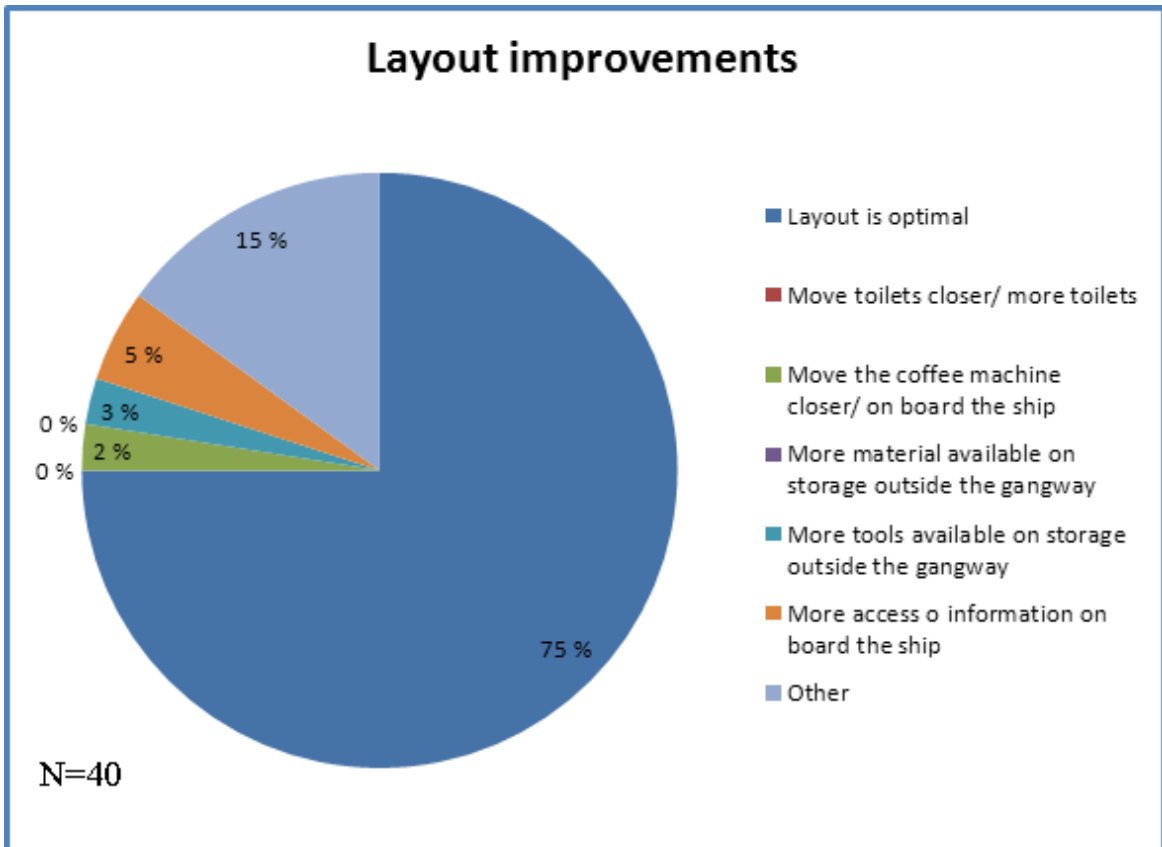


Figure 29: Layout improvements

25 % of the respondents had suggestions on how to improve the layout. 5% of these answered that more access to information on board the ship will be useful to improve the layout and hence reduce the walking time. Possible solutions to this problem are discussed in chapter 5.

Further, 15 % said that they had other suggestions. One of the suggestions was to build a hall outside the dock where the larger modules can be stored. Another suggestion which was frequently mentioned was the crane capacity. One of the respondents said that “*there can be days where I have to wait the whole day to get the crane*”. Another suggestion was a mobile forward storage in the dock. In addition the operators working in the workshop

emphasized that they could reduce their time spent on walking if they had a forward storage located in the workshop.

The majority of the respondents (75%) believe that the layout is optimal. Hence it is potential to say that the proposition: "*The layout in the dock is not optimal*" is incorrect. However this could not be stated as accurate since 25 % had suggestions on how to improve the layout.

Main findings:

- 75 % of the 40 respondents believe that the layout in the dock is optimal.
- Better utilization of crane capacity and better access to information could help improve the layout.

Access to tools and materials

Table 16 and 17 below illustrates that the majority of the respondents believe that the access to tools and materials is OK or good.

| | Access to materials |
|------------------|---------------------|
| | <i>Percent</i> |
| Very bad | 0.0 |
| Bad | 2.5 |
| Ok | 40.0 |
| Good | 45.0 |
| Very good | 12.5 |
| Total | 100.0 |

Table 16: Access to tools

| | Access to tools |
|------------------|-----------------|
| | <i>Percent</i> |
| Very bad | 0.0 |
| Bad | 0.0 |
| Ok | 52.5 |
| Good | 32.5 |
| Very good | 15.0 |
| Total | 100.0 |

Table 17: Access to materials

The questions regarding access to tools and access to materials are significant (sig 0,006). This means that there is a statistically significant association between access to tools and access to materials. Employees who believe the access to tools is good also tend to believe that the access to materials is good. The statistics showed that there is also a significant association between the time spent walking to get tools and time spent walking to get materials.

| | Time spent to get tools |
|-------------------|-------------------------|
| | Percent |
| 10-15 min | 15.0 |
| 20 min | 10.0 |
| 30 min | 12.5 |
| 1 hour | 37.5 |
| 1 hour and 30 min | 10.0 |
| 2 hours | 10.0 |
| 2 hours or more | 5.0 |
| Total | 100.00 |

Table 18: Time spent to get tools

| | Time spent to get materials |
|-------------------|-----------------------------|
| | Percent |
| 10-15 min | 22.5 |
| 20 min | 7.5 |
| 30 min | 12.5 |
| 1 hour | 50.0 |
| 1 hour and 30 min | 7.5 |
| 2 hours | 0.0 |
| 2 hours or more | 0.0 |
| Total | 100.00 |

Table 19: Time spent to get materials

The majority believes that they use 1 hour during a work day to walk to get tools and another 1 hour to walk to get materials. However the observation study showed that it only takes 6 seconds to walk from the gangway on ship #293 to the prop-stock and 12 seconds to the tool storage. This indicates that a lot of time might be used to walk to the main storage outside the dock or the outfitting hall (to pick up tools or materials). In addition it seems like the employees walk several times to the storages each day.

If one employee use 1 hour to walk to get materials and 1 hour to walk to get tools, this is 2 hours out of 7.5 hours during a working day which is spent on *walking*. This does not include the time spent at the destination itself, like for instance finding and picking the tools/ materials.

As shown in the tables above, the majority of the respondents believe that the access to tools and material are ok or good. This indicates that they are satisfied with the layout

regarding access to tools and materials and hence the result back up the proposition “*The layout in the dock is optimal.*” However since so much time is spent on walking to get tools and materials it may indicate that the layout is not optimal after all. If the layout is optimal, why is so much time spent on walking? Other reasons could be that the employees have to walk a lot back and forth from the gangway on ship #293 to the storages due to lack of information or not finding what they are looking for the first time. This will be further discussed in chapter 5.

Main findings:

- The majority of the respondents believe that the access to tools and materials are ok or good.
- There is a statistically significant association between access to tools and access to materials.
- The majority believes that they use 1 hour during a work day to walk to get tools and another 1 hour to walk to get materials. This is 2 hours out of 7.5 hours during a working day which is spent on *walking*.

Lean/ Ulstein Production System

The crosstabulation below shows that 6 of the foremen knew about the term Lean or Ulstein Production System, while 1 had never heard about it. Further, only 9 of the operators knew the term while 19 did not.

| Employee position * Knowledge about Lean/ UPS Crosstabulation | | | | | |
|---|------------------|---------------------------|----|-------------|-------|
| | | Knowledge about Lean/ UPS | | | Total |
| | | Yes | No | Do not know | |
| Employee position | Foreman | 6 | 1 | 0 | 7 |
| | Operator on #293 | 9 | 19 | 5 | 33 |
| Total | | 15 | 20 | 5 | 40 |

Table 20: Crosstabulation of employee position versus knowledge about Lean/UPS

Results from the personal interview/ survey indicated that none of the operators working on ship #293 knew the meaning of Lean or Ulstein Production system. One operator said *“I do not know what Lean is, but it has something to do with the office, and these things should the employees at the office take care of”*. Regarding the foremen, it seemed that only those who were foremen when Ulstein started to introduce and implement Lean knew the meaning of it. The foremen who have knowledge about Lean believed that there was much more focus on it when it was first implemented.

Based on this information and the table above the proposition: *“Lean /Ulstein Production System is fully implemented in the dock. In addition, the employees know the meaning of the term”* is incorrect in terms of knowledge regarding Lean/ Ulstein Production System.

Main findings:

- 6 of the foremen had heard about the term Lean or UPS, while 1 had never heard about it.
- Only 9 of the operators knew the terms while 19 did not.
- None of the operators working on ship #293 knew the meaning of Lean.

Lack of information

The 40 respondents were asked if they often had to walk due to lack of information. Table 21 below shows that 20 respondents answered yes, 14 answered no and 6 answered I do not know. The table also shows that 5 of the 7 foremen answered yes to the question.

The respondents answering yes were asked what they considered as the main reason for the lack of information. The majority of these answered incorrect drawings and lack of drawings as main reasons. Some of the respondents stated that foremen (and sometimes operators) daily walk to the technical department to seek information. Some of the foremen also pointed out the lack of a large printer. One of the foremen stated that *“the lack of a large printer creates unnecessary walking to the technical department and in addition there are huge problems with incorrect drawings.”* In addition it was frequently mentioned that the operators spend a lot of time walking back and forth between the gangway on ship #293 and the foremen’s office.

Thus the proposition *“There is lack of information between foremen and operators”* is correct.

| Employee position * Lack of information Crosstabulation | | | | | |
|---|------------------|---------------------|----|-------------|-------|
| | | Lack of information | | | Total |
| | | Yes | No | Do not know | |
| Employee position | Foreman | 5 | 1 | 1 | 7 |
| | Operator on #293 | 15 | 13 | 5 | 33 |
| Total | | 20 | 14 | 6 | 40 |

Table 21: Crosstabulation of employee position versus lack of information

Main findings:

- 20 of the 40 respondents have to walk due to lack of information.
- 5 of the 7 foremen interviewed have to walk due to lack of information.
- Incorrect drawings are a problem.

4.1.2.3 Summary

The core focus in the personal interviews and the survey was to reveal the root causes of the NVA and NNVA walking. This was done by using the 5 Why method. The results give valuable information in order to answer the last research question:

What are the roots causes of the NVA and NNVA walking and how can Ulstein counteract them?

- Not optimal access to inventory is the main reason for walking.
- The outfitting hall, door 1, foremen's office and the tool storage are the destinations which are most often walked to. Every employee walks in average about 3 times to each these destinations during one working day.
- 75 % of the 40 respondents believe that the layout in the dock is optimal.
- Better utilization of crane capacity would reduce the time spent on NVA and NNVA walking.
- 20 of the 40 respondents have to walk due to lack of information.
- None of the operators and just a few of the foremen knew the meaning of Lean.

5 Discussion

The discussion chapter is divided into two main sections, one for each research question. Each section will use the earlier presented Lean literature and findings from the observation- and the personal interview/ survey study to discuss the research questions.

5.1 *Time spent on NVA and NNVA walking at the shipyard*

This section will answer the first research question:

How much time do the employees working on ship #293 spend at non-value adding and non-value adding but necessary walking at the shipyard?

685 employees left either the gangway on ship #293 or door 1 during 7.5 hours of observation. The observation study revealed that 96 employees spend in total approximately 1 hour and 26 minutes on NVA walking back and forth from door 1 (to the cafeteria) and ship #293 (to the coffee machine, soda machine and door 2) during one working day. Further 589 employees spend in total approximately 6 hours and 22 minutes on NNVA walking back and forth from door 1 (to the workshop, outfitting hall 2 and main storage) and ship #293 (to the outfitting hall, prop stock, foremen's office, men's toilet, women's toilet and prop stock 2) during one working day. This may not seem like high numbers; however there are four important restrictions to remember:

- 1) It is only the time spent *walking* to the different destinations which is included in the observation study, not the time spent at the destination itself.
- 2) The results mainly focus on the walking from the gangway on ship # 293 and from door 1.
- 3) If a person walks to several destinations, only the first destination which is walked to is included in the results and
- 4) During the observation it became clear that very few of the employees actually walk 5 km/h. They mostly walked much slower.

This indicates that the observation results presented is only a small part of all the time spent on walking in the shipyard area. If the focus was on all the walking performed between the destinations, the number of observations and time used on NVA and NNVA walking would be much higher. As the results in chapter 4.1.1 show, 2902 employees spent as much as 20 hours on NVA and NNVA walking between the 17 destinations during one working day (7.5 hours). This indicates that there is a lot of walking traffic inside the dock. The 17 destinations are shown in figure 30, where the blue line represents NNVA walking and the green line represents NVA walking.

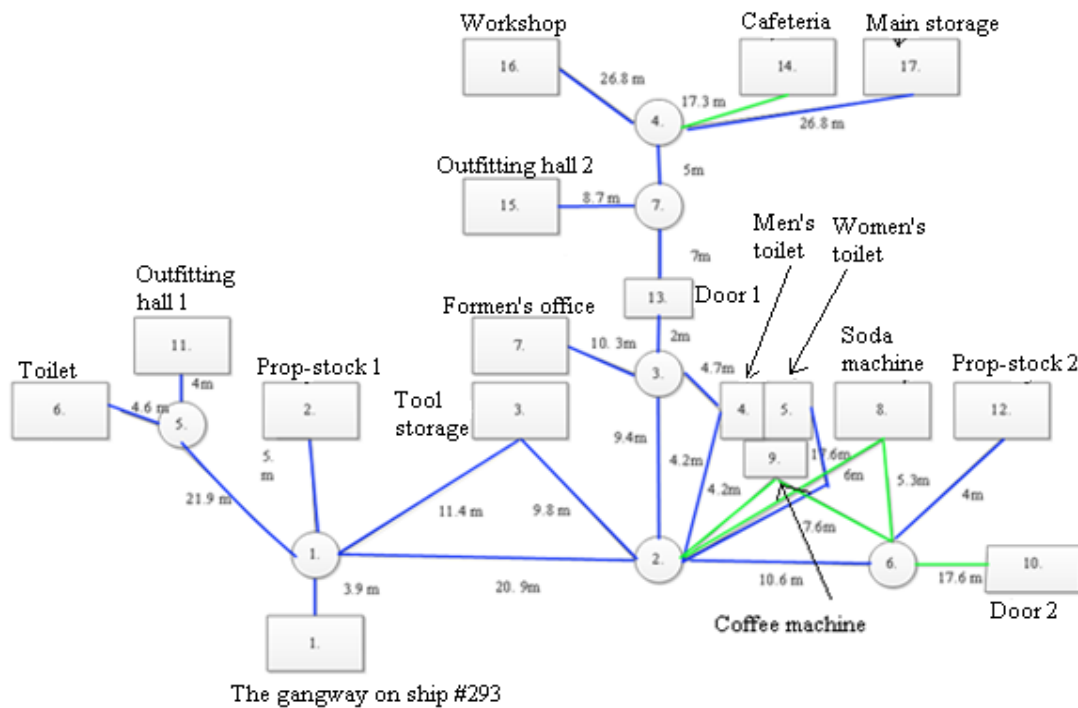


Figure 30: The 17 destinations included in the observation study

The main storage is one of the destinations which employees spend much time walking to; 150 employees spend in total 2 hours and 10 minutes walking between door 1 (the main door in the dock) and the main storage during one working day (7.5 hours). Further the results showed that each employee in average spend 2 hours per day in walking to get tools and materials.

One of the principles in Lean Construction and Lean Thinking is to reduce the share of non-value adding activities. Hence companies should eliminate the time spent at NVA walking and minimize the time spent at NNVA walking. In order to be able to do this, we need to know why there is so much walking. Hence, what is the waste a result of?

Summary:

- A total of 96 employees spend approximately 1 hour and 26 minutes on NVA walking back and forth from door 1 and ship #293 to 4 destinations during one working day.
- A total of 589 employees spend approximately 6 hours and 22 minutes on NNVA walking back and forth from door 1 and ship #293 to 11 destinations during one working day.
- Approximately 20 hours is spent on NVA and NNVA walking between the 17 destinations one working day. This is performed by 2902 employees.

5.2 How can Ulstein reduce/eliminate the NVA and NNVA walking?

This section answers the master thesis' second research question:

What are the roots causes of the NVA and NNVA walking and how can Ulstein counteract them?

As stated above, there is much NVA and NNVA walking in the shipyard at Ulstein. According to Lean theory this is characterized as waste. In order to go deeper into the root causes, the “5 Why method” was used during the personal interviews. Thus the respondents were asked follow-up questions to the initial replies, although not necessarily by asking why as much as five times; this depended on the answers.

The results from the root cause analysis revealed that the main reasons for NVA and NNVA walking are related to:

- Problems in the information flow (Flow Kaizen)
- Problems in the material flow (Flow Kaizen) and
- Problems in the people and process flow (Process Kaizen)

5.2.1 Problems related to information flow

Are the NVA and NNVA walking a result of problems related to information flow? To some degree the answer is yes. The personal interview/ survey results showed that 20 of the 40 respondents often have to walk due to information problems. The time and resources spent on trying to identify the information elements that is needed in the production flow can be characterized as unnecessary/ excess motion waste or waiting.

According to the results, the main problems regarding information are related to:

- Missing/wrong information between the foremen and the technical department,
- Missing/wrong information between the foremen and the operators and
- Missing/wrong information between from the main storage to the operators.

Missing/ wrong information between the foremen and the technical department

The observation result showed that there were 45 employees walking from the foremen's office to door 1 during 7.5 hours. This indicates that the foremen frequently have to walk to the technical department to seek information. The main reason why they have to walk to the technical department is to get new drawings due to missing/wrong information. In addition, the foremen often have to walk to the technical department to find a large copy machine.

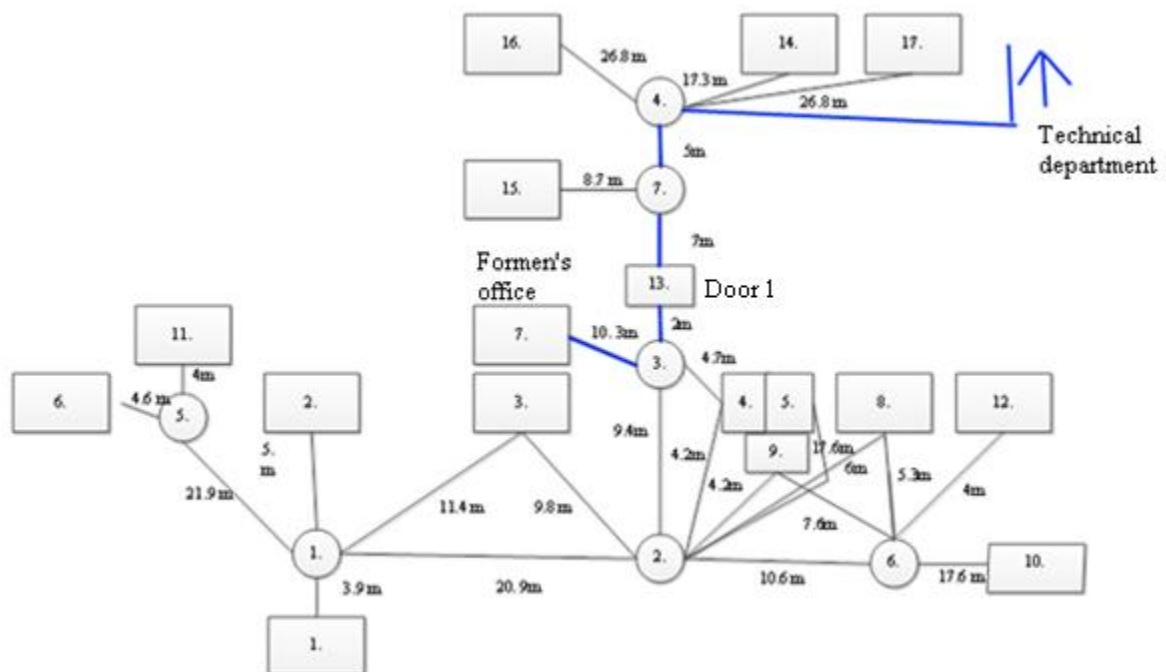


Figure 31: Distance between foremen's office and the technical department.

When the foremen are walking to the technical department, they are mostly walking from the foremen's office and through door 1. The technical department is located in 2nd and 3rd floor in the administration building and was not one of the destinations included in the observation study. The distance from door 1 to the technical department is at least 100 meters (Volle 2012).

In the personal interview/ survey it was frequently mentioned that employees working in the technical department did not have optimal knowledge regarding how the operators in the production work. Thus the foremen and operators believed that this could be one of the

reasons why there were so many incorrect drawings, resulting in time used on walking to the technical department. It was a mentality between the respondents that there is “our” department and “their” department. In Lean Production the employees are encouraged to identify themselves with the company rather than the department. Ulstein would therefore benefit from using the Gemba tool. If the employees at the technical department spend time at the plant floor they will gain a better understanding of the production process. Hence they can make better and more accurate drawings. This will be according to Lean Thinking where the employees should work to the company as a whole instead of sub optimization.

There are some possible solutions for Ulstein in order to reduce the time spent on walking back and forth between the foremen’s office and the technical department. Firstly, there should be a large copy machine located near the foremen’s office. The copy machine could for instance be placed in the meeting room at the end of the hallway.

In addition new drawings could be sent by a safe intranet e-mail to the foremen. The foremen will directly receive the drawings when they are finished. Further they will have the possibility to directly pass them on to their operators. This will be done by adding the new drawings on a notice board outside ship #293. The technical department will also gain from this by having fewer interruptions. Another possibility could be to use new technological solutions. If each foreman had a smart device (for instance an ipad) the drawings could be directly updated on this. Whenever there are small corrections, the smart device will automatically be updated and give a notification to the foremen whenever there are changes or updates. One restriction by using this solution is that the drawings normally are size A0. However it should be possible to split the drawings so that the operators only got information regarding the drawings for “their area”.

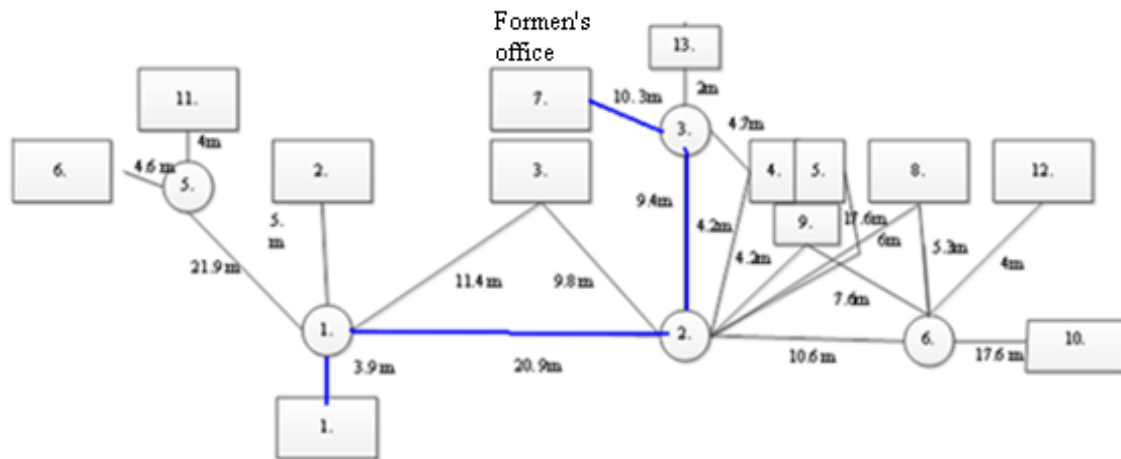
Another solution is to use the Last Planner tool in the technical department. According to Ugland and Gjerstad (2010) many drafts are developed months in advance of the ship hulls arrival (Ugland and Gjerstad 2010). Hence the drawings often need to be altered if change orders come at a later time. Therefore the Last Planner tool can be suitable to use also in this department. This way the drawings do not have to be developed before they are needed.

By doing these changes the time used on NVA and NNVA walking will decrease and hence the proportion of waste will be reduced according to Lean theory. The best solution

for Ulstein would probably be to give smart devices to each foreman. This is a rather cheap solution and it is easy to implement. The foremen will probably need some training in using it; however it is a very easy tool so this would most likely not be a problem. It is not necessary to have good data knowledge in order to use a smart device. In addition, the smart device could be used to further communicate the drawings to the operators. This is discussed in the next section.

Missing/ wrong information between the foremen and the operators

According to the results from the personal interview/ survey an employee walks in average 3.1 times to the foremen's office during one working day. It is also important to remember that some of the foremen rarely are in their offices. If the operators walk to the foremen's office they risk having to wait for them to turn up. Most of the operators walk from ship #293 when they are walking to the foremen's office. The distance is shown in table 32.



The gangway on ship #293

Figure 32: The blue line represents NNVA walking from ship #293 to the foremen's office.

There are two possible solutions to reduce the time spent on walking to the foremen's office. One solution could be to have a "in or out of the office" system. There could be a green light bulb outside each of the foremen's offices towards the ship in the dock. Whenever the foremen left the office they could turn the light of, indicating that they no longer are in the office. This way the operators could easily see if the foremen are in the office or not; if the green light is on, the foreman is in the office. This would reduce the time spent at NNVA walking from the ship to the foremen's offices.

Another solution could be to also give smart devices to the chief operators which are responsible for certain working areas on ship #293. When using the 5 Why method in the personal interview, one respondent stated that:

"The access to information regarding drawings should be improved dramatically. The information on the board outside the ship is not updated often enough, and this leads to a lot of walking to the foremen's office."

Another respondent said that they often do not get the correct information regarding drawings in time. A smart device could reduce this problem since the information would be automatically updated. If each chief operator had this tool, the operators could ask their chief operator, or base as they are called, regarding changes. In addition, there should be some smart devices placed at certain areas inside the ship and in the outfitting hall. Hence the operators can look for updated information themselves. Much of the time spent on walking to the foremen's office would be reduced by using this solution.

Missing/ wrong information from the main storage to the operators

The results further showed that there is often a lack of information between employees working at the storage and the operators. One of the respondents stated in the personal interview that:

“We spend a lot of time walking back and forth from the main storage because the tools or materials we are looking for are not there. Then we have to search for the tools/materials in the other storages.”

In addition the results showed that each employee use in average 2 hours each day on walking to get tools and materials. The distance between the gangway on ship #293 and the main storage is shown in figure 33.

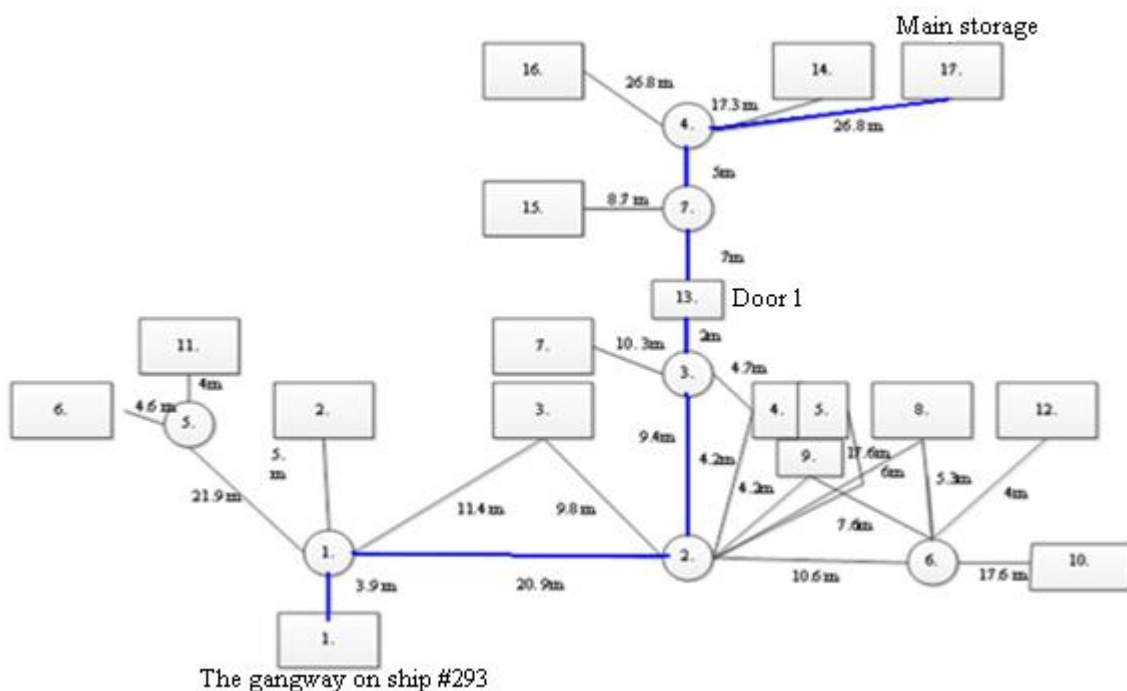


Figure 33: The blue line shows the NNVA walking (in distance) between gangway on ship #293 and the main storage outside the dock

If Ulstein were able to make an updated and reliable information flow from the main storage to the operators it would reduce the time spent at NNVA walking from the gangway on ship #293 to the main storage. As much as 150 operators walk from door 1 to the main storage each day. This means that they spend in total 2 hour and 20 min on

walking back and forth between door 1 and the main storage. If all the 150 employees walk all the way from the gangway on ship #293 they would spend in total 4 hours and 20 min on walking back and forth from ship #293 to the main storage during one working day.

If the chief operators were given smart devices in order to communicate better with the foremen and the technical department, this could also be used to improve the information flow between the main storage and the operators. A smart device could give the operators information about status regarding tools/materials on the main storage, but also status on inventory level at the tool storage and the prop stock (marked 2 and 3 in figure 34). Hence the operators will know what storage the tool/material they need are placed at. This way much of the time spent walking to search for tools/materials can be reduced. In addition, the operators will be able to see the inventory levels of the specific tool/material on the smart device. As mentioned above, the smart devices should be located in different areas inside the ship and in the outfitting hall. Thus the operators will have easy access to them.

When operators pick up tools/materials at the storage they should scan it on a smart device or a computer, which automatically updates the information. If there is no more left of a specific tool/material, the operators could place an automatic order from the smart device. Further this could be marked as an urgent order if they need the tool/material quickly. It should also be possible to reserve tools/materials from the smart devices.

Information regarding status on inventory level at the storages should also be available to the foremen and the technical department. One of the respondents stated in the personal interview that:

“We often get drawings which require that we use for instance steel, but then there is not the correct amount of the steel at the storage. This is extremely annoying and it should be possible to do something about this problem. The technical department should make sure that the materials needed are in the storage before handing out drawings”.

Hence, if both the foremen, drawing department and operators where given information about the inventory level at the different storages this would improve the information flow and reduce the time spent at NVA and NNVA walking.

Summary

According to the results from the personal interview/ survey and the observation study, problems related to information flow are a reason why employees have to perform NVA and NNVA walking. The results show that there are especially three places where lack of information/ missing information creates NVA or NNVA walking. These are; missing/wrong information between 1) the foremen and the drawing department, 2) the foremen and the operators and 3) the main storage and the operators. The table below sums up where the information problems occur, why the problem create waste and possible solutions and tools.

| <i>Problem</i> | <i>Why does the problem create waste</i> | <i>Solutions</i> | <i>Tool</i> |
|--|--|-----------------------------|---------------------|
| <i>Missing/wrong information between the foremen and the drawing department:</i> -Lack of accurate drawings -Lack of copy machine | The foremen spend much time walking back and forth to the technical department | Smart devices, copy machine | Last Planner, Gemba |
| <i>Missing/wrong information between the foremen and the operators:</i> -Lack of updated drawings -Lack of available foremen | Operators spend much time walking back and forth to the foremen's office | Smart devices, light bulb, | |
| <i>Missing/wrong information between the main storage and the operators:</i> -Lack of a system which gives information regarding status on the storages | Operators spend much time walking back and forth to the main storage | Smart devices | |

Table 22: Problems related to information flow

5.2.2 Problems related to material flow

The results from the personal interview/ survey and observation study showed that problems related to storages and crane capacity disturbs the material flow and hence creates NVA and NNVA walking.

Storages

According to the master thesis written by Ugland and Gjerstad (2010), the head of planning at Ulstein estimated that workers on average spent about one hour each working day walking to get parts or equipment they need (Ugland and Gjerstad 2010). However as mentioned in section 4.1.2.2, the results showed that each employee spends on average 2 hours per working day to walk to get tools and materials. Why is so much NVA and NNVA walking spent on this?

As mentioned, the 5 why method was used during the personal interview, hence the respondents were asked why they believe so much time was spent on walking to get tools and materials. Not finding what they are looking for was the main reason. One respondent said that:

“We often have to look for tools and materials. A specific material is supposed to be located in the main storage but all of a sudden it is not there. It happens a lot that the right tool or material is not ordered or that other employees have used it up. Hence much time is spent on walking between the storages to look for materials/tools or information regarding tools or materials.”

Even though the results from the observation study showed that much less time than 2 hours is spent per employee on walking to get tools or materials, the results from the personal interviews/ survey indicates that there is a lot of walking between the destinations before returning to the destination they came from. This was also noticed while performing the observation study.

One suggestion from the personal interview/ survey regarding how to reduce the time spent on walking to search for tools and materials was to have a mobile forward storage.

Especially the operators in the workshop stated that they could reduce their time spent on walking dramatically if they had a forward storage located in the workshop. According to the observation results, 148 observations are walking from the workshop to the main storage during one working day (7.5 hours). If the 148 employees walk directly back to the workshop, a total time of 3 hours and 10 minutes is spent each day on walking back and forth between the workshop and the main storage. In addition they often walk to the storages located inside the dock. Thus a great deal of this walking could be reduced with a forward storage located in the workshop.

Earlier Ulstein had a container-storage outside the dock; however they removed it due to the fact that employees moved it around and made a mess in it. Many employees indicated that it would be a good solution to have this container back again. As the situation is today, the operators have to walk a considerable distance to get the tools or materials they need, especially if they are not finding what they are looking for. This is disturbing the material flow. The distance between the gangway on ship #293, the workshop and the storages is shown in figure 34. As the figure shows, there is a long distance to walk if the operators have to walk often between the different storages.

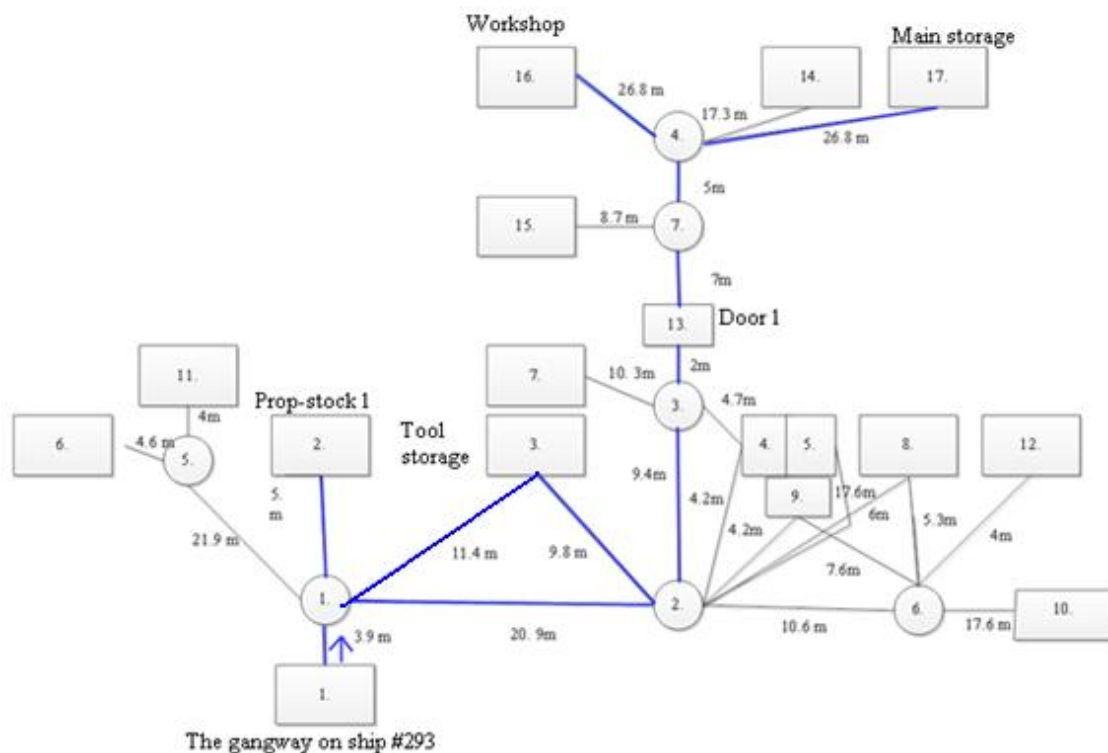


Figure 34: Distance between ship #293 and the storages

In order to make the container storage outside the dock a proper solution for both the employees and the people responsible for the container, it should have a permanent place just outside the dock. Further the 5 S tool (Shine) should be applicable also here. In addition, a mobile forward storage should be placed in the workshop, where tools and small parts should be located. There should be strict rules regarding picking up and delivering tools/materials in order to keep the mobile forward storage and the container tidy. This solution would improve the material flow by making the tools and materials more available to the operators and hence reduce the time spent on NVA and NNVA walking.

Results from the personal interview/ survey showed that employees believe that not optimal access to inventory is the main reason for walking. The 5 S tool – set in order (Seiton) could be used in order to cope with this problem. Seiton focuses on efficient and effective storage methods. Further it focuses on that there should be a place for everything and everything in its place. Ulstein should have a robust system in order to ensure that the materials are replaced once they have been used. Another important principle of Seition is motion economy, which focuses on the removal of human motion waste. Hence implementing Seiton will ensure that all movement is absolutely necessary to perform a given operation. In addition, Seition eliminates searching since every item has a clearly identified location. A good storage method will improve the material flow and hence reduce the time spent on searching and walking.

Crane capacity

When performing the 5 Why method during the personal interviews it was frequently mentioned that the crane capacity created unnecessary walking. According to the respondents there is much “walking around” in the dock while waiting for the crane. Many of the respondents believed that the unnecessary walking would be reduced dramatically if the utilization of the crane was planned better. The lack of optimal crane utilization is disturbing the material flow since the equipment is not transported on board the ship at the right time. Waiting is one of the seven wastes, and according to the theory one way to reduce waiting dramatically is to link processes together so that one feeds directly into the next. In order to make this possible, the crane should be available when needed. Employees should be able to reserve the crane to a certain time of the day. Hence accurate daily planning is necessary and Last Planner is a suitable tool to use.

Summary

According to the results from the personal interview/ survey and the observation study, problems related to material flow are a reason why employees have to perform NVA and NNVA walking. The table below shows where the main problems occur, why the problem create waste and possible solutions/tools.

| <i>Problem</i> | <i>Why does the problem create waste</i> | <i>Solutions</i> | <i>Tool</i> |
|---|--|---|--------------|
| Storages: -Lack of an optimal storage method | Much time spent on walking back and forth between the storages | Mobile forward storage in the workshop, container-storage outside the dock, smart devices | 5 S |
| Crane capacity: -Lack of optimal crane utilization | Much time spent on waiting for the crane | Accurate daily planning, employees should be able to reserve the crane | Last Planner |

Table 23: Problems related to material flow

5.2.3 Problems related to people and process flow

This section discusses problems related to people and process flow. The problems were discovered through the observation study and the personal interview/ survey. The main problems were regarding Lean knowledge and low job motivation. In addition, crowded and dirty men toilets also were a problem.

Toilets

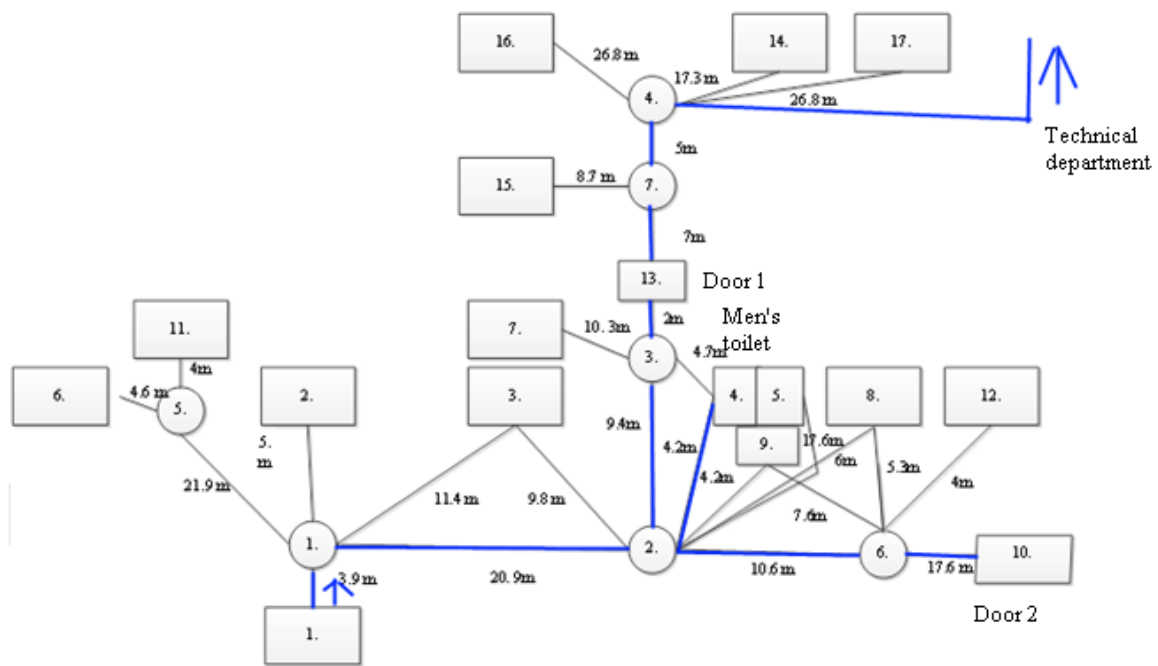
The results from the observation study showed that the women's toilet is one of the least frequent destinations which employees walk to from ship #293. A natural explanation why the women toilet is rarely used is because there are very few women working on ship #293. Actually, during the observation study the authors only noticed 3 women working on ship #293. As a result, the women's toilet is clean and there is never queue. The men's toilet on the other hand is frequently used since there are mainly men working on ship #293. Hence it is often crowded and the toilet is dirty compared to the women's toilet. As a result, some of the men employees use the toilet located in the administration building or the toilet in the cafeteria. This is a factor which leads to unnecessary walking and hence *excess motion*. One way to cope with this can be to have more men toilets located outside the ship in the dock. However this is probably not the best solution due to restrictions in the dock.

A better solution is to clean the toilets more often so it feels and looks hygienic. The 5 S tool (Shine) consist of keeping the workplace clean. To implement cleanliness as a daily five minute cleaning exercise is suitable, not just on the ship but also in the surrounding areas like the toilets. Ulstein already has cleaning-personnel to clean the toilets; however this should be done more often. This way, the time spent on unnecessary walking to the toilets in the administration building or the cafeteria would most likely be reduced.

It was also mentioned in the personal interview/ survey that there should be urinals placed in the area outside door 2. Hence operators working on the ship outside the dock could use these. In addition, the operators working on the ship in the dock could use the urinals outside when the toilets inside is crowded. Even though this leads to extra walking, it will be a shorter distance than walking to the administration building. This is shown in figure 35 below.

Amsterdam airport faced the same problem as Ulstein: their urinals were dirty. An economist who worked for Schiphol International Airport in Amsterdam came up with an idea that resulted in 80 percent spillage decline. The idea was to put a black house fly onto the bowls of the airport urinals, just left to the drain. It turned out that if the men got a target, they automatically aimed on it (Thaler and Sunstein 2008). Ulstein should test this solution. This could result in more hygienic toilets which could reduce the walking to other toilets in the shipyard.

When the operators walk from ship #293 and to the administration building, they walk through door 1 and further at least 100 meters. Hence urinals outside door 2 will be closer to the ship inside the dock than the administration building. It will not eliminate all the walking to the administration building; however it will most likely reduce some of it.



The gangway on ship #293

Figure 35: Distance from ship #293 to the men's toilet

Lean knowledge

Before conducting the personal interview/ survey the authors assumed that the operators and the foremen would know the term Lean or Ulstein Production System as it is called at Ulstein. This assumption was based on Lean Thinking and Kaizen, which states that continuous improvement involves everyone in the organization. The personal interview/ survey results showed that none of the operators working on ship #293 and just a few of the foremen knew the meaning of Lean. Can the waste be a result of this? Is the reason for the NVA and NNVA walking that the operators and the foremen do not know what Lean is and hence is not able to follow Lean principles?

Some of the foremen mentioned during the interview that they had not noticed any change in the production since Lean was implemented. One of the foremen stated that:

“After Lean was implemented the decisions are claimed to be on a lower level in the organization. However the organization has turned out to be more hieratical. There are too many people a foreman has to deal with and too many systems. It has become overly complex”.

According to Runar Toftesund, which is manager at the planning department in Ulstein and a board member in the Lean Construction Forum, Ulstein’s strategy is to organize the shipyard so that the employees automatically perform Lean activities. He states that the employees do not need to know the term itself as long as Ulstein manages to implement Lean tools which make the operators and the foremen automatically use Lean in their work. One of the reasons for this is that a large proportion of the operators are hired labor (Toftesund 2012). Dr. Glenn Ballard also agrees that the operators do not need to know the term and the meaning of it. As long as the layout and tasks is structured in a way which makes the employees automatically be Lean, they do not need to know the theory. It is enough that the employees know that the tasks and layout are structured in a certain way in order to be more efficient and to make the working day consist of less waste. Hence as long as both the foremen and operators follow Lean methods automatically in their daily work, it is not important that they know the theoretical meaning (Ballard 2012).

According to Kaizen theory the different employee positions have different Kaizen involvement. The foremen are categorized as supervisors while the operators are categorized as workers. From the personal interview/ survey it became clear that some of the Kaizen tasks were not optimally applied by the respondents. For instance, the operators do not have a proper suggestion system. This is despite of the fact that several of the operators have ideas on how to improve the process. One respondent said:

“I have a suggestion on how to weld the doors on the ship, and I have tried to pass this information on to the management several times. However it seems like the information stops somewhere before it reaches the right person. This annoys me, because if the welding of doors were done in another way, a lot of time would be saved.”

This indicates that Ulstein should focus on implementing a proper suggestion system. After all, it is the employees working in the shipbuilding production who knows the process best. If they find solutions which can improve the efficiency it is also possible that it would reduce the time spent on NVA and NNVA walking.

The fact that Ulstein do not have a proper suggestion system can be characterized as *underutilization of employees*. Ulstein does not fully capitalize on the employees' creativity. Since Ulstein do not have a proper suggestion system it also means that they do not fully take advantage of peoples thoughts (wasting good ideas). This can be classified as *behavioral waste*. It is however important to mention that not necessarily all suggestions gives improvement. Using the PDCA-cycle will help to see if the suggestion is an improvement or not.

A proper suggestion system for Ulstein could be to create an e-mail address where the operators could send suggestions. The operators should have access to smart devices that are located in some selected areas in the shipyard, as earlier mentioned, or by borrowing one from the foremen or from the chief operators. The smart devices will give the operators access to an e-mail account. The operators should have the opportunity to select if they want to be anonymous or not. If the operators select to use their name they should be given direct feedback after the suggestion have been discussed and elaborated. If the operators chose to be anonymous the answer should be presented in Ulstein's internal

newspaper, Shipbuilding News. Feedback is important for gaining the operators trust to the suggestion system.

This system would help Ulstein to focus on Kaizen, since employees should continually be seeking ways to improve their work performance. One person should be responsible for the e-mail address, and bringing the suggestions further to the right people. The PDCA-cycle is a helpful tool when elaborate the suggestion. It is also important to remember that the improvements must be standardized. According to Imai (1986) there can be no improvement without any standardization. It is only when following work tasks that are conducted in line with the new standard an organization could say that there has been a lasting improvement. Standardization is seen as a way to spread the benefits of improvement through the organization (Imai 1986).

Ballard and Toftesund have a good argument when they said that the employees do not need to know what Lean is as long as they use it in their daily work. However it seems that the foremen and operators lack some of the Kaizen focus which has to be in place to become a learning organization on its road to excellence. Without a proper suggestion system and if the improvements are not standardized, Ulstein will continue with underutilization of employees and behavioral waste.

Job motivation

It is important that an organization focus on having a healthy working environment. Ulstein should have healthy jobs for the employees and a workplace that contributes to an individual's physical, psychological and social well-being. The benefits this gives affect the whole organization through higher job satisfaction, lower sickness absence and turnover, improved job performance, lower accidents rates, reduced health benefit and worker compensation costs (Lowe 2004).

In the conduction of the personal interview/ survey the problem with low job motivation was emphasized by some of the respondents. Some of the problems that were mentioned were similar to the ones Uglund and Gjerstad (2010) found in their master thesis (Uglund and Gjerstad 2010). It was claimed that many of the employees who had worked at Ulstein for several years showed poor job motivation. It was stated that when they were sent to the storage to find something, they could use the whole day. Thus it is likely that there will be performed NVA walking around in the shipyard as a result of low job motivation.

The personal interview/ survey also revealed that there was a problem with employees walking to get coffee and at the same time taking a break without authorization. This corresponded with the perception the authors were left with after conducting the observation study. The coffee machine is placed just outside the ship in the dock; hence not much time is used on walking back and forth from the gangway. However during the observation study it was noticed that most of the employees did not return directly to ship #293 but they walked around in the area and talked to people after getting their coffee. This will be time spent on NVA walking which is not included in the observation results. In addition, during specific times of the day there was a lot of queue. For instance, at 9.00 each day there were approximately 11-15 workers in line in front of the coffee machine. However many employees might go to the coffee machine at this time because they know that there will be queue and hence they can talk to each other and it becomes a social event during the working day. In order to reduce this time spent on NVA walking, the employees should mainly have coffee during lunch. Further, there should be stricter rules regarding how much time employees can use when getting coffee. The foremen should according to the Kaizen tasks in table 1; introduce the discipline and thus stricter rules.

The results further showed that almost 50 employees walked from door 1 to the cafeteria each day. It is important to notice that this was observations made except from lunch-time and when arriving/leaving work. Walking to the cafeteria besides these times during the day is characterized as NVA. As mentioned there is also a toilet and a wardrobe located in the same building as the cafeteria. This means that some of the time spent walking to the cafeteria can be time spent walking to the toilet or to the wardrobe located in the same area as the cafeteria. However, the fact that so many employees walk to this destination before and after lunch can be an indication of low job motivation.

The authors discovered during the observation study that several workers walked together to the storage where they only fetched a small item. The items were often so small that they could be fetched by one operator alone. It seemed from the author's perspective that they walked for the social purpose, and not for fetching equipment. This can be an indication of low job motivation. This type of walking could be characterized as *unnecessary/ excess motion* or *behavioral waste*. However it could of course occur that the tools or materials were not available in the storage, and thus the operators left the storage without anything. Another reason could be that the tools or materials were so small that the operators carried them in their pockets. The same phenomena was noticed when operators walked to the outfitting hall to pick up pipes. Three or four operators were observed walking to the outfitting hall, but only one of them carried anything when they left the outfitting hall. As much as 96 employees walked from ship #293 to the outfitting hall during one working day.

In Lean Thinking the social entity is important and cannot be ignored by the management. The employees can give inputs that could improve the production process and the social network is an important source of coordination and commitment. Goals and incentives are formulated and work tasks are organized to support the social interaction in the organization. The workers in a Lean organization are working for the common good for organization, and not for themselves or their department. The employees are encouraged to identify themselves with the company, because this will make the employee work for the company's goals. Each employee is however responsible for reducing their health threats, but Ulstein can support this through a range of health promotion programs (Lowe, 2004).

Thus Ulstein should focus on health activities that could reduce the NVA walking. Developing a social environment through activities outside the work is one option. If the employees are social in the evenings, they do not need to be it through the working day. In addition Ulstein has several social happenings in the work time through the year, such as one yearly BBQ lunch that everyone can participate in. Ulstein has put job motivation on the daily agenda, and is a part of a large project with the title safety and well-being.¹ This project has developed 38 actions for a better social environment. These are for instance a buddy system, football cups, training offers etc. If Ulstein continues to focus on social activities offers, they will work in accordance with the Lean Thinking on social entity.

¹ A project between Kleven Verft AS, Myklebust Verft AS and Ulstein Verft AS, started in 2010. Sponsered by Hovedorganisasjonens Fellestiltak.

Summary

The table below sums up the main problems regarding people and process flow that creates NVA and NNVA walking. Further the table shows why the problems create waste and possible solutions for Ulstein.

| <i>Problem</i> | <i>Why does the problem create waste</i> | <i>Solutions</i> | <i>Tool</i> |
|--|--|---|-------------|
| Men's toilet: -Crowded and dirty | Unnecessary walking to the toilets in the administration building. | More frequent cleaning, urinal outside door 2 | 5 S |
| Lean knowledge: -Lack of a proper suggestion system | Underutilization of employees, behavioral waste. | Suggestion system | |
| Low job motivation: -Lack of social activities | Unnecessary/ excess motion, behavioral waste. | Health activities | |

Table 24: Problems regarding people and process flow

6 Conclusions

This chapter presents the master thesis conclusions based on the findings in the analysis and discussion chapters. The chapter further presents suggestions for future research.

The master thesis is as mentioned a part of *Lean Shipbuilding project II* at Ulstein. The goal of the project is to increase the productivity and lower the costs connected to production. Thus the master thesis focus was to find solutions on how to reduce the time spent on non-value adding activities (NVA) and non-value added but necessary activities (NNVA) activities, which is waste according to Lean theory. Ugland and Gjerstad's (2010) master thesis revealed that 73 % of the employees work time in the shipyard is spent on NVA and NNVA activities. The aim of this master thesis was to find solutions on how to reduce the share of NVA and NNVA activities by focusing on *walking* in the shipyard at Ulstein and by using Lean theory as theoretical framework.

The master thesis's goal has been to answer two research questions. The objective of the first research question was to reveal how much time which is spent on NVA and NNVA walking in the shipyard. Further the objective of the second research question was to find the root causes of the NVA and NNVA walking, and in addition find solutions on how Ulstein could counteract them. An observation study and a personal interview/ survey was conducted in order to answer the research questions.

The findings showed that 2902 employees spent in total 20 hours on NVA and NNVA walking between 17 destinations in the shipyard during one working day. The main storage is one of the destinations which employees spend much time walking to; 150 employees spend in total 2 hours and 10 minutes walking between door 1 (the main door in the dock) and the main storage during one working day (7.5 hours). Further the results showed that each employee in average spend 2 hours per day on walking to get tools and materials.

The 5 Why method was used during the personal interviews in order to reveal the root causes related to NVA and NNVA walking. The root causes is divided into three main parts; information flow problems, material flow problems and problems related to people and process flow. The Cause & Effect diagram is helpful when presenting the root causes to the NVA and NNVA walking:

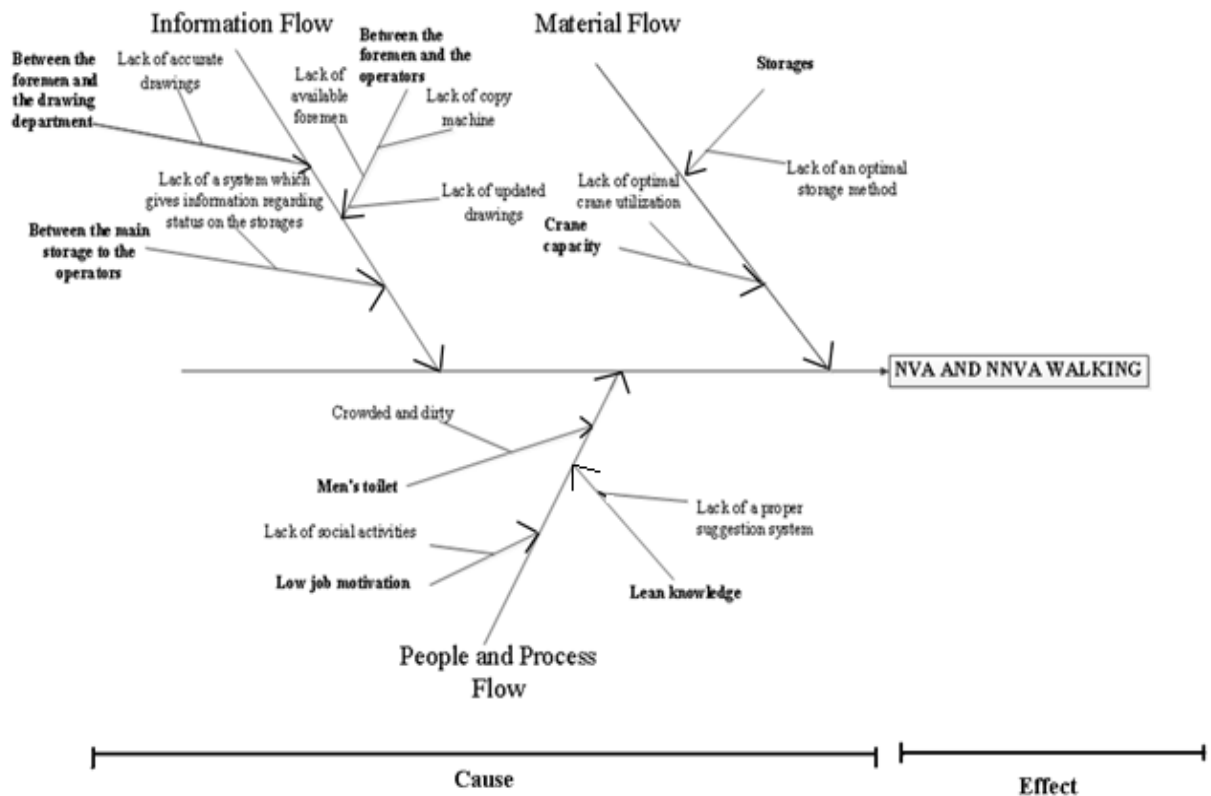


Figure 36: Cause & Effect diagram

The master thesis has further provided solutions to the root causes represented in the Cause & Effect diagram. The solutions are many²; however there is one solution which is common for the majority of the root causes: namely that Ulstein would benefit from using smart devices in the production and in the communication between foremen, operators, technical department and storages. Further Ulstein should continue to focus on Kaizen by implementing a proper suggestion system for the operators. In addition, the Lean tools 5 S, Last Planner and Gemba should be emphasized in order to solve the problems which lead

² See tables 22, 23 and 24 in chapter 5.2.

to NVA and NNVA walking and further to ensure continuous focus on Lean principles and tools.

The master thesis has further showed that an observation study and the transportation method could be a helpful tool in identifying walking patterns at a shipyard. In addition, a personal interview/ survey is suitable to use when identifying root causes regarding NVA and NNVA walking at a shipyard.

6.1 *Further research*

This chapter presents an overview of further research that can be carried out in order to help Ulstein to reduce the NVA and NNVA walking at the shipyard.

Workshop

In order to go deeper into the root causes behind the NVA and NNVA walking, a workshop could be performed. The workshop could include approximately five groups with at least four employees from each employee position. Hence there could for instance be a welder group, a carpenter group etc. Further each group should discuss and present what they believe are the root causes behind the NVA and NNVA walking at the shipyard.

Mapping the information flow

The results from the personal interview/ survey revealed that missing/ wrong information between the foremen, operators, technical department and the storages created a lot of NVA and NVNA walking. Hence Ulstein would benefit from performing a value-stream mapping of the information flow. This will give a deeper understanding of the problems related to information.

Crane utilization

The results from the personal interview/ survey showed that almost all respondents believed that the crane capacity created NVA and NNVA walking. Many of the respondents believed that the unnecessary walking would be reduced dramatically if the utilization of the crane was planned better. This is also in accordance to the findings in Ugland and Gjerstad (2010)'s master thesis. Hence a research regarding how to optimize the utilization of the cranes should be performed.

Follow up of this research

The master thesis has focused on walking between selected destinations inside the dock, and selected destinations outside the dock. The respondents in the personal interview/survey believed that there were much more NVA and NNVA walking among operators working on the ship located outside the dock. Thus a similar research to what has been done in this master thesis could be performed with focus on the area around the ship outside the dock.

7 Bibliography

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8 Appendices

8.1 *Personal interview/ Survey*

The questioner which was used in the personal interview and further was handed out to respondents in the dock is presented below, both in Norwegian and in English.

Spørreundersøkelse

Resultatene vil bli brukt som en del av en oppgave hvor formålet er å komme med forslag til hvordan strukturen på verftet kan forbedres. Vi ønsker å fokusere på gangavstander til områder og vi vil da kunne gi forslag på forbedringstiltak til ledelsen. Undersøkelsen er **anonym** og vil ikke kunne spores tilbake til hver enkelt.

1 Kjønn

Mann
Kvinne

| |
|--|
| |
| |

2 Alder

År

| |
|--|
| |
|--|

3 Stilling

Formann
Operatør på skip #293

| |
|--|
| |
| |

4 Hvis du jobber på skip #293, hva er du ansatt som?

Rørlegger
Elektriker
Sveiser
Snekker
Mekaniker
Annet:

| |
|--|
| |
| |
| |
| |
| |

5 Er du fast ansatt i Ulstein?

Ja
Nei

| |
|--|
| |
| |

6 Hvor lenge har du jobbet i Ulstein?

Antall år

| |
|--|
| |
|--|

7 Kjenner du til begrepet "Lean"/ Ulstein Production System?

Ja
Nei
Vet ikke

| |
|--|
| |
| |
| |

8 Hvis ja, hva vet du om "Lean"/ Ulstein Production System?

Åpent:

9 Hva mener du er den største årsaken til at operatørene på skip #293 må gå mye? (Kryss av en)

Produserer mer enn hva som trengs
Venting
For mye flytting av utstyr
Ting blir gjort i feil rekkefølge
Ikke optimal tilgang til lager
Helse og sikkerhetsgrunner
Må forlate skipet fordi man må gjøre arbeidet på nytt
Mangel på informasjon
Private grunner
Annet:

| |
|--|
| |
| |
| |
| |
| |
| |
| |
| |
| |

10 Hva tror du er de 3 viktigste grunnene til at operatørene på skip #293 forlater skipet iløpet av en dag? (Kryss av tre)

Verktøylager
Toalett
Kaffemaskin

| |
|--|
| |
| |
| |

Brusmaskin
 Formenneses kontor
 Rekvisitt lager
 Kafeteria
 Rekvisitt lager 2
 Utrustnings hall
 Work shop
 Hovedlager utenfor dokken
 Venting
 Andre grunner

| |
|--|
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |

11 Hvor mange ganger går du til disse områdene på en arbeidsdag?

Verktøy lager
 Toalett
 Kaffemaskin
 Kontorene til formennene
 Rekvisitt lager
 Brusmaskin
 Dør 2
 Private ærend
 Rekvisitt lager 2
 Utrustningshall
 Dør 1
 Andre områder

Antall
ganger

| |
|--|
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| |
| |

12 Må du ofte gå mye på grunn av at informasjon ikke er tilgjengelig? (tegninger, uforutsette endringer ect.)

Ja
 Nei
 Vet ikke

| |
|--|
| |
| |
| |

13 Hvis ja, hva mener du er hovedgrunnen til den manglende informasjonen?

Åpent:

14 **Synes du strukturen i dokken er optimal?**

Ja
Nei
Vet ikke

| |
|--|
| |
| |
| |

15 **Hvis nei, hva synes du burde bli gjort?**

Flytte kaffemaskinen nærmere skipet / om bord i skipet
Ha material tilgjengelig rett utenfor landgangen
Ha verktøy tilgjengelig rett utenfor landgangen
Flytte toalettene nærmere skipet / ha flere toalett
Ha tilgang til mer informasjon om bord i skipet
Andre forslag:

| |
|--|
| |
| |
| |
| |
| |

17 **Hvor mange ganger tror du operatørene på #293 må gå av skipet på en arbeidsdag?**

Antall ganger

| |
|--|
| |
|--|

18 **Hvordan synes du tilgangen til verktøy er?**

| | | | | |
|--------------|--------|----|-----|-----------|
| Svært dårlig | Dårlig | Ok | God | Svært god |
|--------------|--------|----|-----|-----------|

| | | | | |
|--|--|--|--|--|
| | | | | |
|--|--|--|--|--|

19 **Hvor lang tid tror du en operatørene på skip #293 bruker på å gå å hente verktøy i løpet av en arbeidsdag?**

Timer / minutt

20 **Hvordan synes du tilgangen til material er?**

| | | | | |
|--------------|--------|----|-----|-----------|
| Svært dårlig | Dårlig | Ok | God | Svært god |
| | | | | |

21 **Hvor lang tid tror du en operatørene på skip #293 bruker på å gå å hente material i løpet av arbeidsdag?**

Timer / minutt

22 **Har du forslag til hvordan man kan redusere gåtiden i løpet av en arbeidsdag?**

Verktøy foran landgangen
Material foran landgangen
Bedre tilgang til informasjon
Vet ikke
Andre forslag:

| |
|--|
| |
| |
| |
| |
| |

23 **Hvis du ser at noe har mulighet til å bli gjort på en bedre måte, har du mulighet til endre det?**

Ja
Nei
Vet ikke

| |
|--|
| |
| |
| |

Takk for at du tok deg tid til å svare på undersøkelsen :-D

Survey

The results will be used as a part of an assignment where the goal is to find solutions on how the shipyard area can be improved. We want to focus on the walking distance to different areas and come up with suggestions on improvement which we can pass on to the management. The survey is **anonymous** and cannot be traced down to each individual.

1 Sex

| | |
|-------|--------------------------|
| Man | <input type="checkbox"/> |
| Woman | <input type="checkbox"/> |

2 Age

| | |
|-------|----------------------|
| Years | <input type="text"/> |
|-------|----------------------|

3 Employee position

| | |
|------------------|--------------------------|
| Foreman | <input type="checkbox"/> |
| Operator on #293 | <input type="checkbox"/> |

4 If you are an operator on ship #293, what is your work

| | |
|-------------|--------------------------|
| Plumber | <input type="checkbox"/> |
| Electrician | <input type="checkbox"/> |
| Welder | <input type="checkbox"/> |

Mechanic
Carpenter
Other:

| |
|--|
| |
| |
| |

5 Are you hired in Ulstein?

Yes
No

| |
|--|
| |
| |

6 How long have you worked at Ulstein?

Years

| |
|--|
| |
|--|

7 Are you familiar with the term "Lean"/ Ulstein Production System?

Yes
No
Do not know

| |
|--|
| |
| |
| |

8 If yes, what do you know about "Lean"/ Ulstein Production System?

Open:

9 What do you think are the main reason why the workers on ship #293 have to walk much? (Select one)

Producing more than actually needed

| |
|--|
| |
|--|

Waiting
 Too much transporting/movement of equipment
 Things are done in wrong order
 Not optimal access to inventory
 Health and safety issues
 Do you often have to go outside ship #293 due to rework
 Lack of information
 Private reasons
 Other:

| |
|--|
| |
| |
| |
| |
| |
| |
| |
| |

10 What do you think is the 3 main reason why employees leave ship #293 / the gangway through one workingday?
(Select three)

Tool storage
 Toilet
 Coffee machine
 Soda machine
 Foremen's office
 Prop stock
 Cafeteria
 Prop stock 2
 Outfitting hall
 Workshop
 Storage outside the dock
 Waiting
 Other:

| |
|--|
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |

11 How many times do you walk to these destinations through one working day?

Tool storage
 Toilet

| |
|--|
| |
| |

| | |
|------------------|--|
| Coffee | |
| Foremen's office | |
| Prop stock | |
| Soda machine | |
| Door 2 | |
| Private reasons | |
| Prop stock 2 | |
| Outfitting hall | |
| Door 1 | |
| Other | |

12 Do you often have to walk much due to lack of information? (drawings, unforeseen changes ect)

| | |
|---------------|--|
| Yes | |
| No | |
| I do not know | |

13 If yes, what do you consider the main reason to the lack of information?

Open:

14 Do you think the layout in the dock is optimal?

| | |
|---------------|--|
| Yes | |
| No | |
| I do not know | |

15 If no, what do you think should be done?

| | |
|--|--|
| Move the toilets closer / more toilets | |
| Move the coffe machine closer / on board the ship | |
| More material available on storage outside gangway | |
| More tools available on storage outside gangway | |
| More access to information on | |

board the ship
Other suggestions:

17 **How many times during one working day do you think employes have to walk of ship #293?**

Number of times:

18 **How would you characterize the access to materials?**

| Very bad | Bad | Ok | Good | Very good |
|----------|-----|----|------|-----------|
| | | | | |

19 **How much time do you think employees on #293 spend on walking to get materials during one working day?**

Hours / minutes

20 **How would you characterize the access to tools?**

| Very bad | Bad | Ok | Good | Very good |
|----------|-----|----|------|-----------|
| | | | | |

21 **How much time do you think operators on #293 spend on walking to get tools during one working day?**

Hours /minutes

22 **Do you have an opinion on how it is possible to reduce the time used on walking through one working day?**

Tools upfront
Equipement prepared
Improve information (wrong
drawings ect)
Do not know
Suggestions:

| |
|--|
| |
| |
| |
| |

20 If you see that something could be done in a better way, do you have any influence to change it?

Yes
No
Do not know

| |
|--|
| |
| |
| |

**Thank you for answering the
survey :-D**

8.2 Observation results

The results are presented for one day, one month and one year. This is based on the assumption that the days spent observing were normal working days (7.5 hours) at Ulstein and that the walking-pattern is similar each day. Although the results varied from day to day they gave the same tendency over time. Further it is assumed that one month contains 19, 17 working days and that one year contains 230 working days (Skatteetaten 2012)

NVA walking from the gangway on ship #293:

| NVA- number of observations | | | |
|--|-----------|------------|--------------|
| * From the gangway/ ship #293 | 1 Day | Month | Year |
| Soda machine | 1 | 20 | 243 |
| Coffee machine | 16 | 306 | 3667 |
| Door 2 | 33 | 630 | 7564 |
| Total # of observations from ship #293 to NVA | 50 | 956 | 11474 |

| NVA- time spent per observation | | | |
|--|---------------------|----------------------|------------------------------|
| * From the gangway/ ship #293 | Day | Month | Year |
| Soda machine | 24 sec | 7 min 6 sec | 1 hour 25 min |
| Coffee machine | 18 sec | 6 min 42 sec | 1 hour 20 min |
| Door 2 | 36 sec | 12 min 24 sec | 2 hours 25 min 48 sec |
| Total time leaving ship #293 to NVA per observation | 1 min 24 sec | 25 min 54 sec | 5 hours 10 min 48 sec |

| NVA- time spent in total | | | |
|--|----------------------|------------------------------|--------------------------------|
| * From the gangway/ ship #293 | 1 Day | Month | Year |
| Soda machine | 24 sec | 7 min 30 sec | 1 hour 29 min 42 sec |
| Coffee machine | 5 min 30 sec | 1 hour 45 min 54 sec | 21 hours 15 min 36 sec |
| Door 2 | 20 min 54 sec | 6 hours 41 min 6 sec | 80 hours 10 min 48 sec |
| Total time leaving ship #293 to NVA | 26 min 54 sec | 8 hours 34 min 12 sec | 102 hours 56 min 24 sec |

NVA walking from door 1:

| NVA- time spent in total (minutes) | | | |
|---|---------------------|-----------------------|-------------------------------|
| * From Door 1 | 1 Day | Month | Year |
| Cafeteria | 16 min 6 sec | 5 hours 12 sec | 61 hours 49 min 48 sec |
| Total time leaving door 1 to NVA | 16 min 6 sec | 5 hours 12 sec | 61 hours 49 min 48 sec |

| NVA- time spent per observation | | | |
|---|---------------|---------------------|-----------------------------|
| * From door 1 | Day | Month | Year |
| Cafeteria | 24 sec | 6 min 42 sec | 1 hour 20 min 54 sec |
| Total time leaving door 1 to NVA per observation | 24 sec | 6 min 42 sec | 1 hour 20 min 54 sec |

| NVA- number of observations | | | |
|---|-----------|------------|--------------|
| * From door 1 | 1 Day | Month | Year |
| Cafeteria | 46 | 879 | 10554 |
| Total # of observations from door 1 to NVA | 46 | 879 | 10554 |

NNVA walking from the gangway on ship #293:

| NNVA- time spent in total | | | |
|---|----------------------|-------------------------------|--------------------------------|
| * From the gangway/ ship #293 | Day | Month | Year |
| Women Toilet | 1 min 6 sec | 21 min 6 sec | 4 hours 13 min 12 sec |
| Prop-Stock 2 | 3 min 36 sec | 1 hour 9 min | 13 hours 45 min |
| Toilet | 3 min 36 sec | 1 hour 8 min 24 sec | 13 hours 40 min 12 sec |
| Formen Office | 5 min 30 sec | 1 hour 45 min 36 sec | 21 hours 15 min 36 sec |
| Prop-Stock | 7 min 54 sec | 2 hours 30 min 18 sec | 30 hours 24 min |
| Tool-Storage | 13 min 48 sec | 4 hours 23 min 24 sec | 54 hours 44 min 24 sec |
| Men Toilet | 15 min 6 sec | 4 hours 49 min 48 sec | 58 hours 1 min 12 sec |
| Door 1 | 21 min 6 sec | 6 hours 43 min 48 sec | 80 hours 45 min 36 sec |
| Outfitting Hall | 34 min 18 sec | 10 hours 57 min | 131 hours 26 min 24 sec |
| Total time leaving ship #293 to NNVA | 1 hour 46 min | 33 hours 51 min 36 sec | 406 hours 20 min 27 sec |

| NNVA- time spent per observation | | | |
|---|---------------------|----------------------------|------------------------|
| * From the gangway/ ship #293 | Day | Month | Year |
| Prop-Stock | 6 sec | 2 min 6 sec | 25 min 24 sec |
| Tool-Storage | 12 sec | 3 min 30 sec | 42 min 12 sec |
| Men Toilet | 18 sec | 6 min 42 sec | 1 hour 20 min |
| Door 1 | 24 sec | 8 min 18 sec | 1 hour 39 min 36 sec |
| Outfitting Hall | 24 sec | 6 min 54 sec | 1 hour 22 min 12 sec |
| Toilet | 24 sec | 7 min | 1 hour 23 min 54 sec |
| Women Toilet | 30 sec | 9 min 48 sec | 1 hour 57 min |
| Prop-Stock 2 | 30 sec | 9 min 6 sec | 1 hour 48 min 36 sec |
| Formen Office | 30 sec | 10 min 12 sec | 2 hours 2 min 24 sec |
| Total time leaving ship #293 to NNVA per observation | 3 min 18 sec | 1 hour 3 min 30 sec | 12 hours 42 min |

| NNVA- number of observations | | | |
|--|------------|-------------|--------------|
| * From the gangway/ ship #293 | 1 Day | Month | Year |
| Women Toilet | 2 | 42 | 498 |
| Prop-Stock 2 | 8 | 146 | 1751 |
| Toilet | 10 | 187 | 2249 |
| Formen Office | 10 | 199 | 2389 |
| Men Toilet | 44 | 834 | 10005 |
| Door 1 | 49 | 930 | 11155 |
| Prop-Stock | 72 | 1377 | 16522 |
| Tool-Storage | 75 | 1436 | 17237 |
| Outfitting Hall | 96 | 1838 | 22054 |
| Total # of observations from ship #293 to NVA | 365 | 6988 | 83861 |

NNVA walking from door 1:

| NNVA- number of observations | | | |
|--|------------|-------------|--------------|
| * From door 1 | 1 Day | Month | Year |
| Outfitting Hall | 16 | 299 | 3588 |
| Workshop | 59 | 1130 | 13564 |
| Storage | 150 | 2866 | 34392 |
| Total # of observations from door 1 to NNVA | 224 | 4295 | 51544 |

| NNVA- time spent per observation | | | |
|---|--------------------|----------------------|------------------------------|
| * From door 1 | Day | Month | Year |
| Outfitting Hall | 12 sec | 3 min 36 sec | 43 min 18 sec |
| Workshop | 30 sec | 8 min 54 sec | 1 hour 46 min 48 sec |
| Storage | 30 sec | 8 min 54 sec | 1 hour 46 min 48 sec |
| Total time leaving door 1 to NVA per observation | 1 min 6 sec | 21 min 30 sec | 4 hours 17 min 24 sec |

| NNVA- time spent in total | | | |
|--|----------------------|------------------------|-------------------------|
| * From the door 1 | Day | Month | Year |
| Outfitting Hall | 2 min 54 sec | 56 min 18 sec | 11 hours 15 min 36 sec |
| Workshop | 27 min 30 sec | 8 hours 46 min 12 sec | 105 hour 15 min |
| Storage | 1 hour 9 min 36 sec | 22 hours 14 min 24 sec | 266 hours 52 min 48 sec |
| Total # of observations from door 1 to NNVA | 1 hour 35 min | 31 hours 57 min | 383 hours 24 min |

8.2.1 Balanced matrix inside the dock

The table below shows the balanced matrix regarding observations inside the dock during 13.5 hours.

| Balanced | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
|----------|-----------------|---------|------------|--------------|------------|--------------|--------|---------------|--------------|----------------|--------|-----------------|--------------|--------|-------|
| | | Gangway | Prop-Stock | Tool-Storage | Men Toilet | Women Toilet | Toilet | Formen Office | Soda Machine | Coffee Machine | Door 2 | Outfitting Hall | Prop-Stock 2 | Door 1 | Total |
| 1 | Gangway | 0 | 129,3 | 134,9 | 78,3 | 3,9 | 17,6 | 18,7 | 1,9 | 28,7 | 59,2 | 172,6 | 13,7 | 87,3 | 746 |
| 2 | Prop-Stock | 124,7 | 0 | 33,4 | 3,5 | 1 | 2,1 | 1,1 | 0 | 5 | 36,6 | 46,8 | 5,4 | 20,5 | 280 |
| 3 | Tool-Storage | 99,7 | 39,1 | 16,2 | 12,1 | 0 | 0 | 8,7 | 2,2 | 6,9 | 51,9 | 52,3 | 19,5 | 33,4 | 342 |
| 4 | Men Toilet | 48,8 | 11,2 | 22,8 | 0 | 0 | 1 | 4,3 | 1 | 18,6 | 78,1 | 11,2 | 9,6 | 52,4 | 259 |
| 5 | Women Toilet | 5,4 | 0 | 3,8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,8 | 0 | 0 | 15 |
| 6 | Toilet | 19,6 | 4,2 | 0 | 0 | 0 | 0 | 0 | 0 | 3,7 | 2,1 | 19,4 | 0 | 0 | 49 |
| 7 | Formen Office | 27,8 | 3,4 | 6,1 | 2,3 | 0 | 3,1 | 0 | 1,9 | 4 | 37,6 | 17,7 | 14,3 | 80,8 | 199 |
| 8 | Soda Machine | 6,3 | 1,5 | 0 | 0 | 0 | 0 | 0 | 0 | 1,3 | 4,3 | 4,1 | 0 | 2,5 | 20 |
| 9 | Coffee Machine | 14,4 | 10,3 | 3 | 3,5 | 0 | 0 | 6,5 | 1,5 | 0 | 30 | 39,1 | 39 | 27,8 | 175 |
| 10 | Door 2 | 52,5 | 16,4 | 50,5 | 83,4 | 0 | 10,9 | 50,1 | 5,6 | 60,7 | 0 | 40 | 19,8 | 12,2 | 402 |
| 11 | Outfitting Hall | 208,8 | 41,9 | 47,3 | 10,5 | 10,1 | 13,3 | 6,5 | 1,9 | 18,9 | 38,6 | 0 | 5,3 | 6,8 | 410 |
| 12 | Prop-Stock 2 | 39,3 | 11,1 | 7,6 | 10,1 | 0 | 0 | 1,2 | 1,1 | 9,7 | 45,5 | 0 | 0 | 7,4 | 133 |
| 13 | Door 1 | 98,8 | 11,6 | 16,5 | 55,1 | 0 | 1 | 102 | 3 | 17,4 | 18,1 | 1,1 | 6,4 | 0 | 331 |
| | Total | 746 | 280 | 342 | 259 | 15 | 49 | 199 | 20 | 175 | 402 | 410 | 133 | 331 | 3361 |

The tables below show number of observations inside the dock during one working day (7.5 hours). The columns show the destination which are walked from, while the rows show the destinations which are walked to.

| Balanced | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
|----------|-----------------|---------|------------|--------------|------------|--------------|--------|---------------|--------------|----------------|--------|-----------------|--------------|--------|-------|
| | | Gangway | Prop-Stock | Tool-Storage | Men Toilet | Women Toilet | Toilet | Formen Office | Soda Machine | Coffee Machine | Door 2 | Outfitting Hall | Prop-Stock 2 | Door 1 | Total |
| 1 | Gangway | 0 | 72 | 75 | 44 | 2 | 10 | 10 | 1 | 16 | 33 | 96 | 8 | 49 | 415 |
| 2 | Prop-Stock | 69 | 0 | 19 | 2 | 1 | 1 | 1 | 0 | 3 | 20 | 26 | 3 | 11 | 156 |
| 3 | Tool-Storage | 55 | 22 | 9 | 7 | 0 | 0 | 5 | 1 | 4 | 29 | 29 | 11 | 19 | 190 |
| 4 | Men Toilet | 27 | 6 | 13 | 0 | 0 | 1 | 2 | 1 | 10 | 43 | 6 | 5 | 29 | 144 |
| 5 | Women Toilet | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 8 |
| 6 | Toilet | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 11 | 0 | 0 | 27 |
| 7 | Formen Office | 15 | 2 | 3 | 1 | 0 | 2 | 0 | 1 | 2 | 21 | 10 | 8 | 45 | 111 |
| 8 | Soda Machine | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 1 | 11 |
| 9 | Coffee Machine | 8 | 6 | 2 | 2 | 0 | 0 | 4 | 1 | 0 | 17 | 22 | 22 | 15 | 97 |
| 10 | Door 2 | 29 | 9 | 28 | 46 | 0 | 6 | 28 | 3 | 34 | 0 | 22 | 11 | 7 | 223 |
| 11 | Outfitting Hall | 116 | 23 | 26 | 6 | 6 | 7 | 4 | 1 | 11 | 21 | 0 | 3 | 4 | 228 |
| 12 | Prop-Stock 2 | 22 | 6 | 4 | 6 | 0 | 0 | 1 | 1 | 5 | 25 | 0 | 0 | 4 | 74 |
| 13 | Door 1 | 55 | 6 | 9 | 31 | 0 | 1 | 57 | 2 | 10 | 10 | 1 | 4 | 0 | 184 |
| | Total | 415 | 156 | 190 | 144 | 8 | 27 | 111 | 11 | 97 | 223 | 228 | 74 | 184 | 1867 |

In order to calculate how much time the observations use at walking between the destinations, it is assumed that the employees walk 5 km/h (Larsen 2012). Hence they walk 0,012 km/min. 0,012 km/min is multiplied with number of observations and the distance between the destinations. The table below show how much time (in minutes) which is spent on walking between the different destinations.

| | | Gangway/Ship #293 | Prop- Stock | Tool- Storage | Men Toilet | Women Toilet | Toilet | Formen Office | Soda Machine | Coffee Machine | Door 2 | Outfitting Hall | Prop- Stock 2 | Door 1 | Total |
|----|--------------------|----------------------|----------------|------------------|---------------|-----------------|--------|------------------|-----------------|-------------------|-----------|--------------------|---------------------|-----------|-------|
| 1 | Gangway | 0 | 7,9 | 13,8 | 15,1 | 1,1 | 3,6 | 5,5 | 0,4 | 5,5 | 20,9 | 34,3 | 3,6 | 21,1 | 132,9 |
| 2 | Prop- Stock | 7,6 | 0,0 | 3,7 | 0,7 | 0,3 | 0,4 | 0,3 | 0,0 | 1,0 | 13,3 | 9,7 | 1,5 | 5,1 | 43,8 |
| 4 | Tool- Storage | 8,3 | 3,6 | 2,2 | 2,7 | 0,0 | 0,0 | 2,9 | 0,5 | 1,6 | 20,0 | 12,0 | 5,7 | 9,1 | 68,6 |
| 5 | Men Toilet | 9,4 | 2,3 | 5,1 | 0,0 | 0,0 | 0,3 | 0,4 | 0,1 | 1,0 | 16,9 | 3,8 | 1,2 | 2,3 | 42,9 |
| 6 | Women Toilet | 1,5 | 0,0 | 1,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 2,5 | 0,0 | 0,0 | 5,2 |
| 7 | Toilet | 4,0 | 0,9 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,3 | 1,1 | 1,1 | 0,0 | 0,0 | 8,3 |
| 8 | Formen Office | 8,2 | 1,0 | 2,0 | 0,2 | 0,0 | 1,4 | 0,0 | 0,3 | 0,6 | 12,0 | 7,8 | 3,3 | 6,6 | 43,6 |
| 9 | Soda Machine | 1,3 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,1 | 0,7 | 1,4 | 0,0 | 0,3 | 4,1 |
| 10 | Coffee Machine | 2,8 | 2,1 | 0,7 | 0,2 | 0,0 | 0,0 | 1,0 | 0,1 | 0,0 | 5,0 | 13,3 | 3,0 | 2,9 | 31,1 |
| 11 | Door 2 | 18,6 | 5,9 | 19,4 | 18,0 | 0,0 | 5,5 | 16,0 | 0,9 | 10,2 | 0,0 | 20,0 | 2,9 | 3,2 | 120,6 |
| 12 | Outfitting Hall | 41,5 | 8,7 | 10,9 | 3,6 | 4,3 | 0,8 | 2,9 | 0,7 | 6,4 | 19,3 | 0,0 | 2,2 | 2,6 | 103,8 |
| 13 | Prop- Stock 2 | 10,3 | 3,0 | 2,2 | 1,3 | 0,0 | 0,0 | 0,3 | 0,1 | 0,8 | 6,6 | 0,0 | 0,0 | 1,3 | 25,8 |
| 14 | Door 1 | 23,8 | 2,9 | 4,5 | 2,5 | 0,0 | 0,4 | 8,4 | 0,3 | 1,8 | 4,8 | 0,4 | 1,1 | 0,0 | 50,9 |
| | Total | 137,4 | 38,8 | 65,7 | 44,3 | 5,7 | 12,4 | 37,7 | 3,3 | 30,3 | 120,4 | 106,5 | 24,4 | 54,6 | 681,6 |

8.2.2 Balanced matrix outside the dock

The table below shows a balanced matrix regarding number of observations collected outside the dock during 4.5 hours of observation.

| | Door 1 | Cafeteria | Outfitting hall | Workshop | Storage | Total |
|-----------------|--------|-----------|-----------------|----------|---------|-------|
| Door 1 | 0,0 | 27,5 | 9,4 | 35,4 | 89,7 | 162 |
| Cafeteria | 29,6 | 0,0 | 1,0 | 20,7 | 4,7 | 56 |
| Outfitting hall | 3,0 | 6,9 | 0,0 | 0,0 | 33,1 | 43 |
| Workshop | 41,2 | 13,2 | 1,1 | 0,0 | 88,5 | 144 |
| Storage | 88,1 | 8,4 | 31,6 | 87,9 | 0,0 | 216 |
| Total | 162 | 56 | 43 | 144 | 216 | 621 |

In order to make the number of observations reliable for one working day (7.5 hours) the numbers are divided by 4.5 and then multiplied by 7.5 (Larsen 2012). Thus the table below shows number of observations during one working day.

| | Door 1 | Cafeteria | Outfitting hall | Workshop | Storage | Total |
|-----------------|--------|-----------|-----------------|----------|---------|-------|
| Door 1 | 0,0 | 45,9 | 15,6 | 59,0 | 149,5 | 270,0 |
| Cafeteria | 49,4 | 0,0 | 1,6 | 34,5 | 7,8 | 93,3 |
| Outfitting hall | 5,0 | 11,5 | 0,0 | 0,0 | 55,2 | 71,7 |
| Workshop | 68,7 | 22,0 | 1,8 | 0,0 | 147,5 | 240,0 |
| Storage | 146,9 | 14,0 | 52,6 | 146,5 | 0,0 | 360,0 |
| Total | 270 | 93 | 72 | 240 | 360 | 1035 |

In order to calculate how much time the observations use at walking between the destinations, it is also here assumed that the employees walk 5 km/h (Larsen 2012). Hence they walk 0,012 km/min. 0,012 km/min is multiplied with number of observations and the distance between the destinations. The table below show how much time (in minutes) which is spent on walking between the different destinations outside the dock.

| | Door 1 | Cafeteria | Outfitting hall | Workshop | Storage | Total |
|-----------------|--------|-----------|-----------------|----------|---------|-------|
| Door 1 | 0,0 | 16,1 | 2,9 | 27,5 | 69,6 | 116,2 |
| Cafeteria | 17,4 | 0,0 | 0,6 | 18,3 | 0,9 | 37,1 |
| Outfitting hall | 0,9 | 4,3 | 0,0 | 0,0 | 26,8 | 32,0 |
| Workshop | 32,0 | 11,6 | 0,9 | 0,0 | 94,9 | 139,4 |
| Storage | 68,4 | 1,6 | 25,6 | 94,2 | 0,0 | 189,8 |
| Total | 118,7 | 33,6 | 30,0 | 140,0 | 192,2 | 514,5 |

8.3 Biproportional matrix balancing

Assume that we by observation or other means have obtained a matrix M^0 with elements m_{ij}^0 .

This matrix contains a certain amount of information, but may not be correct. For example: If we look at trips undertaken by people between different origins and destinations and a sufficiently long time period, it is natural to assume that the number of trips leaving an origin is equal to the number of trips arriving at the same origin. Otherwise people will accumulate in certain places as time goes!

Denote a “correct” matrix by M and the elements m_{ij} . For this matrix we should have:

$$\sum_{i=1}^n m_{ij} = \sum_{i=1}^n m_{ji} = X_j \quad \forall j \quad (1)$$

Biproportional matrix balancing finds a matrix M that satisfies (1) and has minimum information value relative to M^0 .

In this particular case, the elements of M^0 do not satisfy (1) in general. For the sum on rows and columns we therefore choose:

$$X_j = \max\left(\sum_{i=1}^n m_{ij}^0, \sum_{i=1}^n m_{ji}^0\right) \quad \forall j \quad (2)$$

Biproportional matrix balancing solves the optimization problem:

$$\text{minimize} \quad \sum_{i=1}^n \sum_{j=1}^n m_{ij} \ln \frac{m_{ij}}{m_{ij}^0} \quad \text{subject to} \quad (3)$$

$$\sum_{i=1}^n m_{ij} = X_j \quad \text{and} \quad \sum_{i=1}^n m_{ji} = X_j \quad \forall j$$

The solution has the form:

$$m_{ij} = m_{ij}^0 e^{\mu_i + \sigma_j + 1}$$

where μ_i is the Lagrange-multiplier for the constraint on row “i” and σ_j is the Lagrange-multiplier for the constraint on column j.

m_{ij} will in general not be integers as the case will be with observations of trips. However, in this case we may interpret m_{ij} as the mean value over several observation periods.

Source: Odd I. Larsen