Master's degree thesis

LOG950 Logistics

Impacts of Lean in Reducing Lead time: A Case Study in Glamox

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Molde University College

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Acknowledgements

All the credit for the successful completion of our research work goes to our family, supervisor, friends, and to all the interviewers who participated from the Glamox Company. It would not have been possible without their support and guidance to pursue and accomplish this valuable degree. We would like to express our respectful gratitude towards our supervisor Professor Judith Molka-Daneilsen of Molde University College for guiding us even with her busy schedule and motivating us to grow and flourish in our way to success.

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At last by the God's grace, we bow and thank to the almighty for all the things he has given and for the strength we have received to endure our challenges and difficulties during this course of our thesis.

Abstract

This paper is a research based on Glamox Company, manufacturer of professional lighting solutions for the global market. The objective of this paper is to review the implementation of Lean in Glamox Company and provide necessary feedback for improvement process. The focus is on the process flow, identification of wastes, and how can it be improved to create more value to customer. The intent of this thesis is to define and measure the waste and provide the root cause of the problem.

Integration of Lean and Theory of Constraint (TOC) limits our focusing power from range of problems into best solution to improve process flow efficiency. In the course of Lean journey of transformation in the company, we use help of Lean tools such as Value Stream Mapping (VSM), 5s, Total Productive Maintenance (TPM), Single-minute Exchange of Dies (SMED) and Kaizen in focusing step of TOC to map and understand the process flow and meet the orderly demand of the customer without further delays.

The paper focuses on removing non-value added waste from the process and increase the performance of machine to decrease buffer and increase the lead time of the product. Clear visual charts, quality measurements and delivery performance are measured and analyzed further in this thesis.

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1. Introduction

As we study through research paper on Lean one word that struck our mind was 'Simplicity'. Implementing Lean in any organization whether we call it seeking perfection, continuous improvement, eliminating waste, or just-in-time production, it's a learning process in understanding and simply doing the best. Lean thinking contributes proper planning and commitment of where you start and what you put into it to get the desired result.

In 2012, Glamox just started their journey towards Lean production in process as improvement culture. This paper is about our theoretical knowledge stimulating case study research. In 1793, Kant idea of, "Some things are fine in theory, but do not work in practice" to some extent is applicable in our practical experience. Basically we try to understand the existing state of company's production process to simply measure it and reduce the waste.

This brings us the question how we see the production process, is there any improvement to be obtained and where can the case company start to seek improvement. In this thesis we seek for the answers to these questions and try to simplify it further.

1.1 Background to the research problem

Womack, Jones and Roos (2007) stated, "New ideas emerge from a set of conditions in which old ideas no longer seem to work." Absolutely true indeed when it comes to Lean production and is essential to understand further by going back to time of this evolution from the motor industry at the end of the nineteenth century. Over the past three decades, Lean manufacturing has changed the fundamental principle of doing business, with minimum effort and minimum time deriving maximum production. According to Pedersen & Huniche (2011), many public organizations implement Lean with the concept of "do more with less" i.e. generating value by banishing unnecessary waste. The root cause of the need for Lean is simply increasing customer variable demand for high quality service at lower price and difficulties in determining qualified human resources.

Lean has proven successful not only in manufacturing companies but also in service sectors like hospitals and banks etc. It is simply change to improve the way of doing things as efficiently as possible. While at the same time its challenge that companies endeavor to expect and overcome resistance to change because without worker acceptance and support any process improvement is impossible. Change is essential but usually the workers are reluctant as sometimes not enough knowledge can often be risky. The sustainable benefit can be achieved however it can take months or years for the successful implementation of Lean. Lean projects should include workers and management working together to find a solution to problem. A positive attitude towards change in continuous improvement can bring about smarter solution. Employee adaptation and development is critical part of Lean culture to accomplish the goal and success in Lean thinking.

There are lots of Lean tools that can help solve the problem however understanding that there is room to improve has to come from worker themselves. Identifying the waste and getting rid of it is easier to share but sometimes this is not always the best solution. Sometimes it's confusing what to keep and throw so we start by creating value.

> Value is certain forms of characteristics, not substantive quantities. To create value is not to create products, but products with certain characteristics and qualities (Salvatierra-Garrido and Pasquire 2011).

1.2. Glamox ASA

The main unit of study of our thesis is a case study based on leading manufacturing company in Norway, Glamox ASA. In 1947, a Norwegian inventor Birger Hatlebakk discovered a method named glamoxering - energy efficient light fixtures, from which the name of the company was adapted. In 1957, Glamox, built in Molde, made its glamorous entry in the field of professional lighting market; both on land and at sea, with a wide range of variety of high technical quality, designed to perform even in demanding environments. It is easy to install and offers 5 years warranty against workmanship and material defects on all products labeled Glamox, Luxo, and Nanaimo (Glamox 2014).

Glamox values are customer, cooperation, commitment, quality and ethics (Glamox 2014). It understands the demand and expectations of customer, promise to deliver on time with high quality & services and treats everyone with respect and dignity. It has quality standard ISO 9001 and also production facilities ISO 14001 certified factories. The Glamox group has turnover of approximately 1.8 billion NOK with 1200 employees in Norway and also the company has offices in several European countries, in Singapore, China, Korea and North America. It is leading supplier of light fixtures and Professional Building Solutions (PBS) to Global Marines and offshore (GMO) markets. Professional Building Solution offer products for schools, healthcare facilities, commercial and industrial building, retail facilities, hotels and restaurants. On the other hand, Global Marine offshore offer range of products for all marine applications like commercial marine, cruise and ferries, oil and gas, recreational boats, navy, obstruction lightening.

1.2.1. Introducing Lean at Glamox Company

In 2012, an initiation of Lean began with the aim to increase the profit by reducing waste through the help of consulting company TPM Team. They were the aspiring sources of Lean in Glamox and started their journey in Lean. The production manager in each section was trained the basics of Lean, finding a waste and motivating employees working under them.

FORBEDRINGSGRUPPER GLAMOX 2.4.12TR Lagr Forbedr.gr Lean Oppdatert. 4.4.13(Nye gr ledere)

Arb gr. Nr	Navn	Arb oppgaver	Avd leder	Ant delt	Tavlemøte	Prosj møte	Teamleder	Gruppeleder	Viseleder	Støtteperson	Oppstart
					5 min/dag	30 min/14 dag					
1	Slitte/Stanse/Klippe	Slitt, automatstanse, klippe	Kjell Ove	7	Morgen	14.45-15.1	Trond	Herzl Giladi	Hallgeir Heggernes	Toralf Rein	[illegible]
2	Samesor	Stansing/knekking/rullforming	Kjell Ove	6	Skift	14.45-15.1	Per, Arne	Frank Hagen	Sigmund Johansen	Gunnar Hoem	25.06.2012
3	Pivatic	Stansing/knekking/rullforming	Kjell Ove	4	Skift	14.45-16.1	Per/Arne	Paul Boyle	Tor Arne Gusdås	Hernan Zuniga	11.06.2012
4	Nibble, knekkesenter, Toxilinje		Kjell Ove	5	Skift	14.45-15.1	Stein/Hans	Ola Øverland	Per Solbakken	Gunnar Hoem	05.09.2012
5	Multi deleprod	Mekanisk prod av Multi ov.	Kjell Ove	6	Morgen	14.45-15.1	Per/Arne	Eivind Stave	Gustav Aaberg	Arild Småge	26.06.2012
6	Knekking/montering	" + Vaskeanl og valse	Kjell Ove	11	Skift	14.45-15.1	Raymond	Hilde Iren Hoem	Arnstein Syvertsen	[illegible]	[illegible]
7	Rasterprod maskiner	Lager enhetsraster	Kjell Ove	11	Skift	14.45-15.1	Robert	Gunnar Magerøy	Ingrid Folland	Hernan Zuniga	03.08.2012
8	Raster manuelt arbeid	Småordrer/innmontering/spesial	Kjell Ove	8	Skift	14.45-15.1	Robert	Cecilia Vestad	Kelly Oormais	Jonny Strømme	19.09.2012
9	Downlight formontasje	Lager units + div	Arild	8	Dag	14.45-15.1	Laila	Anne K Havnvik	Ann H Hole	Åge Eliassen	13.06.2012
10	Downlight sluttmontasje	Setter sammen prod og pakker	Arild	9	Dag	14.45-15.1	Laila	Hilde Sørmoen	Thomas Bryhn	Toralf Rein	13.06.2012
11	Multi formontasje	El montasje	Arild	15	Skift	14.45-15.1	Anders	Bendik Solvåg	Knut Holsether	[illegible]	[illegible]
12	Multi ettermontasje og pakking	Ettermontasje og pakking	Arild	14	Skift	14.45-15.1	Bedri	Arild Brandsæter	Anita Schøiberg	[illegible]	[illegible]
13	Sluttmontasje	Steril og spes	Hernan	6	Dag	14.45-15.1	Kari	Åse Botterli	Anne Marie Slemm	Kjell O Heggem	15.08.2012
14	Mek og ledn klipp	Mek og ledn klipp + div	Hernan	6	Dag	14.45-15.1	Kari	Vasyl Maltsev	Michael Brandshal	Inge Bratteteig	07.06.2012
15	ADS1 Formontasje og slm	Formontasje og ettermontasje	Hernan	6	Dag	14.45-15.1	Kristin	Marlon Y Tangen	Andreas Reitan	Anita Lyngstad	22.08.2012
16	Reserve										
17	Sluttmontasje	Bordmont/Sala	Hernan	5	Dag	14.45-15.1	Kristin	Malin Skorgen	Magdalena Chorz	Åge Eliassen	20.08.2012
18	Lakkering	Pulver og våtlakk	Hernan	6	Dag	07.30-08.0	Olav	Vidar Venås	Loyd Silseth	Gunnar Hoem	11.06.2012
19	Pakking	2	Hernan	4	Dag	14.45-15.1	Olav	Bjørn Ole Berg	Odd Randen	Anita Lyngstad	19.09.2012
20	Multi Nøclys	Sluttmontasje og batterimont	Hernan	8	Skift	14.45-15.1	Vigdis	Tone F. Aarøe	Tove Torsen	Arild Småge	15.08.2012
21	ADS2 Formontasje og slm GIR	Formont og slm	Gunnar	8	Dag	14.45-15.15	John	Arnt Skarahaug	Randi Moen	Jonny Strømme	28.09.2012
22	Reserve										
23	ADS 3	Sl.mont./Formont./Pakking	Gunnar	9	Dag	14.45-15.15	Rigmor	Irene Åsebø	Anne M.Meyer	Hernan Zuniga	27.08.2012
24											
25	ADS4 1. skift	Formont./ADS/Pakkemaskin	Gunnar	11	Skift	14.45-15.15	Solfryd	Stefan Brozban	Ann K. Ovesen	Jonny Strømme	18-19.6.12
26	ADS4 2. skift	Sluttmontering	Gunnar	11	Skift	14.45-15.15	Svein	Leif B. Bjørsmo	Hilde Witsøe	Toralf Rein	18-19.6.12
27	Diverse 1	Man slm+spes mont	Gunnar	6	Dag	14.45-15.15	Leo	Aasta Pettersen	Bjørn Hustad	Kjell O Heggem	20.08.2012
28	Diverse 2	Man sluttmontering	Gunnar	9	Dag	14.45-15.15	Leo	Mads Rishaug	Sidsel Birkeland	Inge Bratteteig	28.09.2012
29	Vedlikehold		Bjarne Lie		Dag						Mars(2013)
30	Teknisk	Teknisk underlag	Inge	5+1	Dag		Inge				Okt (2012)
31	Innkjøp	Fabrikkinnkjøp	Åge	2+1	Dag		Åge				Okt (2012)
32	Planlegging	Produksjonsplanlegging og avrop	Helge O	3+1	Dag		Helge O				Okt (2012)
33	Flytgruppe 1	Multi, lakkere montere			Skift						Mars(2013)
34	Flytgruppe 2	Samesor, Pivatic, montere			Skift						Mars(2013)
35	Flytgruppe 3	Nibble, kn, lakkere, montere			Skift						Mars(2013)
36	Flytgruppe 4	DownLight			Dag						Mars(2013)
GER/LOGISTIKK											
L1	lp1	Eksternt varemottak	S.Myren	6	Dag	14.00-14.3	Eide/Gård	Ø. Botterli	D. Taylor	A. Gjerde	05.02.2013
L2	lp2	Internt varemottak/prod. Forsk.	S.Myren	5	Dag	14.00-14.3	Eide/Gård	R. Steniøs	A. Moltubakk	A. Gjerde	05.02.2013
L3	Retur/Reklamasjon	Beh. Retur og Reklamasjon	S.Myren	4	Dag	14.00-14.3	Eide/Gård	W. Nerlandsrem	B. Eidem	V.Andreassen	05.02.2013
L4	Kundeplukk 1	Plukke og pakke kundeordrer	S.Myren	10	Dag	14.00-14.3	Eide	A. Nilsen	J. Solemdal	V.Andreassen	05.02.2013
L5	Kundeplukk 2	Plukke og pakke kundeordrer	S.Myren	10	Dag	14.00-14.3	Gårdvik	L. Taylor	A. Henriksen	A. Gjerde	05.02.2013
L6	Logistikk	Distribusjon/Innkjøp/Prosjekt	A.Gjerde	6	Dag		A.Gjerde	D.Smørdal	M.Eikrem	S.Myren	mars
L7	Kundeservice Norge	Betjene salg + kunder	Å.F. Carlse	6	Dag	Etter arb.ti	Å.F. Carls	O.J Ekroll	A.K. Kristiansen	S.Myren	mars
L8	Kundeservice Export	Betjene salgsselskap	Å.F. Carlse	6	Dag	15.30-16.0	Å.F. Carls	E. Hoel	I.Haukås	S.Myren	mars

Figure 1.1: Names of Focus groups in *Lean* (By Glamox)

PILOTGRUPPE			Ant pers	
FlytGr 1	TL Multi	gr 5	1	Per
MULTI	TL Mont	gr 11	2	Bedri/Anders
	TL Mont	gr 12	0	"
	TL lakk	gr 18	1	Olav
	TL pakk	gr 19	0	"
	TL Mont nødlys	gr 20	1	Vigdis
	Plan		1	Gjermund
	Innkjøp		1	Tore L
	Teknisk		1	Sigbjørn
	Lager/Logistikk		1	Helge S
	Sum ant pers		8	

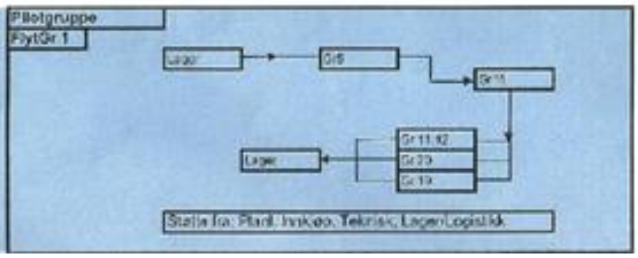


Figure 1.2: Focus Group 1 for MIR LED (Mid Infrared Light Emitting Diode) (By Glamox)

In order to implement the Lean in Glamox Company they took a help for implementation, from TPM Team Company, this TPM Team company people first provided training for the higher officials about identifying the wastes, 5s and so on. Then they prepared a plan for providing the training for the employees about 7 +1 wastes and 5s. The figure in Appendix 6.1 shows the knowledge of higher authorities about Lean in the Company.

First they started looking for wastes in each production department, and also finding the solutions to removal of wastes. Further going into details the Figure 1.1 shows that the implementation of Lean in individual departments was started in the year of 2012. They focused on search for the waste in production line rather than just focusing on one particular product. The emphasis was to check the lead time and flow of the each product. Then they started implementing Lean tools for MIR LED (Mid Infrared Light Emitting

Diode) lights in March 2013 which is a GMO product. A MIR LED light is a make to order product which is expensive, high quality and extremely on demand by the consumer. They formed focus group for each different product families. The first focus group is on MIR LED (see Figure 1.2) and second is C10 which is just in process in implementing Lean.

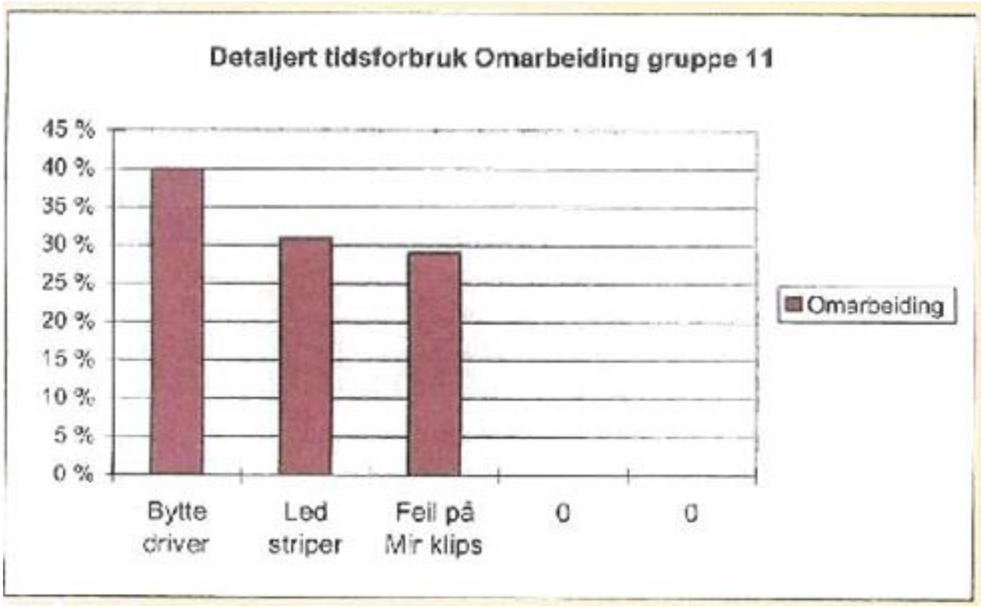


Figure 1.3: Percentage of rework rate in MIR LED (By Glamox)

The MIR LED product suffered from re-work rate about 40% for switch driver, 31% for LED stripes and 29% for Failure MIR clips (see Figure 1.3) in total 275 minutes. Through interview with the project manager, focus group improved the rework rate (see Figure 1.4) reducing in total approximate 700 minutes with the help of Lean.

Heft i forbedringsgrupper GLAMOX

GPM

UKE:26-28 2013

Gruppe	1. Transport	2. Omarbeid	3. Lager	4. Overproduksjon	5. Venting/leting	6. Bevegelser	7. Overarbeid	8. Produksjon undertag	Sum Heft i periode
1. Sille / Slanse / Knekke									
2. Samesor		150			780				930
3. Pivatic				485	770	15		30	1300
4. Nibble, knekkesenter, flex					655				656
5. Multi deleproduksjon	10	15			1645				1760
6. Knekking / montering				250	90				340
7. Rasteprod maskiner					4435				4435
8. Raster manuelt arbeid		60							60
9. Downlight formontasje		40			30				70
10. Downlight sluttmontasje		60			5				65
11. Multi formontasje		310			30				340
12. Multi ettermontasje og pakking		420							420
13. Sluttmontasje		180			20				200
14. Mek og ledn klipp									
15. ADS 1 For- og sluttmontasje					60				50
16. Reserve									
17. Sluttmontasje		30						85	115
18. Lakkering		130			510				640
19. Pakking									
20. Multi nødlys		285							285
21. ADS 2 For-og sluttmontasje G/R					260				260
22. Reserve									
23. ADS 3 Formontasje		200			35				235
24. ADS 3 Ettermontasje og pakking									
25. ADS 4 1.skift		245			75			5	325
26. ADS 4 2. skift		410			125			5	540
27. Diverse 1		255						25	280
28. Diverse 2		375			120				495
29. Vedlikehold									
								Sum heft i perioden	13800

Figure 1.4: Reduction in rework rate after implementing Lean (By Glamox)

Vidar Andreassen, illustrating his experience from transport company, a senior Consultant is responsible for the Lean group consisting of 9 members in Glamox, Molde. Vidar is solely responsible for introducing Lean methods as he is one of several managers with experience and background study of Lean. In his view, Lean in Glamox is continuous improvement just in process because his most of the time is spent on teaching others what Lean is all about and how it can make a difference. The employees are less enthusiastic about the new changes as they have already built a culture of way of doing things and some of the workers have more than 30-40 years of experience so you can imagine if a new guy suddenly walks in and ask you to change what you've been doing the same thing for several years, would you change it?

Lean is perceived as an improvement culture in Glamox. They still must answer the question to figure out "Why must we improve?"

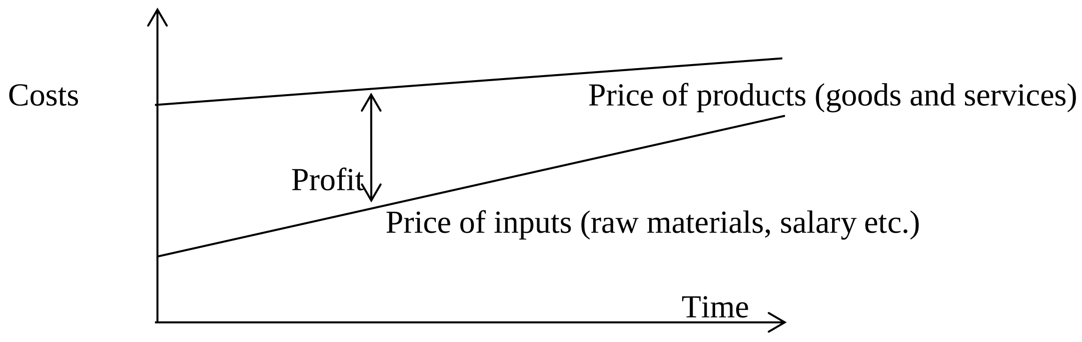


Figure 1.5: Glamox view of time and cost (By Glamox)

As you can see above on the diagram the profit is decreasing over time. The goal of any organization is to maximize profit. So "Why must we improve?" view in Glamox is:

- Produce more at the same cost (Increase efficiency)
- No input wastage (Increase Dividends, decrease wastes)
- Short line jobs and faster restructure (reduce inventory cost)
- Do right first time (No production quality defects)

The path to reach the goal is to develop employees that are the greatest resource. How to get all the employees to contribute for achieving the objectives? The company scrutinizes every employee as a leader to be an example – a good role model and contribute to continuous improvement culture and to ask why always before action. And also as a culture the employees are treated with respect, praised for good efforts, directed when something can be done better, build up the confidence in the individual's willingness and abilities to improve business. Basically it is not about working harder but to work smarter. Modern improvement tools such as 7+1 waste, 5+ 1 S, TPM, kaizen event are used to improve the productivity and achieve zero waste or reduce non-value added cost.

1.2.2. Product

C10 and C20 lights are two products belonging to same family group which have high demand in schools, health facilities, industries, retail houses, hotels and restaurants etc. It is Professional Building solution having more than 50% customers only in Norway and rest in Europe and Asia. C10 is a simple, efficient luminaire family with variety of different items. C10-S1 is available in different modules and sizes: 150, 225, 440 and 480mm and with four different optics finding it more suitable for many different applications. To add simplicity and effectiveness, the optic has spring locking that can hinged during tube replacement. (Glamox 2014)

Product Family	C10	C20
Product Items	>150 different items	> 298 different items
Product Series	C10-S1	C20-S3
Product Items	57 different items	30 different items
The focused Product Item	C10 -10054120	

Table 1.1: Product family and Item at Glamox Company

C10-10054120 is the product which we have narrowed our study in this research. “It is a surface-mounted or suspended luminaire in classic style. (Glamox 2014)” The body is made up of white painted steel and with white plastic end caps. This product is available only in white color. The optic is a double parabolic reflector Louvre type LL/LU. The total power consumption it takes is 62W and maximum ambient temperature is 40˚C. The length of the product is 1237mm, width of 229mm and height 52mm with 2 lamps and 28W lamp power. It is the highest runner product in Glamox therefore it is kept in stocks until minimum security level of 1525 units to avoid the stock-out situation. In 2013, Glamox sold total 12442 units approx. of C10-10054120 only.

Figure 1.6: Image of Product C10-10054120 (Glamox 2014)

1.2.3. Production Line

In order to produce C10-10054120 item, the company has total 5 production lines (see Figure 1.7) from raw materials to finished products. The first production line is for preparing the side brackets for hanging in the wall or fixes the holders. The second production line is for preparing body. The third production line is to prepare the louvers and fourth is assembling the louvers and finally all the semi-finished products are assembled into fifth assembly line to be shipped or placed in the warehouse. Several different products of several different sizes also run in this production line every day so it is the job of production planner to decide the efficient schedule without stoppage in daily activities.

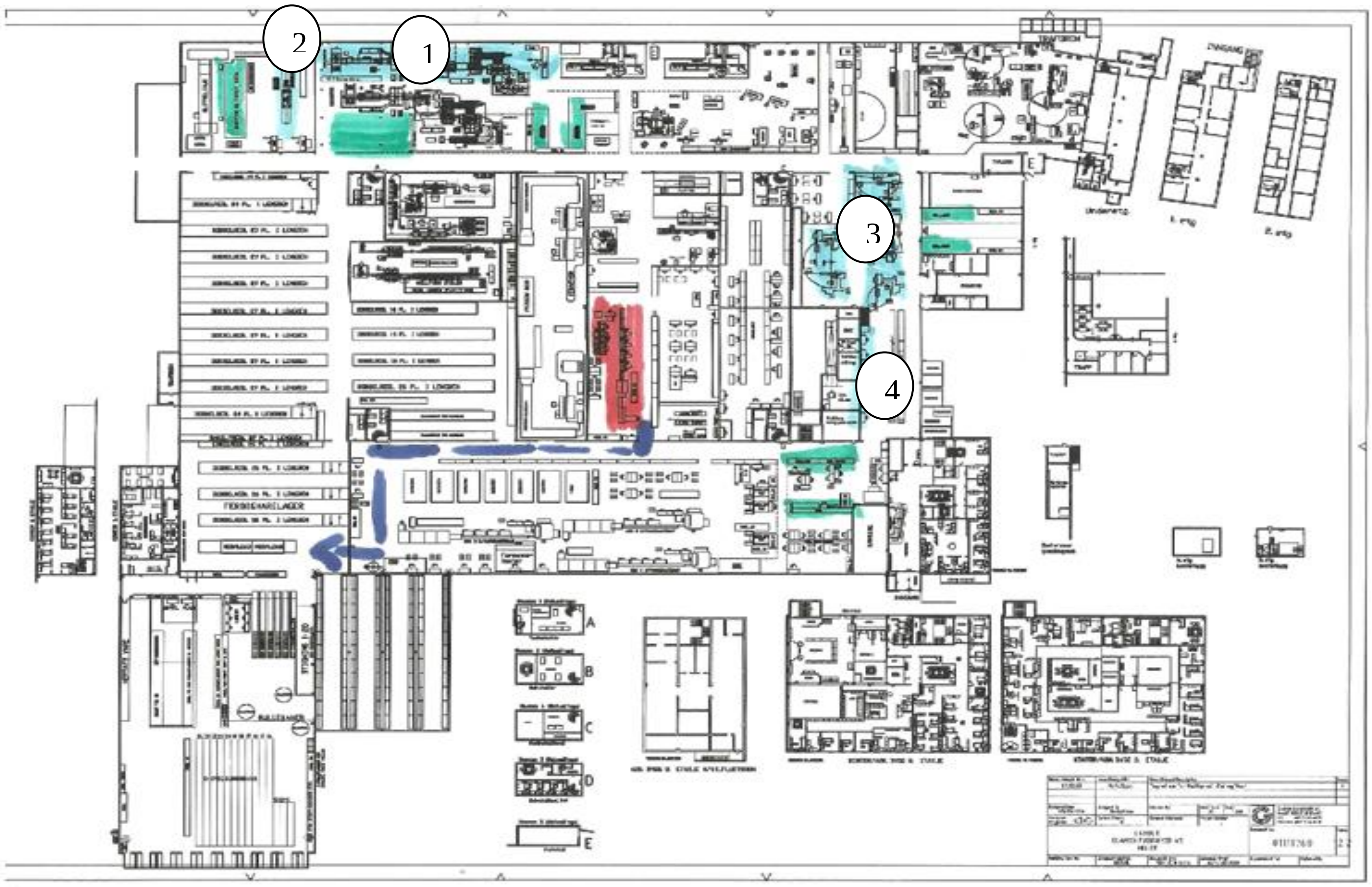


Figure 1.7: Production Line (By Glamox)

Final Assembly Lines

Four Production Lines

Buffers in Each Production Line

Goods transported to Warehouse

1 First Production Line for Body

2 Second Production Line for Brackets

3 Third Production Line for Louvers

4 Fourth Production Line for Louvers Assembly

1.2.4. Research Problem

The logistics management is basically an integrative process that optimizes the flow of materials and supplies through the organization and its operations to the customer (Vinod 2007). The basic goal of the company is to make more money by obtaining a continuous flow of materials, with the result of shorter lead times and lower costs.

As you see below, the rough example of 4 production line handling C10-10054120 from raw material to semi-finished products. The light green notes represent Machinery; yellow notes represent work activities of material flow process; and the pink notes represent buffers in each production activities. Buffers occupy space, manpower, time and money related to operation and transportation cost. These buffers also indicate the stoppage or waste in each and every stage related to inventory holding, overstocking leading to issues with quality and time consumption. For instance, Production line 3 and 4 indicates only for producing louvers which can be optimised into one workflow then to divide it into different production line. It creates efficiency and smooth workflow. The main aim of the company in implementing Lean is to reduce lead time and storage cost which can add up to other waste of material, quality and labour. We aim to explore the company’s implementation of Lean and examine how effective the implementation of the production line is for reducing waste.

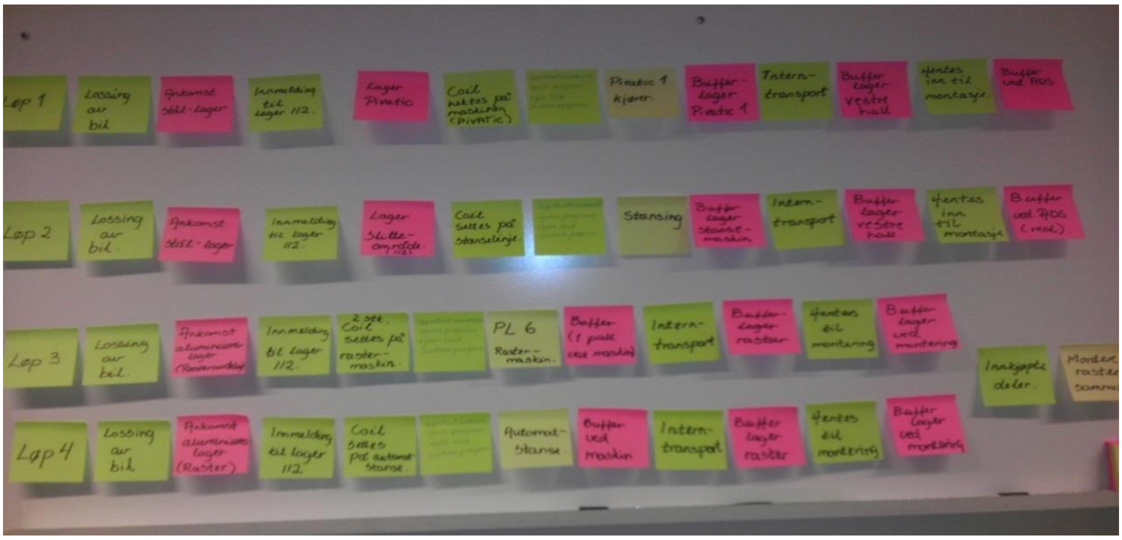


Figure 1.8: Four Production Line of C10-10054120 (By Glamox)

The most important thing is to formulate the research questions when solving a research problem. According to (Yin 1994) defining the research question is probably the most important step to be taken in a research study, so patience and sufficient time is necessary for this task. In this master thesis the research questions are defined in the next Section 1.3.

1.3 Purpose and Research Question

In this thesis we seek to identify the problems in Glamox production process, what factors lead to increase the lead time of the production, and also find the root causes for this problem. In additional to that we also want to measure and analyze the production process and also explain about their present situation. Furthermore, after identifying the problems of the company's production process, the brief explanation about recommendations on how to improve the problems and production process is discussed as a part of the study. The research questions are described below:

a) ***Main Research Question:***

Understanding the existing state of a company's production process and the emerging to improve production process and reduce lead-time, we establish the following main research question for this dissertation:

"An opportunity exists to improve the production performance and reduce the waiting time with the application of Theory of Constraints."

The production process includes the following phases: the fabrication, procurement, assembly and internal transport of the goods. Figure 1.8 shows the rough image of production flow.

b) ***Secondary Research Questions:***

Based on the main question we formulated secondary research questions, stated below, that are applied to a case study in implementation of a production process. The case selected is applied to the business Glamox ASA Company in Norway. The case is described in more detail in the next subsection.

- *How can production line performance be measured at Glamox?*
- *How can the lead time be reduced or the production performance be increased and how can we find the root cause of delays in production?*
- *How can the buffer capacity utilization be reduced?*

1.4 Structure of the Thesis

This study is based on number of journal articles, conference papers etc. In this research we conduct a survey and report on it in the case study analysis. We hope that our analysis of the survey data will lead us to a better understanding of Lean as it is implemented in the case. The Literature reviews are used as a basis of understanding Lean in organizations in general. Our data is then applied to contemplate Lean in the context of this case.

The thesis is divided into Five chapters: Chapter 1 is an overview of the study and research question; Chapter 2 contains a brief background of Lean and Theory of Constraint, reviewing relevant literatures; Chapter 3 describes the relevant methodology to justify the written case study material; Chapter 4 provides an analysis determining the research questions; and Chapter 5 discusses the conclusion, suggestions and limitation of the research study with appropriate recommendations for future research.

2. Literature Review

This chapter will provide the brief description about the relevant literatures for this research. This chapter is divided into four main sections. The first section presents brief introduction about Lean Philosophy. The second section presents brief introduction and explanation of Theory of constraints. Third section presents the integration of Theory of Constraints and Lean Philosophy and the fourth section will provide the theoretical summary of the Lean tools. The first section Lean Philosophy is divided into four main sections. First section presents brief description of Lean manufacturing, the second presents Lean tools. Further the theories present in this chapter are relevant to solve the research questions present in Section 1.3. These theories are also used as a base for the research methodology discussed in Chapter 3, and the analysis discussed in Chapter 4. At the end of this chapter you will find a summary (Table 2.3) of the Lean tools that we will use to solve the research questions using Theory of constraint focusing steps.

2.1. Conceptual framework for Lean

Today's challenge of any company is to stay competitive by offering better products and services, improve quality and excel performance. Several academics and practitioners, over the decades, have accepted Lean as a crucial strategy to become a market leader for any organization. Eliminating waste in current systems, adding value to the products and product flow advancement leading to productivity improvement and lead time reduction, Lean surely seems to clear out the ways of facing challenge by the low cost economies (Lee-Mortimer 2006). In other words, Lean manufacturing simply means delete waste. Waste is anything that does not give value to customer which certainly can be reduced or totally eliminated. Implementing Lean manufacturing in the system of the company despite wide knowledge and available resources is not an easy task (Taj and Morosan 2011). Lean manufacturing is much more than a technique; rather it a culture of new way of thinking involving everyone in the organization working for continuous improvement.

As we step backwards, twenty six years ago, the term "Lean manufacturing" was first introduced by John Krafcik (1988) in his article *Triumph of the Lean Production system* which was the first publication from the International Motor Vehicle Program (IMVP). Later on the term received more popularity after the publication of the book *the machine that changed the world* by the MIT researchers Womack, Jones and Roos (1990) (Langstrand 2012).

In the research of Krafcik (1988), the study to access the range of manufacturing performance, particularly productivity performance, they discovered that high technology is not often the solution to poor manufacturing performance rather appropriate production management policy is what the industry needs.

2.1.1 History of Lean

The revolution started in the course of auto industry discovered by Henry Ford and his co-workers with the concept of continuous moving assembly line. Ford's successful plants, Rouge River and Highland Park, were the example of manufacturing concept with continuous-flow production and vertical integration and no doubt was the center of attention for their efficiency and scale. According to Kovacheva (2010), the Ford model of mass production was the example of production efficiency through worker performance where a repetitive task was replaced by job rotation and teamwork in intention to improve employee morale and attain higher product volume at lower price. Each worker were trained not just production task but maintenance, quality control, record keeping etc. (Kovacheva 2010).

Taiichi Ohno of Toyota group observed some defects in the model. Later Japanese automakers achieved world-leading levels of efficiency with Toyota Production System (TPS) (Krafcik 1988)– "original Fordism with a Japanese Flavor". Mass production was highly inflexible due to large amount of capital and space, high inventories, over-standardization of the products. A Japanese company Toyota merged with the innovative discovery of "taking the minds + hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist system, and adding the glue of teamwork for good measure (Krafcik 1988, 43)".In the early 1950s Toyota began implementing TPS system and by 1965 Toyota Motor Corporation was more efficient than American famous companies like General Motors, or Ford etc. "In craft production, skilled workers use relatively simple but very flexible tools to produce one of kind products to meet precise customer requirements. In mass production, highly skilled specialists design products to be made in high volumes by relatively unskilled operators using expensive and inflexible machines (Kovacheva 2010, 8)."

Excess inventory or stock keeping is usually undesirable and do not add value to the product. Low inventory levels save time, space and precious capital. However, many companies have a tendency to keep large stocks of parts in their warehouse just in case something goes wrong. "Just-in-Case" or "Just-in-Time" (Krafcik 1988)system is also another Toyota translation of Ford's mass production system by minimizing the waiting time or cycle time. Unlike Ford's Model of standardize product, Toyota also found their way to produce wide variety of products using continuous-flow principles adding another benefit of 'flexibility'.

The successful application of Toyota's Lean production system still continues to be subject of interest within academic research. The focus on manufacturing industry during the late 1990s and early 2000s is shifting to the areas such as marketing, accounting, sales and services, hospitals and service industry etc. TPS innovation includes elimination of waste or "muda" (the Japanese word for waste), quality at the source - Jidoka, continuous improvement - Kaizen, Just-in-Time – Kanban. Lean thinking is continuous improvement process which cannot be restricted to material supply or inventory. It is the culture of Learning Organization set to achieve flexibility and consistent efficiency to obtain new opportunities and sustainability for long-run.

In order to show the development of the Lean concept Stone(2012)underlines four decades of Lean: Discovery phase (1970-1990), Dissemination phase (1991-1996), Implementation phase (1997-2000), Enterprise phase (2001-2005) and Performance phase (2006-2009). The purpose was to spread knowledge beyond its origin from Toyota production system and highlight the voids from within the scholarly Lean literature. Many have argued about the missing clear Lean definition and what is or what is not part of it. Nevertheless we can't deny the fact that it's a continuous process and will continue to develop as a whole management system.

2.1.2 Value and Waste

The main objective of Lean is to *maximize the value by minimizing the waste.* The ultimate goal is to produce a perfect value to the customer. To perform this organization should have a perfect value creation process with zero wastes. This Section presents about the concepts of value and waste.

a) Value

A manufacturing organization buys raw materials from their suppliers and converts them into finished goods through a series of process. In each and every process step the value of the raw material will be increased, and finally it will become as a product value. According to (Gopalakrishnan.N 2010) the customer plays a very important role in fixing the value of the product/service. In case the customer is not willing to buy a particular product; it means that it has no value. This may seem very odd but it is the truth. The value of a product or service is decided by *what the customers' willingness to pay.*

According to (Carreira 2005) this concept and definition of value take us to two of the key analytical terms of Lean, value added and non-value added. The value added refers to activity that transforms the product or deliverables, in the view of the customer, to a complete state. The product has been physically changed, and its value to the customer has increased. Conversely, the term non-value added refers to activity that consumes time (people expenses), material and space (facilities expense), yet does not physically advance the product or increases its value.

b) Waste

In Japanese language the word "Muda" means waste. According to (Gopalakrishnan.N 2010, 6)"however it is not easy to understand the exact meaning of waste but *the waste is anything that consumes resources and does not add value to the customer*." In any organization the manufacturing process starts from raw materials, and these raw materials processed through various machines and finally it becomes as finished product, in this process there are many steps that add value to the customer and not add value to the customer. The processing steps that don't add value to the customer increases the price of product as well as increase the non-value added cost for the organization. The manufacturing process include all activities such as value added and non-value added, by eliminating the non-value added activities from the manufacturing process the organization can reduce the non-value added cost and also the price of the product. Overall there are seven types of activities that lead to wastes those are 1) Over production, 2) Defects 3) Inventory 4) Transportation 5) Waiting 6) Motion 7) Correction. In the next Section (2.1.3(1)) describe in-depth about the most common wastes in any organization.

2.1.3 Key Principles of Lean Manufacturing

The summary of the key principle of Lean Manufacturing as developed by Womack & Jones (1996) in their book Lean Thinking are described below (Ismail 2007):

1. *Recognition of waste*

The initial step is to clearly distinguish value and non-value process or feature. Once you recognize the waste one task is over as sometimes people get confused if it is really waste or efficiency. For example, keeping large inventory in each work station creates inflexibility and unnecessary movement of materials or parts.

Primitively Toyota Production System had identified 7 main types of waste. Most recently, 7 + 1 waste is popularized as waste of *talent* has gain a serious attention which is discussed below (Ismail 2007):

i. *Over-Production* – Over-production is the seriously undesired waste of all which is the source for other waste. Large batch sizes, unreliable processes, unstable schedules, inaccurate demand forecast, inflexible workstation etc. are all the result of overproduction. Producing wrong thing can probably end up at discount rate or even discarded as scrap. Therefore reducing or banishing these wastes is a golden opportunity for efficiency and high productivity. However, even by *Lean* manufacturers, minimum about of security level for semi-finished or finished items is kept for some cases.

ii. *Defects* – Defects is waste of correction caused by inadequate training, skills shortage, incapable processes, transportation and excessive stock etc. Late delivery also adds up to costs of goods sold which can also be eliminated.

iii. *Inventory* – Continuous flow and pull production can help achieve excess inventory in stock. Longer set-up time can also lead to large inventory holding both unfinished and finished materials. First-In-First-Out is simple way of observing the material flow. It can add up the addition cost in storage, defect as well.

iv. *Transportation* – Transportation includes any movement of materials that do not add any value to the product. Excess transportation is caused by poor layout, lengthy or complex material handling, multiple storage location, working faster to accomplish customer demand. The space between each process must be as close as possible and direct material flow without stoppage is *Lean* thinking.

v. *Waiting* – The idle time for work in process or working slowly is waste. Poor machine or worker co-ordination, long changeover time, unreliable processes and quality, and time required for rework are all effects of waste of waiting. It increases labor cost as well as depreciation costs per unit of output.

vi. *Motion* – Motion is any unnecessary physical movement of machine and workers which can direct to addition cost of waste. Unnecessary motion is caused by poor layout, poor method design, poor workplace organization etc.

vii. *Correction*– Re-doing is generally boring and consumes more time than usual. The inefficient use of labor and equipment, re-processing generated by bottlenecks and stoppage is not the situation any desires. “Prevention is better than cure” or pursuing to doing it right first time do not need correction work.

viii. *Talent* – Workers must me motivated and guided towards the commitment of design and development of their workplace to build employee morale. Then only one can achieve practical solution. It isn’t about working harder but working smarter to get continuous feedback about the process and development. Lack of correct information often leads to bottleneck and defects.

2. *Standard Processes:* The second step is to standardize each station into sequence, timing and outcome. It needs details and through inspection to get the standard time and workers performance. Value stream mapping is used as a tool to observe the flow of production and eliminate waste or find a solution to improve it.

3. *Continuous Flow: Lean* is a culture in process for continuous flow of production free from bottlenecks, stoppage, defects, backflows or idle time. The successful implementation as Ismail (2007) points out can be reduced as much as 90%.

4. *Pull-production:* Whether we call Just-In-Time (JIT) or Kanban or pull production is a strategy to avoid excess inventory and only produce, when demand is placed, as soon as possible. According to Womack & Jones (1996), pull is defined as a “system of

cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need."

5. *Quality at source:* When defects are prevented automatically the result is quality materials at right time and right place. *Lean* thinking emphasize on total quality management (TQM) which is also another tool of lean.

6. *Continuous Improvement:* Without any defect, bottlenecks, Kanban and continuous workflow must be perfect situation. Therefore *Lean* is about striving for Perfection with continuous improvement process and continues success.

2.1.4 Objectives of Lean Manufacturing

Lean Manufacturing is a set of tools to reduce waste and for the continuous improvement in the production process. In Figure 2.1, we can see distinct aim of lean, its guiding principles and Lean tools (Abdulmalek, Rajgopal and Needy 2006).

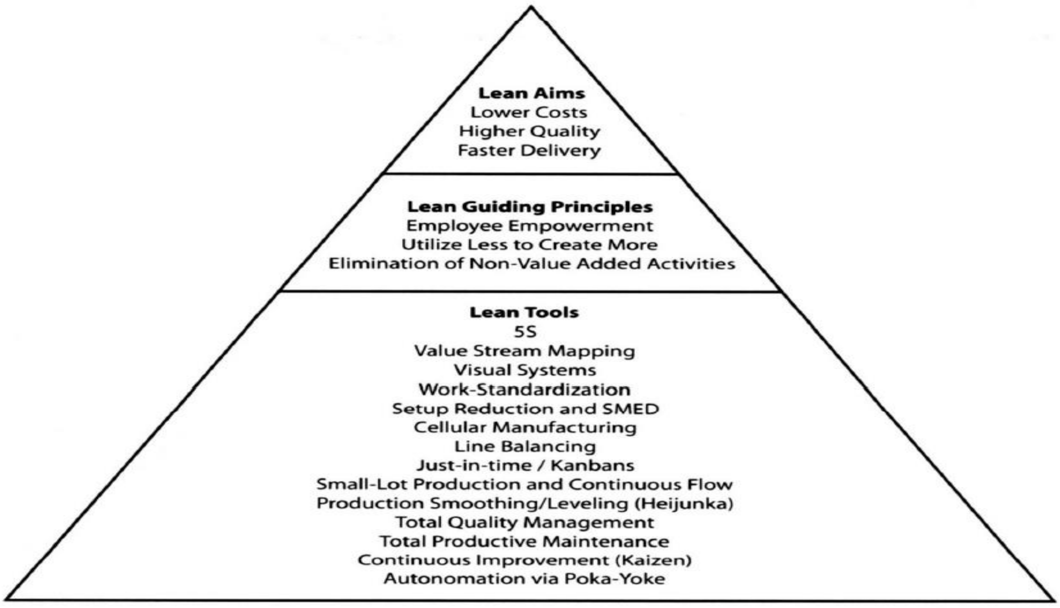


Figure 2.1: Lean Aims, Guiding Principles and tools (Abdulmalek, Rajgopal and Needy 2006, 16)

Lean aims to reduce cost, improve quality and quick delivery through waste elimination and employee empowerment. Moreover some of the goals include (Ismail 2007):

1. *Defects and wastage* – Excess use of raw material inputs, preventable defects, rework rate, excess inventory and space utilization are the problems associated with defects and wastage which do not add value to the customer. *Lean* aims to reduce defects and unnecessary physical wastage.

2. *Cycle Times* – It is the total time between when customer places an order and when he receives it. *Lean* is all about fast process speed which leads to less waste, less cost, less

complexity, and higher quality. Reduce the idle time between processing stage and set-up time. "As an example, it is much more difficult to produce in small lots in the process industry, where setup times tend to be long and it is costly to shut down the process for a changeover (Abdulmalek, Rajgopal and Needy 2006, 17)."

3. *Inventory levels* – Minimum inventory level is suitable for doing business. Excess inventory always increase cost whether in working capital requirement or in production cost resulting in low quality and high rework rate. "For example, at Dow Chemical one of the problems that existed between the company and one of its customers was excess inventory and long lead-time. At the customer site more tank carloads were present than were actually needed. In order to reduce the inventory and lead time, JIT principles were used between Dow and its customer. As a result, demand forecast accuracy increased 25%, the average distribution lead-time decreased 25%, and inventory was reduced from sixteen to six tank carloads (Abdulmalek, Rajgopal and Needy 2006, 17)."

4. *Labor productivity* – Unnecessary motion of material and labor is improved by using idle time of workers and ensuring workers exercise full commitment towards their task.

5. *Utilization of equipment's and space* – Lower inventory and lower rework rate contributes to continuous improvement by eliminating bottlenecks and working efficiently.

6. *Flexibility* – It is so far the aim of *Lean* to produce different varieties, at lower cost without adding value to customer.

7. *Output* – Continuous improvement with increased labor productivity is the desired goal of any organization and *Lean* is famous for its maximum output. "For example, at DuPont's May plant in Camden, South Carolina, where textiles are produced, JIT was used to fix the problem of product shortages, excessive backlogs, and lost or misplaced yarn at the spinning area. A pull system was utilized using a Kanban-like approach. The results were significant: 96% reduction in WIP, working capital decline of $2 million, and product quality improvement of 10% (Abdulmalek, Rajgopal and Needy 2006, 17)."

2.1.5 Lean Tools

2.1.5.1 Value Stream Mapping

Once the organization defines the "value" explores the value stream as explained in Section 2.1.2 (a). The value stream in VSM is the point at which value is actually added to the product or service by changing the market from or function to meet the customer's needs (T. Manos 2006). Value Stream Mapping (VSM) is a tool used to visually indicate all actions required to bring a product or service in logical steps from start to finish

(Gopalakrishnan.N 2010). The value stream includes both value added and non-valued added activities. The main purpose of the value stream map is to understand the flow of value. The value stream map in detail represents each process or activity, inventory between each process, setup times for each process, cycle time for each activity, timeline for the entire value stream, information flow from customer through the production process, the material flow from supplier through the production process to customer, representation of complete process, and alterations needed to be implemented. The objective of value stream mapping is to rapidly identify business problems within the context of a value stream and to create solutions to resolve them (Wang 2011).

According to the (T. Manos 2006), VSM is arguably one of the most powerful *Lean* tools for an organization waiting to plan, implement and improve on its Lean journey. "The purpose of value stream mapping is to assist a management team in visualizing and communicating not only how its organization acts today, but also how it should act in the future to influence the cost, service and quality of its products and services" (Keyte and Locher 2004, 6).

> The authors Lixia Chen and Bo Meng(2010), explained in their paper that the value stream mapping helps us to understand where we are (current State), where we want to go (Future State) and map a route to get there (Implementation Plan), which can create a high level look at total efficiency, not the independent efficiencies of individual work departments, visually show three flows material flow, product flow and information flow to identify improvement opportunities and help identify applicable Lean improvement tools and plan for development (Chen and Meng 2010).

According to (Womack and Jones 2009), VSM is an essential tool because it is much more useful than quantitative tools and layout diagrams that produce a tally of non- value creating steps, lead time, distance traveled, the amount of inventory, and so on. VSM is quantitative tools by which you describe in detail how your facility should operate in order to create flow. There are five focusing steps for developing Value stream mapping:

i. *Product family selection*

The authors Womack and Jones (2009) explained in their book that value stream mapping means walking and drawing the processing steps(material and information) for one product family from door to door in plant. They also describes that a family is a group of products that pass through similar processing steps and over common equipment in your downstream process. In general, you should not try to discern product by looking at upstream fabrication steps, which may serve many product families in a batch mode.

ii. *Current State Drawing*

"The current state map is the beginning point of the enterprise transformation: it represents how the company organizes and progress work today its baseline work condition (Keyte and Locher 2004)."According to (Gopalakrishnan.N 2010) the value stream map should not be drawn for the entire operation or multiple product lines. When drawing the current state map, the first step is to gather the information like cycle time, change over time, available work time, uptime, value added time, lead time, customer demand from the production floor or office area. The map should reflect what happens from start to finish in the entire value stream. By using the data which is collected from the production floor such as cycle time, value-creating time and lead time, the current-state map highlights waste in the value stream and helps as the foundation for developing a future state map.

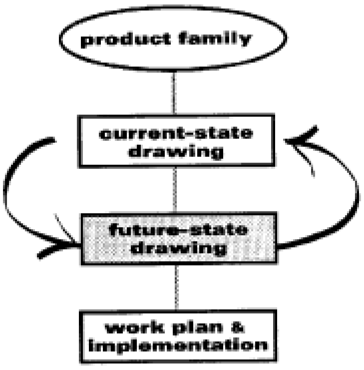


Figure 2.2: Initial Value Stream Mapping Steps (Womack and Jones 2009)

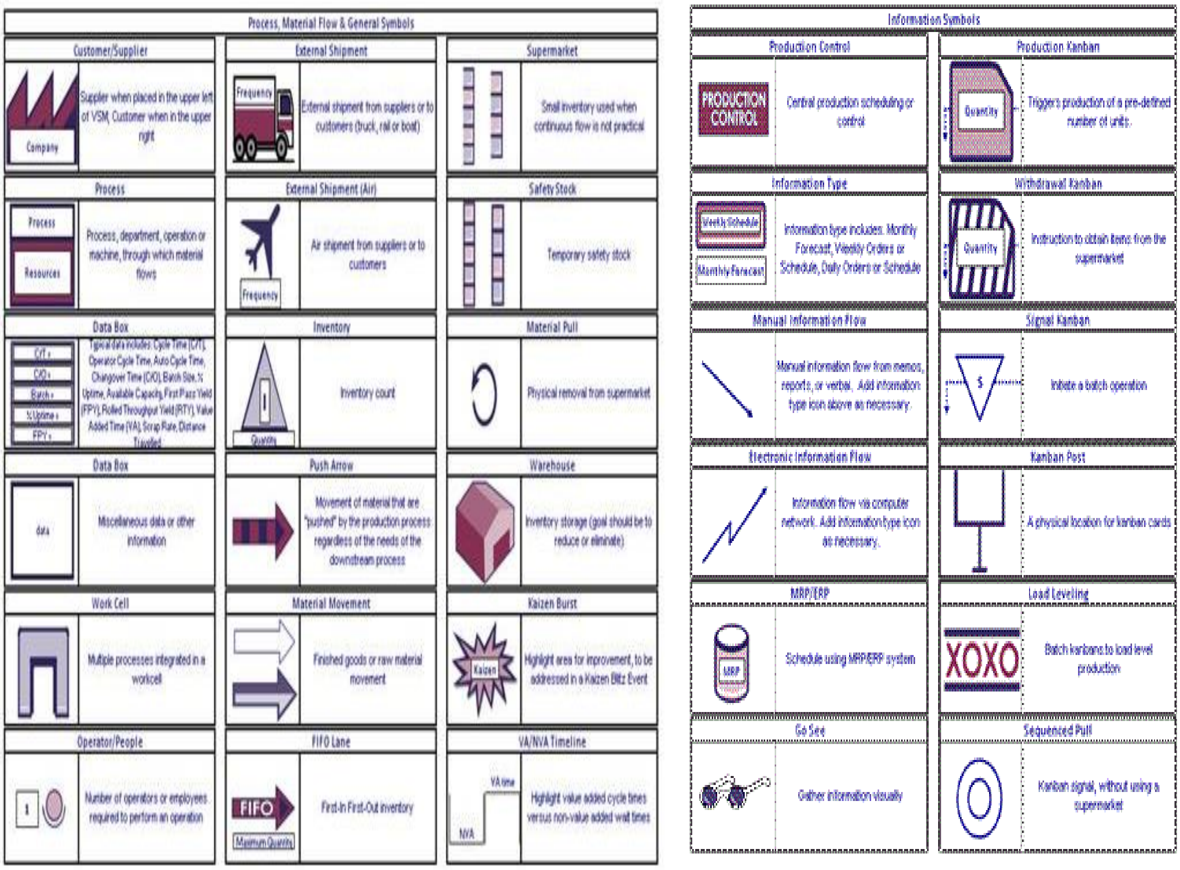


Figure 2.3: Value stream mapping tools (XL 1998)

iii. Future State Map

The authors (Womack and Jones 2009, 72)“explained in their book the purpose of value stream mapping is to highlight the sources of wastes and eliminate them by implementation of a future state value stream that can become reality within a short period of time. They also describe most useful questions for the people to help in drawing future state map those are: 1) What is takt time? 2) Will you build to finished goods supermarket from which the customers pulls or directly to shipping? 3) Where can you use continuous flow processing? 4) What process improvements will be necessary?” A future-state map is created when the waste from the current-state map is removed or at least decreased and the materials are pulled from door to door in the value stream in a smooth flow.

iv. Work Plan Implementation

The most significant and final step for any organization is to develop an in depth work plan for putting into practice. After implementing the current-state map and the future-state map, the variance flanked by two maps helps us to find the way to start applying the performance improvements. According to (Keyte and Locher 2004, 8)“the work plan should describe the required improvement projects that are necessary for realizing the future state - or when Lean practitioners refer to as kaizen”.

2.1.5.2 5-Why Analysis

5-Why is a method used for reminiscing and evaluating the problem by iteratively asking ‘why’ or ‘what was the problem’ to find the root cause of the problem. The famous saying “To err is human” has been the attitude of individuals but learning from the mistake is the only way to redeem. As Søren Kierkegaard, a famous Danish philosopher, said, “Life can only be understood backwards; but it must be lived forward.” The 5-why analysis is easier than other tools without requirement of large detailed investigation from many resources. “The 5-Why method helps to determine the cause-effect relationships in a problem or a failure event (Sondalini 2014, 1).” When the mangers are unsure of the root cause of the problem, they can question why making Why Tree. Sondalini (2014) explains 5-why analysis can be done, “By repeatedly asking the question, ‘Why?’ you peel away layers of issues and symptoms that can lead to the root cause.” And furthermore adds, “But it is never certain that you have found the root cause unless there is real evidence to confirm it. (Sondalini 2014, 1)”

First we start with the problem statement and ask why it happened. The answer to the question evokes to second why question. And iteratively the second answer becomes the third Why question and so on. This technique also represents the five rule of thumb (Sondalini 2014). Simply refusing to believe in each answer leads to finding the possibility of root cause of the consequence.

For instance, Ohno's illustration of root cause analysis is:

"1. ***"Why did the robot stop?"***
The circuit has overloaded, causing a fuse to blow.
2. ***"Why is the circuit overloaded?"***
There was insufficient lubrication on the bearings, so they locked up.
3. ***"Why was there insufficient lubrication on the bearings?"***
The oil pump on the robot is not circulating sufficient oil.
4. ***"Why is the pump not circulating sufficient oil?"***
The pump intake is clogged with metal shavings.
5. ***"Why is the intake clogged with metal shavings?"***
Because there is no filter on the pump. (Abilla 2014)*"*

The cause and effect tree or why tree is built to map the root of the basis. This method is also known as Fault Tree Analysis. Why Tree will help to see even the simple problem can have numerous cause-effect branches. The why question can be more or less than 5 times as research showed 7 whys is better to undercover the truth behind the problem (Sondalini 2014).

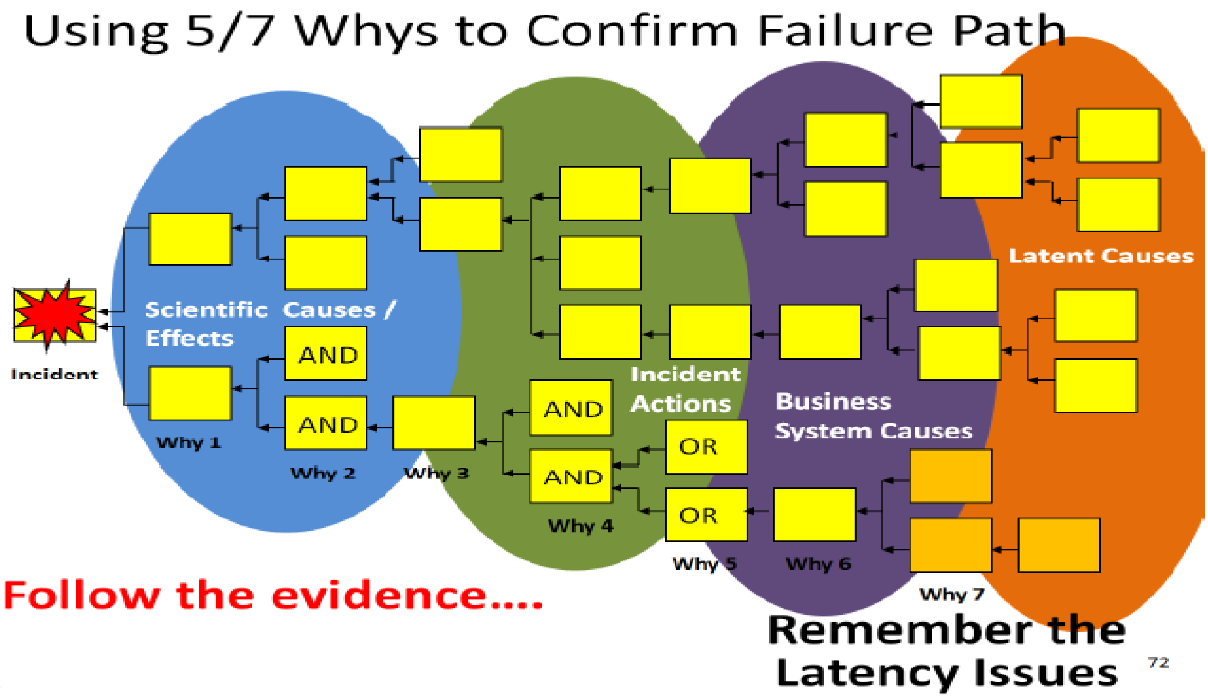


Figure 2.4: The Progression of Failure Incidents and Events (Sondalini 2014)

Ishikawa diagram or cause and effect diagram is another tool to visualize "5-why". This method is also known as Fishbone Diagram (Abilla 2014). The main head of the Fishbone represents problem or effect in the form of question. The major bones are main causes of problem and minor bones represent the details of item involving people, material, equipment, information, environment etc. which may or may not be applied to the specific problem (See fig 2.4) The main goal is to correct something that is wrongly done or reduce it or totally eliminate the root cause of problem.

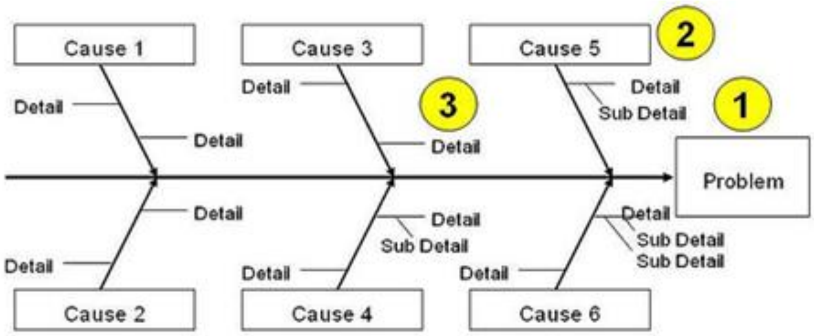


Figure 2.5: Cause and Effect Diagram (Abilla 2014)

Brainstorming through diverse thoughts of people ensures clarity and potentiality to get to right path (Abilla 2014). Involving many people to give their thoughtful advice also gives them sense of ownership. When a people feels themselves part of each process, they tend to contribute more consequently to non-resisting behavior for change as change is with them, for them and by them.

2.1.5.3 4M's

The 4M includes Machine, Man, Material and Method these all together is used to attain the basic stability. General stability in Lean manufacturing means the company should be able to produce steady results all the time. According to " (Art 2005, 9) in simplest sense the basic stability implies general predictability and consistent availability in terms of manpower, machines, materials and methods. He also describes without the fundamental items like machine uptime or human resources in place the company cannot run a production line and achieve perfect flow or pace to takt time." With enough people, machinery and material the company can achieve the perfect tack time flow and basic stability. Achieving the basic stability is the basic improvement for the Lean manufacturing which is described below:

1) Man power: This is the main consideration to increase the stability. By good work force the manufacturing companies can achieve stability, for this the companies should provide and appropriate training to their employees.

2) Machines: If the theoretical capacity of the machinery meets the customer demand than the machine works flawless. If the capacity doesn't meet the customer demand then it is a sign of basic stability problem.

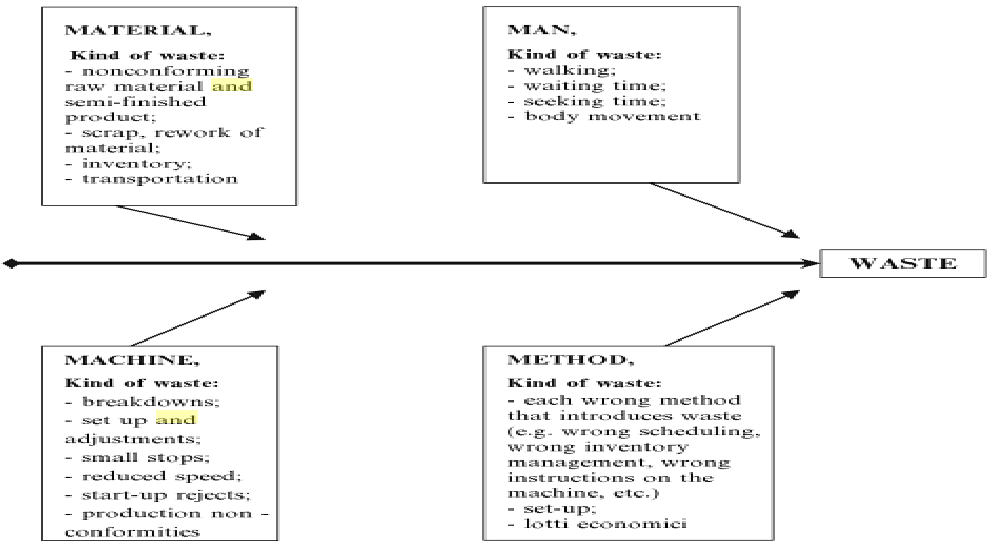


Figure 2.6: 4M's (Chiarini 2013, 19)

3) Materials: The Lean is all about reducing the wastage, reducing the time between orders received to the order produced and dispatched. Normally Lean validates reduction in the inventory but if there is an occurrence of instability then there is a chance to increase in inventory.

4) Method: The main aim of Lean thinking is reducing the waste and establishing improvements by slight changes in the way of performing and doing things. This is the last step to achieve the basic stability. According to " (Art 2005) the standard is defined as a rule or way to do things. The unintentional side effect is that the people are not encouraged to question or change the rule. But the Toyota definition for standard is different. A standard means rule or basis for comparison. A standard is nothing more than a tool to measure how we are doing".

2.1.5.4 5S waste management

With the rise in globalization, the consumers have become more demanding and so are stakeholders. The growth and adaptation of company to change is so intensified due to high competition. Hiroyuki Hirano constructed 5S framework, an extension work on his just-in-time production systems, to eliminate waste or non-value added cost (Shil 2009). According to Hirano, "Without the organization and discipline provided by successfully implementing the 5Ss, other manufacturing tools and methods are likely to fail (Shil 2009, 35)." 5s is a motivating Lean tool for everyone in the company to get involved in the improvement process. The 5s in Japanese are Seiri, Seiton, Seiso, Seiketsu and Shitsuke also known as Sort, Straighten, Shine, Systemize and Sustain and also "Security" as the 6th optional S. "Alternative Americanization's have also been introduced, such as CANDO (Cleanup, Arranging, Neatness, Discipline, and Ongoing improvement) (Shil 2009, 36)." However the interpretations are 5s practice techniques have done wonders removing waste and smoothing the flow of order batches.

- Sort (Seiri)

The essence of this technique is related to Just-In-Time philosophy by sorting or arranging by asking three questions of any item (Shil 2009, 37):

a. Is the item needed?
b. If it is needed, how much quantity is required?
c. If it is needed, where should it be located?

It indicates whether the item should be disposed, relocated or leave it just as it is when the audit team cannot decide on outcome of an item.

- Straighten (Seiton)

The removal of unnecessary items creates clarity and efficiency in accessing and retrieving as quickly as possible. Motion economy is the focused principle of Seiton and enables the removal of human motion waste. It helps in saving time, energy and effort by intelligent location of parts and equipment. Basically its benefits to the organization are (Shil 2009):

a. Strategic location helps eliminate motion waste.
b. Clear identified location eliminates the waste of searching and returning items.
c. Reduce employee frustration be saving time and effort.

- Shine (Seiso)

"First impression is last impression." Keeping clean and tidy work environment is essential from the perspective of external viewpoint. A clean workplace can make critical difference between gaining new business or reputation (Shil 2009). The other benefits include:

- ✓ Creating more comfortable and safe working environment
- ✓ Clear visibility reduce searching time
- ✓ Good impression at the time of plant tour
- ✓ Cleaning also helps inspecting or maintaining activities. Can be viewed as problem detection before hand

- Systemize (Seiketsu)

"Seiketsu defines processes that sustain the improvements to date and drive further improvements. The first 3 elements (3S) are made habitual by incorporating 3S duties into regular duties. (Shil 2009)" Standardized clean-up is defined to measure and maintain the cleanliness including personal tidiness. Personnel are trained to detect mistakes and eventually correct them.

- Sustain (Shitsuke)

Shitsuke means 'Discipline' or 'commitment to practice' the first 4S by making a routinely habit which are constantly monitored. It secures the first 4S together through self-assessments and gain continuous productivity improvement. "Senior management must realize that 5S is a part of the organizational culture rather than a task to be performed yearly (Shil 2009)." The communication about the benefits of 5S must encourage and motivate people in their voluntarily observation to take action.

- Security

Security is a fundamental concern for any company which is a requirement rather than a choice. The daily maintenance and regular check plan of machinery will not only increase the performance of machine but also secure company from the future uncertainty of sudden machine breakdown leading to deficit and delay in order demand. Unsatisfied customer is unfavorable situation for any company as it increases competition and decrease in customer loyalty.

2.1.5.5 Kaizen

The word Kaizen was termed by Masaaki Imai in his book *KAIZEN – The Key to Japan's Competitive Success (1986)*. In Japanese: KAI – change, ZEN – to make good (improvement) which typically means "continuous improvement". Suarez-Barraza, et al., (2011) simply states kaizen as, "they work with their hands but use their brains to think"; they symbolizes staff and how they voluntarily solve daily problems and value their work. The definition of KAIZEN depends on how the companies adapt their staff involvement in continuous improvement process.

Both *kaizen* and *kaizen events* are regarded differently than the traditional mode of improvements. For instance, in North America, organization uses *kaizen* as priority to huge and complex changes to earn profit (A. Manos 2007).

Type of improvement	*Kaizen*	*Kaizen* events	Traditional improvements
Large or small scale improvements	Small, steady improvements over time.	Big, fast, simple improvements in three to five days.	Dramatic, one-time, complex, technologically based.
Who is affected	Individuals or groups.	Team based.	Top-down approach.
Costs	Low cost.	Low cost.	High cost usually.
Buy-in potential	Good because employee(s) came up with the ideas.	Good because employee(s) came up with the ideas.	More difficult because users weren't asked their opinion.
Intended benefits	Can be used for any benefit, including quality of work life.	Usually focused on reducing time or nonvalue added activities.	Meant to revolutionize an organization.

Table 2.1: Difference between Kaizen, Kaizen events and Traditional Improvements (A. Manos 2007, 47)

These simple Lean tools are easier to apply but getting it done by the people is difficult. Perhaps it's the typical human behavior to want big improvements all at once than simple and steady improvement for long term. "Lean is not the tools. Lean is in your head and heart. It's how you approach your job, customers, suppliers and processes (A. Manos 2007, 47)."

Furthermore, it is a business strategy that involves everyone in an organization contributing towards continuous improvement by reducing waste without high capital investment to increase efficiency and work flow. Hamel(2010) describes Kaizen as:

> Kaizen is much more than an event; it is a philosophy, mindset and, for breakthrough performance, a most critical vehicle to achieve strategic imperatives and execute value stream/process improvement plans (Hamel 2010, 36).

In the book of Hamel(2010), a survey on Lean implementation showed that 59% of the 2,500 business people were planning or in early stages of Lean while 7% were enjoying the fruitful benefits of "advanced" level of Lean and 34% at growth. Furthermore the study also encountered companies primary barriers were:

1. Pushback from middle management (36%)
2. Lack of implementation know-how (31%)
3. Employee resistance (28%), and
4. Supervisor resistance (23%) (Hamel 2010, 3).

Excluding lack of implementation know-how, rest all the barriers are related "to change management and transformation leadership nature (Hamel 2010)." However all the barriers are interdependent to each other and kaizen event plays a significant role in implementation of know-how.

THE HERITAGE OF KAIZEN

Kaizen or continuous improvement has a well-built association with two sources: the Training within Industry (TWI) initiative and the plan-do-check-act (PDCA) cycle (Hamel 2010). Surprisingly both began its journey at roughly the same time during world-war II in United States and developed afterwards in Japan as Lean thinking. Between 1940 and 1945, TWI brought a change in training people to improve production by decreasing waiting time of 5 years to 6 weeks to master the art and science of lens grinding (Dinero 2005). Dr. Deming initiated plan-do-check-act cycle and later gave credit to his mentor, Dr. Walter Shewhart, which is both known as Deming cycle or Shewhart cycle (Koehler and Pankowski 1996).

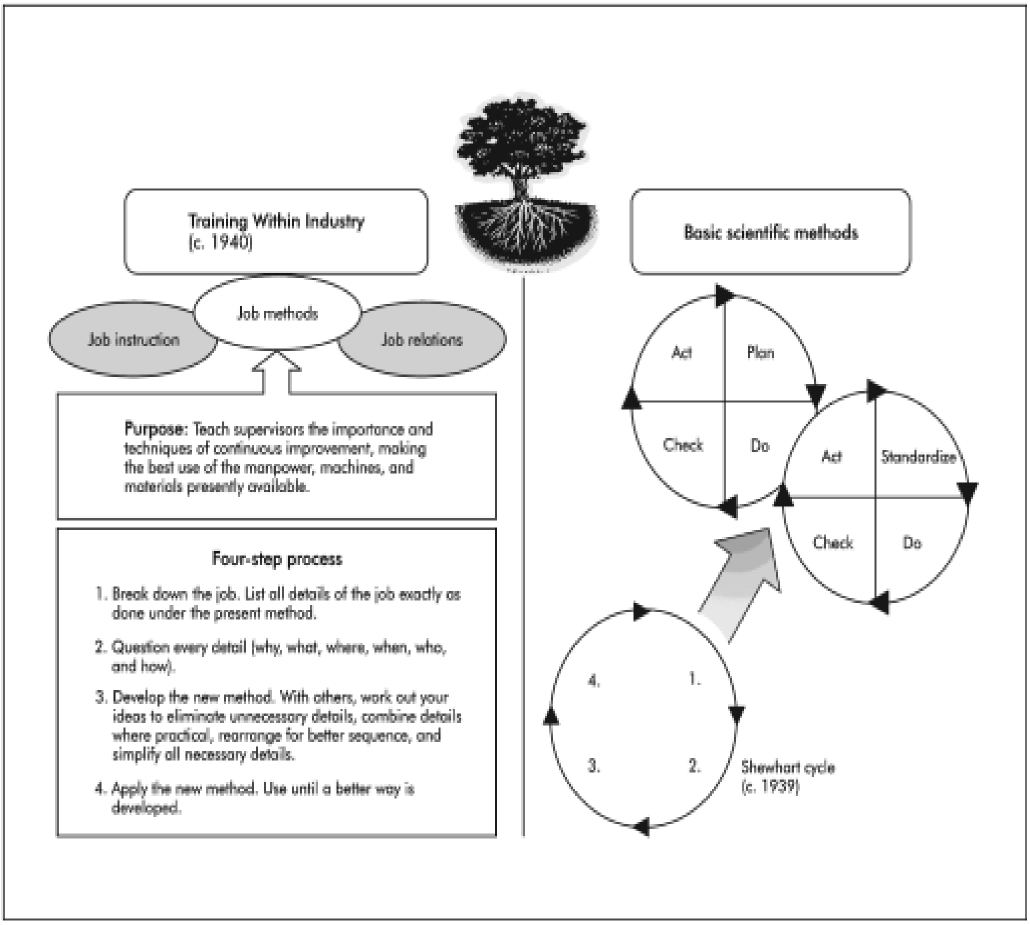


Figure 2.7: The Heritage of Kaizen (Hamel 2010, 17)

1. *Training within Industry:* TWI astonishingly had a great impact in increasing U.S. wartime production (Hamel 2010). The success of decreasing scrap, manpower and training time with increase in production made TWI effective tool of that time. The four programs in TWI were (Dinero 2005):

    a. Job Instruction Training (JI): Workers are trained to work correctly and safely; and be efficient enough by reducing rework, scrap and damage of tools and equipment.
    b. Job Relation Training (JR): Employees are trained to solve personnel problems using an analytical, restrained method by treating people as individuals and understanding their position at each level.
    c. Job Methods Training (JM): Employees are trained in ways to improve performance of each job to achieve high quality with high quantities and in less time and effort of man, machine and materials.
    d. Program Development (PD): Employees are trained to solve unique production problems through training personnel to solve technical problems.

2. *Shewhart Cycle (PDSA):* Shewhart Cycle contains four continuous steps: Plan, Do, Check and Act which was believed to overall total quality improvement. As the word implies the steps are:

a. Plan- “Establish the goals for the targeted process and identify required changes (improvements) to achieve the goals (Hamel 2010, 18)”.
b. Do- Implement the effective solution or changes.
c. Check- Compare results if the targeted results are met and how much has it improved.
d. Act- Priority to previous step results are standardized, stabilize and sustain and go back to first step again to explore next possible problem for continuous improvement (Hamel 2010).

Benefits from kaizen and kaizen events:

Most of the managers are busy increasing the profit of organization to set their own mark and dignity rather than focusing on working people’s feelings, mentality and other intangible benefits. There are several benefits but Manos(2007) has categorized it into qualitative and quantitative benefits from *kaizen* and *kaizen events.*

a) Quantitative benefits

The quantitative benefits are tangible results that are measured and monitor the time, effort and money spent for specific improvements such as (A. Manos 2007):

- Money saved
- Time saved (Contributing to money saved)
- Less manpower
- Reduced lead time or cycle time
- Shorter distance travelled
- Reduced inventory
- Value vs. non-value added substance
- Decrease processing time

b) Qualitative benefits

The qualitative benefits are intangible results related to “feeling” that human show or behave in *Lean* thinking process. Certainly these types of benefits are not easier to measure. For instance, if we consider 5s *Lean* tool, the outcome can be quantified as shorter travelling distance within a workplace, high machine performance, lower machine breakdown, fewer safety incidents and lower inventory (A. Manos 2007). However the human side of *Lean* is not analyzed.

> If you listen to participants at a successful event, you’ll hear things like: “Now I can find things around here,” or “These changes will help reduce my stress level,” or “Look how much more room we have. (A. Manos 2007, 48)”

Moreover it is the lasting human impression which is important to understand the qualitative benefits that organization enjoys without spending much monetary value on it. *Kaizen* comes with the serious commitment of company's vision to improve. The change in the way of thinking is what *Lean* and its tools are all about not the process or system of management.

2.1.5.6 SMED (Single-minute Exchange of Dies)

Globalization and increased customers choices has influenced high competition among manufacturers. Early manufacturing application for duration of setup time was not much of an issue because customers were willing to wait for the product. Times have changed now, manufacturers who offers quality product at lower price and at right time are the only ones who can survive the competitive market. Companies should be as flexible as possible due to demand for same quantity of parts but with mix of varieties and with smaller delivery quantities. The requirement of smaller batches and with smaller lead time can only be possible by reducing setup time to minutes instead of hours. The single-minute exchange of dies (SMED) is a methodology to reduce setup process and setup process is a "time required to go from the end of the last good from one batch to when the first good part of the following batch is produced (Santos, Wysk and Torres 2006, 120)."

Shigeo Shingo, an expert engineer behind Toyota Production System, developed SMED methodology from 1950 to 1980s which achieved quick and good results without high investments (Santos, Wysk and Torres 2006). During 1960s, stamping press had setup time more than a full day which was bizarre. This was when Shingo hoped to bring down the setup time in few minutes. Just-in-time (JIT) is also referred to reduction in setup time process. The possibility of defective parts at setup has also increased the build to stock. For instance, "Let us suppose that an order for 500 parts is made; the setup process takes 3 hours to get the press ready, and the defects rate is 6 percent. The machine will be scheduled to produce 530 parts to cover the possible defective parts. If the 530 parts were acceptable, it would be necessary to store 30 parts, with the related inventory costs (Santos, Wysk and Torres 2006, 123)." In order to reduce the setup process either we need to make faster setup time or increase the production lot size. With the help of SMED, Shingo was able to reduce setup time from 8 hours to 58 seconds for a screw machine manufacturer and 24 hours to 2 minutes and 40 seconds for press setup at Mitsubishi Company which was exceptional.

Shingo realized the two types of operations that make up a process change: *External setup* is related to the "operations that can be carried out with the machine running and producing parts for the previous lot (Santos, Wysk and Torres 2006, 126)" and *Internal setup* is related to "operations that required the machine to be idle while they were performed (Santos, Wysk and Torres 2006, 126)". First separating internal and external setup and converting internal setup to external setup can economically reduce setup time. It is essential to know all the steps before getting ready for the setup process. Most of the time is wasted in: moving the materials to the warehouse after stopping the machine, looking for dies and tools, taking the tools which are not used before starting the machine and so on. Before starting the machine it is necessary to answer following questions: “What has to be done before starting the change? How many screws are necessary to fix the die? Of what type? What tools are necessary? Are they prepared properly? Where the tools should be placed after using them? (Santos, Wysk and Torres 2006, 131)”

A simple questionnaire checklist before each setup process should be checked to verify in advance the availability of tools, ready and prepared to be processed. The checklist or check panel should be placed near the machine so that the operator can use minimum time in transition of tools. For instance, “the worker can visually check if all the necessary tools are located in the right place or if a needed tool is missing (Santos, Wysk and Torres 2006, 132).” Even functional check can be done by using special device for checking the molds before placing them when the machine is stopped. The longer setup time, in traditional press exchange process, was due to unloading old mold and uploading new mold in the machine after the machine was stopped. In this way the worker wasted their time in slow movement of transportation when machine was idle. SMED methodology solves this problem by employing two employees and reducing the idle time of machine. Before changeover process, the worker could collect new mold, leave it next to machine and install it when changeover is required then take the old mold to the warehouse after operating the machine.

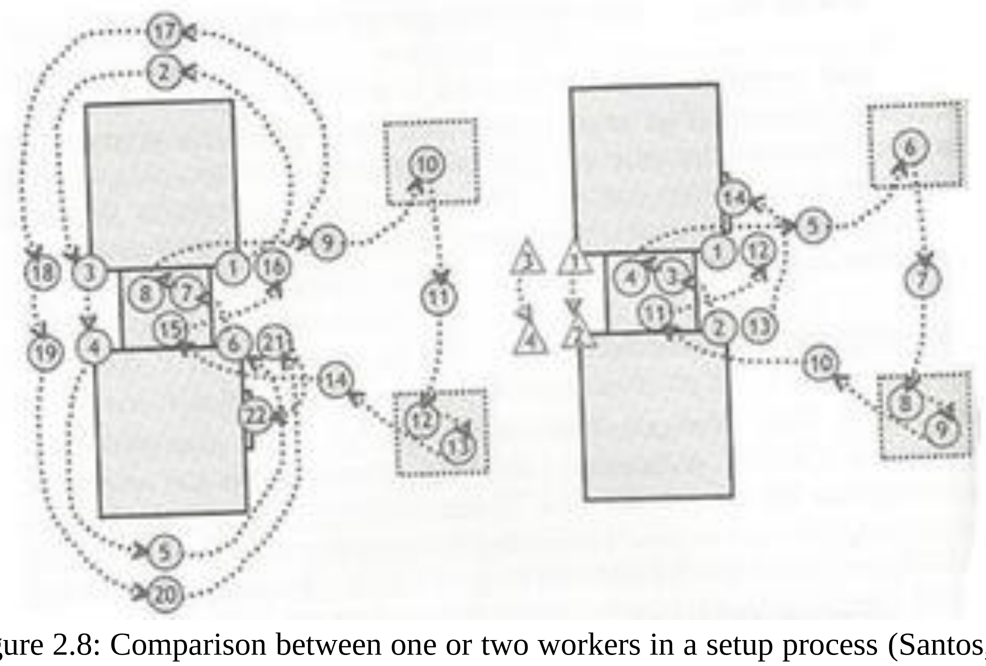


Figure 2.8: Comparison between one or two workers in a setup process (Santos, Wysk and Torres 2006, 138)

2.1.5.7 TPM (Total Productive Maintenance)

The development of TPM was first introduced by Nakajima in 1970s as a new maintenance management philosophy in Toyota's improvement process (Santos, Wysk and Torres 2006). TPM focuses on zero breakdowns, no small stops and zero defects to maximize the Overall Equipment Efficiency (OEE) ratio. "OEE quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run (Gulati 2008, 182)."

Calculating OEE,

$$OEE = Availability \times Performance \times Quality$$

TPM is a proactive approach of an equipment-focused improvement effort in reducing the deficiencies in equipment performance, technicians, operators and engineers working habit. The change in mindset of them together with each TPM step can improve equipment productivity. TPM seeks for optimizing and minimizing equipment breakdowns, by increasing equipment efficiency. "Under the TPM concept, equipment operators become owners of their assets. Working closely with maintenance, they take care of all details that will preserve the assets in the best possible condition (Gulati 2008, 186)."
The eight pillars of activity in TPM, with an ultimate goal of increasing uptime, reducing cycle time and eliminating defects are (Gulati 2008, 186):

i. Autonomous maintenance
ii. Focused improvement – Kaizen
iii. Planned maintenance
iv. Quality maintenance
v. Training and development
vi. Design and early equipment management
vii. Office improvement
viii. Safety, health and environment

Autonomous maintenance is a key pillar where operators empower modification of the program according to the situation and from required observation. The operators are responsible for the operation and act immediately for small adjustments like fixing the loose parts, checking and reporting noises, vibrations, or temperature rise with the equipment. "An important factor in the success of the TPM program is the pride that operators experience from the optimal condition in which their equipment is preserved (Gulati 2008, 187)." Adequate training and awareness is an essence for motivation of employees and effectiveness improvement.

Therefore, the elimination of six big losses (Breakdowns, Setup and changeover, Idling minor stoppages, reduce speed, defects and reworks, and starting losses) contributes to maximizing the overall equipment efficiency in TPM (Santos, Wysk and Torres 2006). Breakdown can be motor and tool failure, unplanned maintenance, overheat which lead to downtime loss and stoppage in between the process. Changeover or setup time is another type of loss which can be reduced using SMED tools. Small stops or speed loss is caused by traffic of components, minor adjustment, cleaning and checking which is not required for maintenance. The loss related to quality i.e. rework and defects are the most expensive of all the losses which could be completely eliminated or at least reduced to minimum. TPM is a roadmap to reduce all this losses. A deeper understanding of TPM and highly committed employees or leaders can achieve zero defects and zero breakdown in daily production process.

2.1.5.8 Kanban

Kanban was developed by Taiichi Ohno which is a Japanese word meaning “sign” or “signal”, “It can be a simple card, often with a bar code, that communicates to the parts supermarket which particular parts will be required to assemble the custom tailored computer just ordered. As Kanban’s arrive, parts are pulled and sent to the assembly shop floor (Henderson and Larco 2003, 26).”It is a simple Lean tool to decrease inventory and lead time of the product. It is a visual technique that signals an action when it is needed, at right quantity and at right time. It is also known as pull systems or Just-In-Time production.

> “The final assembly line, having received the schedule, proceeds to withdraw the components necessary, at the times they are required and in the quantities they are required, from the feeding work centers or subassembly lines. These work centers or subassembly lines produce in lots just sufficient to replace the lots that have been removed. However, to do this, they also have to withdraw parts from their respective feeder stations in the quantities necessary. Thus, a chain reaction is initiated upstream, with work centers only withdrawing the components that are required at the correct time and in the quantities required (Wong 2014, 2).”

Kanban Card is used as the indicator for the Kanban operating system and well-trained group of operators are only required for the practice. The withdrawal of more parts from the buffers is not allowed so the operators must be well disciplined. The work centers should only produce which are removed from the buffers according to the Kanban production system. The work center should not pass defective items along the production system. It affects the flow of parts in the final stage of the process. The minimum number of Kanban is favorable to reduce the inventory level as each Kanban represents standard container. The small fluctuation in the demand pattern of the final assembly line is only desirable for the usage of Kanban system. The small fluctuations can be handled by increasing overtime or by hiring temporary operators. (Wong 2014)

2.2 Theory of Constraints

The Theory of constraints is a practice or an approach for identifying the constraint i.e. the most important blocking element that position on the way to achieve a goal and then methodically improving that constraint until it no longer is the blockage. This constraint is also called as a bottleneck in the manufacturing process. For an organization to have an ongoing improvement process, it is necessary to answer these questions?

- *What to change?*-"Assessment of what are the constraints to improved performance. Applying the TOC to the "What to change" question often leads to the identification of an organizational constraint" (Donald and Raanan 1996).

- *What to change to?*-"devising simple, practical changes to the core problem/constraint identified. The TOC emphasizes that only simple solutions have a real chance of working in a real organization" (Donald and Raanan 1996).

- *How to cause the change?*-"developing strategies and actions to break undesired constraints and manage constraints in desired areas. An important aspect of this phase is to create ownership and commitment throughout the organization" (Donald and Raanan 1996).

The constraint may be anything that limits the process flow of the organization towards the goal. The theory of constraints (TOC) introduced by Eliyahu M. Goldratt in his 1984 book titled *The Goal*, this concept helps organizations to achieve their goals. The main ability of TOC is to create an extremely strong focus towards a single goal (profit) and to eliminating the main obstruction (the constraint) to reaching additional of that goal. According to (Woeppel 2010, 18) "Constraint management begins with one underlying assumption; the performance of the system's constraint will determine the performance of the entire system".

2.2.1 The Five focusing steps of TOC

According to " (Seth n.d., 4) One definition used by Eli Goldratt for TOC is a thinking process that enables people to invent simple solutions to seemingly complex problems. He also assumes that the system as a chain "a chain is no stronger than its weakest link". However the system's performance is mainly limited by its constraint. So, our procedure is to manage the system chain and also find the focal point of the constraint. The main goal of these five focusing steps is to ensure continuing improvement exertions are focused on the organizations constraint.

1. Identify the Constraint:
2. How to exploit the constraint:
3. Subordinate the constraint
4. Elevate
5. Repeat

The first step is to identify the constraint, proceeding to identify the constraint; two basic requirements must be fulfilled to gain potential for the analysis.

a) *State the system and its determination (goal).*

It is clearly explained that the roots of TOC is entrenched into the manufacturing often the organization is primarily distinct as the manufacturing process or the plant. The determination of the manufacturing process is to support the entire group to achieve the goal. According to (H. Dettmer 1997)*, "A goal can be defined as the result or achievement toward which effort is directed. The essence of management is recognizing the need for change, then initiating, controlling and directing it, and solving the problems along the way".* One common goal for most of the manufacturing companies is to make more money in present as well as in future too. Even though making money is a constricted necessary condition, more or less for every organization. Making money is definitely provides the resources of fuel ongoing process and growth irrespective of other goals. The necessary condition can be defined as "*a circumstance indispensable to some result, or that upon which everything is contingent.* (H. Dettmer 1997)". The next question is how to measure the system's goal (i.e. making money?)

b) *Determine how to measure the system determination*

Actually the process of organization is to purchase the raw materials from vendors and add value by converting those materials into products their customers purchase. Now the interesting question is that how do we measure the effects of making money. The TOC helps to classify that what a firm organizes with its money in three ways i.e. throughput, Inventory, Operating Expenses. Goldratt has generated an easy relationship for defining the effect of local action on the way to the system goal.

i. *Throughput (T)*

The throughput is defined as "the rate at which the organization generates money through sales" (H. Dettmer 1997). In TOC terms the throughput is also assumed to be Value added work for the product. The throughput is also like the manufacturing process that produces a value when the clients are willing to pay additional money for the manufactures for the product than the manufacturers paid to their vendors for raw materials and services for that product. "Therefore, Throughput is calculated by taking gross revenue minus all totally variable (with the order shipped) expenses- purchased material cost, sales commission, any subcontract expenses (again, associated with the orders being shipped) and freight if you prepay and then add" (Woeppel 2010).

ii. *Inventory (I)*

Return on investment is also an important quantity of profitability. In TOC terms this is also known as Inventory. The money apprehended within the organization is known as inventory. “Inventory is defined as all the money the system invests; purchasing items it intends to resell (Woeppel 2010, 13)”. To calculate the Return on Investment (ROI)

The concept of Inventory is measured by two variables, one is Fixed Inventory and other is Variable inventory. The fixed inventory is all assets like buildings, equipment, fixtures these are at depreciated cost. Whereas the variable inventory are raw materials, work in process and finished goods needed. In order to improve the manufacturing operations one should mostly concentrate on reduction of variable inventory cost.

iii. *Operating expenses (OE)*

In general, the Operating expenses are defined as the actual money taking from your account in order to produce the products or services to gratify the buyer. According to (H. Dettmer 1997)“All the money spent to turn inventory into throughput is operating expenses”. In order to increase the profits, the company desires to produce sufficient throughputs to pay all operating expenses. The operating expenses may be fixed or variable. The variable expenses are direct labor salaries etc.

iv. *Measurements*

The performance of system is mainly depends up on variables 1) Return on Investment and 2) Net Profit. In any organization the Throughput, Inventory and Operating Expenses (T, I, OE) are tied together to measure the system performance.

$$\boldsymbol{Net\ Profit = Throughput(T) - Operating\ Expenses(OE)}$$

$$\boldsymbol{Return\ On\ Investment(ROI) = \frac{Net\ Profit}{Inventory(I)}}$$

$$\boldsymbol{Productivity = \frac{Net\ Profit}{Operating\ Expenses(OE)}}$$

$$\boldsymbol{Inventory\ Turns = \frac{Throughput(T)}{Inventory(I)}}$$

Goldartt stated that all of the three values are interdependent to each other if one affect in the system it automatically change the output of other two values. For example if there is any increase in the throughput by increasing sales automatically the inventory and operating expenses also increases. The increase in sales will automatically affect the production in inventory and spending on variable cost therefore the change in inevitable.

There is a way to make more money without increasing the sales also, i.e. Producing with a less inventory and spend less on operating expenses. So automatically the net profit will increase and more money runs into the system.
These three measurements do not fully satisfy the system in order to make decisions. Because one can think about what type of machine can be used to increase the throughput? And also reducing the labor or shifting them from one place to another can increase throughput? In addition to calculate the values for these three terms, the actors in the system must understand how the manufacturing process works and they should also understand the reason and consequence relationship that administrate the behavior of the manufacturing system.

After defining fundamentals of the system's goal and all its measures, let's travel to next step the Five Focusing Steps:

1. ***Identifying the Constraint***

   In the above section we defined that the constraint is a limiting factor for the system. The first step is to find out that what are the physically limiting elements that are preventing to generate throughput? So, constraint can be identified anywhere in the system process, mostly they are identified in four places 1) when the system is not generating enough sales 2) when the system does not have enough material to generate the finished goods 3) when the system does not have enough capacity of resources like machinery etc. 4) "Look for large accumulations of work-in-process on the plant floor. Review equipment performance data to determine which equipment has the longest average cycle time (Vorne 2010)."

2. ***How to exploit the Constraint***

   Once the constraint is found, make immediate arrangements to improve the throughput of the constraint by using existing resources. "In other words, what can we do to get the most out of this constraint without committing to potentially expensive changes or upgrades?" (H. Dettmer 1997, 14).

3. ***Subordinate the Constraint:***

   The step 1 identifies the constraint and step 2 defines what to do about the constraint. This step gives us how to adjust the system in order to get maximum value of the system. "Review all other activities in the process to ensure that they are aligned with and truly support the needs of the constraint (Vorne 2010)".

4. ***Elevate***

   If the constraint still exists, that means the step 2 and 3 were not adequate to eliminate the constraint. So, we need to think about adding new resources to the system and increase their capacity by giving new machinery, extra labor, process improvements etc. This step is able to occupy extensive investment in time, labor, money and energy.

"Elevating the constraint means that we take whatever action is required to eliminate the constraint (H. Dettmer 1997, 15)". After this step the constraint is no more present in the system.

5. ***Repeat***

In the step 4 we are breaking an existing constraint, then we go to step 1 and find out the new constraint in the system. Finding a constraint and breaking it, is an ongoing process improvement in the system.

These five focusing steps are interrelated to those three questions as stated earlier in Section 1.3

2.3 Combining Lean and TOC

The concept that "Toyota Production system is better known than the Theory of constraint is just a matter of birthdays than merit. (H. W. Dettmer 2014)" In fact Eliyahu M. Goldratt, the father of Theory of constraints, was just a baby when Taiichi Ohno and Eiji Toyoda were forming Toyota Production System. According to Nave (2002), "All change programs challenge the existing ways of doing things. This necessitates asking what purpose a specific policy serves and whether that purpose is still valid in today's environment (Nave 2002, 77)." The hybrid of the two philosophies is potential for more productivity and robust improvement.

Program	Lean Thinking	Theory of constraints
Theory	Remove waste	Manage constraints
Application Guidelines	1. Identify waste 2. Identify value stream 3. Flow 4. Pull 5. Perfection	1. Identify constraint 2. Exploit constraint 3. Subordinate processes 4. Elevate constraint 5. Repeat cycle
Focus	Flow Focused	System constraints
Assumptions	Waste removal will improve business performance. Many small improvements are better than systems analysis	Emphasis on speed and volume. Uses existing systems. Process interdependence.
Primary effect	Reduced flow time	Fast throughput
Secondary effects	Less variation. Uniform output. Less inventory. New accounting system. Flow-performance measure for managers. Improved quality.	Less inventory/waste. Throughput cost accounting. Throughput-performance measurement system. Improved quality.
Criticisms	Statistical or system analysis not valued.	Minimal worker input. Data analysis not valued.

Table 2.2: Comparison of improvement programs (Nave 2002, 77)

1. *Similarities*

Both *Lean* thinking and TOC emphasize on continuous improvement with the objective of higher profit. Value is what both agree on as customer's perspective of value by increasing the throughput rate for TOC. Both *Lean* and TOC, the early stage starts with defining the system and understanding the process flow of the system in order to acknowledge the customer value created by a chain of inter dependencies (Moore and Scheinkopf 1998).Every person in the organization work together for the efficient flow of the inventory into finished goods. "Simplify and goods will flow like water (Moore and Scheinkopf 1998, 22)." Pull principle in both is also common technique to control the flow of product from the market. And seeking perfection in *Lean* is what it is all about. TOC also bases on removing constraints and working efficiently in a pursuit of ongoing improvement in a sense that the endless journey of continuous improvement will continue in future to create a perfect and flawless process. Furthermore, the worker participation in improving system is equally important in both cases. Workforces are the source of the improvement effort and an attitude of “This is my job and no one else than I am fully responsible for it” has to come within them.

2. *Dissimilarities*

1. *Cost*

   The primary goal of any organization, whether they call it increasing efficiency, reducing waste, zero defects, continuous improvement, is to make cash and increase the profit or return on investment. TOC cost strategy is viewed as “*What is the impact on throughput of adding this cost?* (Moore and Scheinkopf 1998, 29)*”* By theoretically, Inventory and operating expenses could be reduced to zero however even the *Lean* managers maintain some amount security level on stocks to avoid the stock out situation without affecting the company’s ability to produce value for the customer.
   In TOC, unlike Lean, Throughput is measured in financial terms rather than in units of products or materials. It is justified to distinct the calculation of throughput since not all products units are of equal value in order to make an effective decision making.

2. *Variability and Uncertainty*

   Lean thinking and TOC contradict in their respective treatments of variability and external uncertainty. Variability looks at the internal side of the organization whereas uncertainty is quite often external sources. Variability can be at technical products and process factors including quantitative and human factors as well. It can be estimated or predicted at times but it’s still obscure. However in order to have a control over the system as a whole effectively, the organization has to learn how to deal with variation.
   Moreover, Uncertainty is the factors that are beyond control of the organization such as customer behavior or suppliers attitude. Changes in market fashion, demand, economy, or natural calamities are unavoidable and risky. Therefore only a market opportunist using *Lean* tools and TOC can gain advantage in any situation.
   Lean thinking approaches internal variability as a challenge to overcome whereas TOC presumes that the system is already in a flow, producing high quality products (H. W. Dettmer 2014).

3. *Takt and cycle time*

   Cycle time can be measured as production of single unit of product from raw materials into finished goods before repeating them. On the other hand, *Takt* in German means rhythm or beat which is demand-based (H. W. Dettmer 2014). It is the ratio of available production time by customer demand.

For example, if a manufacturing company operates 8 hours (480 minutes) per day with 30 minutes paid break and 30 minutes unpaid breaks and the customer demand is 420 units per day, takt time is 1 minute or 60 seconds per item. It is important determine to how many people to assign for the job. However not every person can work 100% efficiently so takt time may vary. Most factories do not calculate takt time which is just fine however what do they lose? Takt time gives the idea of the situation what actually should happen and what actually is happening and immediate action to control the difference. It is a *Lean* approach to understand the capacity of each and every process. By just looking at the process, optimum number of people required can be determined with the minimum batch sizes.

Dettmer H. W.(2014) states, “a *Lean* production process will assume that each unit of capacity (a person, or person-machine combination) will work as fast as possible, while still assuring mistake-free operation, for all of the available production time.” The main objective is an efficient workforce at minimum in expectation of maximum volume of output.

Theory of Constraints consider only approximate cycle time, takt time does not exist. The cycle time may vary in degree of skills among employee leading to variance in nominal cycle time; therefore approximate cycle time is considered for the entire manufacturing process, rather than individual cycle time of each work. “Only one link in the chain can be the weakest, and that link sets the pace for the entire chain: the output of the system over time is the same as the output of the constraint. (H. W. Dettmer 2014)”

Despite having dissimilarities, the main objective of our thesis is to combine the best of Lean and TOC together into a single improvement process (see Figure 2.9). The technique “standing in the circle” introduced by Taiichi Ohno emphasized observing and understanding why do the waste exists in the process. And what Sproull (2009) believed was “that the waste exists without trying to eliminate it (Sproull 2009, 14).” The synergy of best of Lean and TOC maximizes the full improvement potential and ensures increase in ROI. With the use of five focusing steps in TOC, the appropriate Lean tools are initiated to get an integrated and excellent result. In order to do that, we need a careful planning and step-by-step executing the plan into action with the involvement of employees’ initiation in the process from raw materials until the delivery of the service.

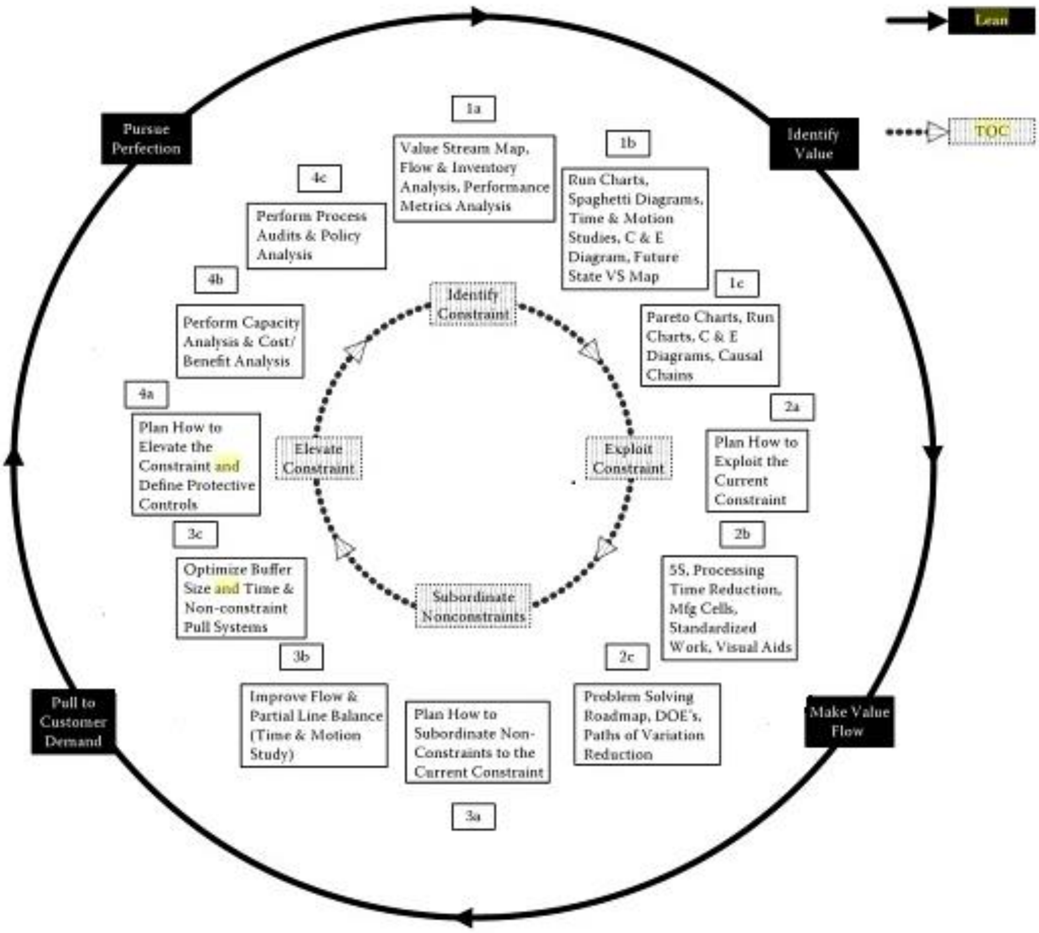


Figure 2.9: Ultimate Improvement Cycle Tools and Actions (Sproull 2009, 14)

3. *Accomplishing Each Step by combining Lean and TOC*

By integrating Lean tools in each step of TOC, we can accomplish robust improvement. Figure 2.8 is a layout of the tools and actions we will implement at each step. It is simple and basic tools to get the maximum objective.

Step 1: Identify

In the first step 'identify' from the TOC cycle, we use value stream from Lean cycle to identify the current and next constraint. "In some respects, this first step is the single most important one, because it forces you to view and evaluate the entire value stream to locate the acre, policy, or process step (the system constraint) that is preventing you from reaching your full financial potential (Sproull 2009, 18)." It is based on continuous improvement where the result is always good. The performance metrics not only motivates to emphasize the drive to right behaviors but also guides us to the right direction in order to accomplish the goal.
Value stream mapping is a Lean tool that will be used to identify and map the value-added and non-value added actions, which are demand forecasting, receiving orders and raw

materials, producing it, and delivering it to the customer. “VSM are methods for receiving orders, methods for communicating information about production requirements (i.e., scheduling system), the locations and amount of inventory, the current processing and cycle times for all process steps, the distance traveled between process steps, and so on. All this information will be the focal point of your improvement activities (Sproull 2009, 18).”

Many improvement initiatives fails due to excess inventory which can increase holding or carrying costs, unwanted labor production and many more. “It is important to understand that unless you improve the total system throughput, any improvement in a non-constraint is just really an illusion (Sproull 2009, 18).” Illusion in a sense that improvement in the process anywhere will not transform the whole system performance rather it might end up carrying unneeded inventory with longer cycle time. So proper planning is essential not to jeopardize at the expense of some earnings.

In step 1a, after identifying the current constraint it is important to identify next constraint as well to predict and plan ahead the effect of breaking the first constraint. The immediate effect after breaking the current constraint is the appearance of the next constraint unless you predict in advance to save some time searching for another (Sproull 2009).

Step 2: Exploit

Exploiting the constraint strongly holds onto doing the best from what you have. The use of Lean tools such as 5s motivates the employees to standardize working habit and involvement of employees directly to the Lean culture (Vorne 2010). For instance, Kaizen helps us to provide a framework in order to exploit the constraint by Plan, do, check and act cycle for continuous improvement.
By exploiting we can implement process controls, reduce change over time, shorten the distance travelled as well as time, on-time delivery, and reduce down-time etc. (Sproull 2009). The improvement on these will automatically generate improved throughput rate and higher revenue. “Planning is critical to the success of the improvement initiative, so proposed changes should be fully discussed up front before they are actually implemented, and this dialogue should take place in step 2a if the proposed changes are known (Sproull 2009, 24).”

Step 3: Subordinate:

So far, we were looking for constraint and exploiting it but we can’t also deny the fact of non-constraint operations existence along the chain. Therefore by subordinating non-constraint to current constraint operation through planning is what we aim at this step. “Subordinate in its simplest form means that you will produce product at the same rate as the constraint operation, no slower or faster (Sproull 2009, 25).”
The opportunities that lie along the upstream and downstream of the chain are accessible through brainstorming and proper planning. We also should be cautious not to convert

non-constraint into constraint, which could be achieved by careful strategy and plan. Moreover “contrary to what many production managers believe, having a perfect balanced line is not necessarily a good thing (Sproull 2009, 26).”

Step 4 & 5: Elevate and Repeat

Lean tools such as Total Productive Maintenance are used as a means to reduce the frequency of constraint breakdown and stoppage in between. Quality at source, the Lean tools enables maintenance to be planned and scheduled. The removal of root cause of the problem is analyzed in this step of elevation (Vorne 2010). And further repeat the same step from 1 from identifying the constraint and so on to get a continuous improvement and maximum throughput as an outcome.

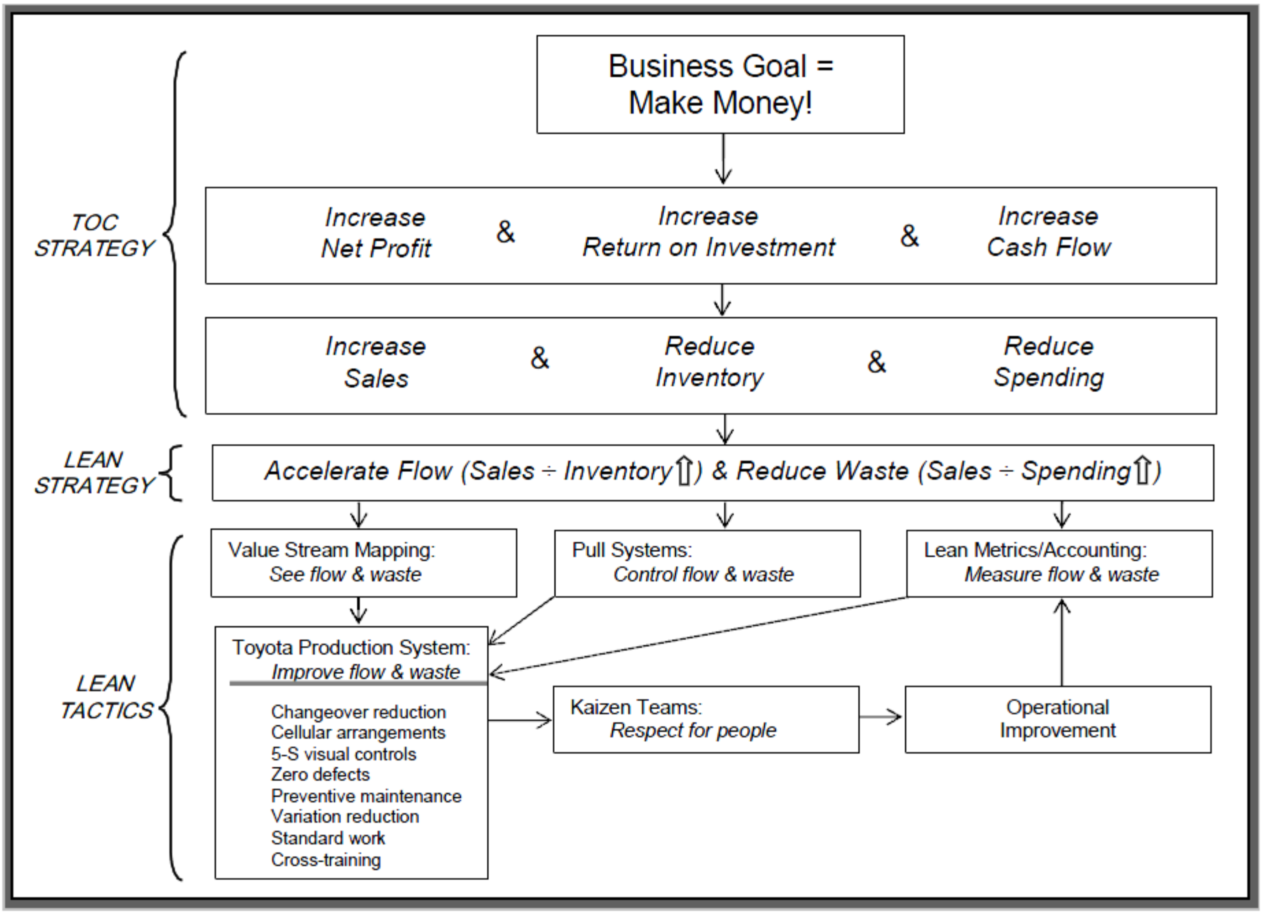


Figure 2.10: *Lean* and TOC (Guild 2014, 1)

2.4. Summary of Literature Review:

Research Question	Theory of Constraint	Lean Tools	Section	Page Number
1	Step1:Identifying the Constraint	VSM, Lean Metrics 5-why and Cause and effect diagram	4.2.1	71-75, 80-83
2	Step2: Exploiting the Constraint Step3: Subordinate the Constraint	5S TPM, Kaizen, Kaizen Event(PDCA Cycle) SMED	4.2.2 4.2.3 5.1.2	84-91 91-101 104
3		Kanban	5.1.1	103

Table 2.3: Summary of Literature Review

The Table 2.3 is the summary of Lean tools used in focusing steps of Theory of Constraint. The relevant literatures are a basis to further analyze and support our analysis determining our research question in this paper. Basic understanding about the tools and steps are supported through the research paper by several academics and practitioners over the decade. This table also shows the section and page number of the tools in analysis to make it easier and convenient.

3. Research methodology

This section will present about the research methodology that will be used in this project. Section 3.1 shows the brief description about research design. Section 3.2 is followed by data collection methodologies and also the types of data collected for the project.

3.1. Research Design

The research is mainly conducted to find the statistics as regards to a specific research question, and the research design is obliged to be closely connected with the purpose of research.

> *"A research design is an action plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions* (Yin 1994, 19)*".*

The purpose of our research may be in one of these three types of research strategies they are exploratory, explanatory, and descriptive. Exploratory research basically focuses on identifying key issues and key variables. Descriptive research is responsible for providing a precise description of observations of phenomena. Explanatory research can be conducted to explain the phenomenon (Yin 1994).

The purpose of this project has an exploratory-explanatory behavior, because the project target is to discover that what activities in the value stream that delay the flow of materials this make an exploratory research design. Moreover, the thesis objective is to explain the basic reasons for these delays, this shows explanatory research design.

The main objective of the research design is to evade the condition in which the evidence does not discourse the research questions. According to (Yin 1994), the five components of a research design are especially important:

a) *Study Questions*: These questions shows that what type of research should apply in the study. The questions should put into words with "Who", "What", "Where", "Why" and "How". In this master thesis the study questions are presented in research questions.

b) *Study proportions:* The proportions show the way of consideration to something that should be observed within the scope of the study. The proportion also provides an assistance to reflect important theoretical issues and also assist the writers where to look for relevant evidence. In this master thesis the study proportions are presented in Section 3.2.1.

c) *Unit of analysis:* The unit of analysis is associated with the way initial study questions have been defined. Selection of a suitable unit of analysis is done after the study questions are prepared. The unit of analysis is defined in the research problem.

d) *Linking data to proportions:* The name itself defines that linking the data to proportions, means the tools and techniques that are used to analyze of data. This also provides a concrete foundation for the analysis. In this master thesis this is done in the Section 4.1

e) *Criteria for interpreting the findings:* This can be done by using statistical test, but it might also be about recognizing and discussing other explanations that do not support the explanations of your results. Chapter 4 Analysis is all about our interpretation and data to support our research questions.

The methodology of research design mainly depends up on the type of analysis and type of data used in the research. There are two types of analysis are there Qualitative analysis and Quantitative analysis. According to (Thomas 2003) the qualitative analysis is a multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. Qualitative research involves the studied use and collection of a variety of empirical materials. Quantitative analysis use numbers and statistical methods. It tends to be based on numerical measurements of specific aspects of phenomenon. The type of data is dived into two types, either it is empirical or modeled. According to (Ellram 1996), the data can be empirical, which is data gathered from the real world via surveys or case studies. The modeled data, which means it, is either hypothetical or real world data to be artificially manipulated by a model.

		Type of Analysis	
		Primary Quantitative	**Primary Qualitative**
Type of Data	Empirical	Survey data Secondary data Statistical analyses	**Case studies** **Observation** **Limited statistical analysis**
	Modelling	**Simulation** **Linear programming** **Mathematical programming** **Decision analysis**	**Simulation** **Role playing**

Table 3.1: Basic Research design (Ellram 1996)

The above table above shows how the Ellram (1996) classified the methodologies according to the type of data to type of analysis.

In this master thesis the research design study can be considered as primarily qualitative empirical data, since the study is related to a real life company. According to (Thomas 2003) the qualitative analysis involves a collection of a variety of empirical material like case study personnel interviews observational, historical, interactional etc. The qualitative results are frequently expressed verbally, often to create an understanding of relationships or complex interactions (Ellram 1996).

3.1.1 Case Study method

The term case study is also often taken to carry implications for the kind of data that are collected, and perhaps also for how these are analyzed (Roger, Martyn og Peter 2000).According to " (Yin 1994, 13) a case study method is an empirical inquiry that investigates a contemporary phenomenon with its real life context, especially when the boundaries between phenomenon and context are not correctly evident". A case study research may consist of both or only qualitative or only quantitative case studies. According to " (Yin 1994, 14) some qualitative research follows ethnographic methods and seeks to satisfy two conditions a) the use of close up, detailed observation of the natural world by the investigators and b) the attempt to avoid prior commitment to any theoretical model".

Case study may be proceeded in variety of ways, there are six types of case studies, defined in two dimensions 1) in terms of number of cases: single or multiple, 2) in terms of the purpose of the study: exploratory, descriptive or explanatory (Blaxter, Hughes og Tight 2010). A case study research may contain either single case study or multiple case studies or both. The multiple case studies take place when the similar study encloses more than one case. According to (Yin 1994) there are six key sources of evidence applicable to case studies, direct observation, participant observation, physical artifacts, interviews, documentation, and archival records. He also explained that the participant observation emerged as a data collection technique. In this thesis the use of these six sources will be discussed in next section.

For this thesis the case study approach is considered as the examination of non-value added activities and sources of these within a real world environment will be used. In addition, the selected approach is a single case study of the flow of product item C10 with in Glamox. It should be noted, that the main purpose of this thesis is to reduce the lead time mean while also developing the sympathies of what activities in the value stream that delay the flow of material and what are the reasons for delay, somewhat it is related to an in-depth qualitative analysis of a particular product line.

There are some merits and demerits of case study that comes along as a motivation as well as challenge. The advantage that we have was since it was based on real life practices it was easier for data collection. We have more accessible and more persuasive experienced people to interview and understand the company articulately (Blaxter, Hughes and Tight 2010). It also helped us in building further analysis to explore beyond interpretation and research. However, Glamox being manufacturer of lighting producing more than 150 varieties in each different product family lead to complexity of connecting between various events, variables and outcomes. The other problem that we've faced was getting the information from the company took longer period as the things and figures keep changing and finally end up in massive and unreadable documents (Yin 1994).

3.2 Data collection

After the research problem is defined and research design/plan evaluated the formal task is to collect a data. Data collection can be collected by two different types: Primary and Secondary data. Kothari (2006) defines, "The primary data are those which are collected afresh and for the first time, and thus happen to be original in character. The secondary data, on the other hand, are those which have already been collected by someone else and which have already been passed through the stastical process (Kothari 2004, 95)". The decision of data collection depends on the researcher's perspective of what sort of data are needed. Primary data can be collected through observation, questionnaire, interview and focus group whereas secondary sources of data can be books, journals, newspapers, letter, E-mails, data stored in electronic form, diaries, government organization's reports, archived data sets, etc. (Pawar 2004).

Primary and secondary data can be divided into two categories: Qualitative and Quantitative data (Otterlei and Myrold 2012). The list of primary data collection technique is shown below:

	Solicited	Spontaneous
Quantitative	• Experiment • Interview survey • Mail survey • Structure diary • Web survey	• (Passive) observation • Monitoring • Administrative records (e.g., statistical records, databases, internet archives)
Qualitative	• Open interview • Focus group • Unstructured diary	• (Participant) observation • Existing records (e.g., ego-documents, images, sounds, news archieves)

Table 3.2: Primary data (Otterlei and Myrold 2012)

In this thesis, we have used qualitative method of data collection. The primary sources of data are collected from direct observation, personal interview and secondary sources are collected from literatures written over the period, background of the company from website, annual reports and various research papers. The purpose of preferring qualitative method was to obtain quality information and opinions from experts which were more suitable for our case study. According to our research question, as well as taking time into consideration, the understanding of the production line, determining the constraint and evaluating the flow of materials, appropriate qualitative approach of data collection is obtained.

Even though we have measured lead time, cycle time, takt time, Productivity, Return on investment, non-value added time and more; and “Quantitative research is numerical and can be statistically treated. Data may be analyzed by the use of hand and calculator (Taylor 2005, 240)”; the numerical calculation was to analyze data for further analysis without any statistical procedure. Therefore we can categorize it into qualitative research based on narrative descriptions of theories to support our analysis with quantitative records to support and validate our data.

3.2.1 Study Proportions

In this section the proportions for master thesis were organized as stated above in Section 3.1(b).

3.2.1.1 Direct Observation

The direct observation is related to primary qualitative data collection as stated in above section. According to (Kothari 2004, 96) observation become a scientific tool and the method of data collection for the researcher, when it serves a formulated research purpose, is systematically planned and recorded and is subjected to checks and controls on validity and reliability.

In this thesis the direct observations mainly help us to formulate the answer our first and third research questions explained in Section 1.3 (b). The company gave us permission to walk in production area, warehouse, and office, which helped us to observe more ongoing things from near and also had a chance to make observations. Most of these observations are casual observations which are connected with data collection interview.

The use of this data collection has some advantage and disadvantage. Among the several advantages of direct observation the one that we can’t ignore is the willingness of respondent in course of our study which made our research easier and relatively less complicated for data collection. However the limitation of information and unforeseen factors that influence the observational task is inevitable (Kothari 2004).

3.2.2. Interview Method

Data collection through interview method is the most commonly used and easier form to collect data. The reply is in the custom of oral-verbal responses which can be through personal interview, telephone interview or e-mail interview.

a) Personal interviews

The personal interview/ survey help us to answer thesis first research question: *"How can production line performance be measured at Glamox?"* Furthermore, aspiring on understanding how the way things work in real life situation and crosscheck result if necessary it was obligatory for us to interview employees of Glamox in different positions. The first meeting with the Lean Project manager and Production manager was to comprehend the overview of production line and generalize the problem in Glamox to understand the current situation. And further we had several meetings to discuss in details about the problem profoundly to achieve certain research question to further analyze. The interview with the Lean Project Manager and Logistics Manager were mainly conducted to analyze the in-depth issue in Glamox after taking prior appointment from the managers. We also had an informal conversation with employees working in the area to gather more information as various categories of employees can provide a variety of information.

b) E-mail Interview

E-mail interview is easier and low cost interview technique used to answer questions by sending an e-mail to the interviewer. When we forgot to ask some questions to the managers through personal interview or get more updated data from them this method was used. It was less time consuming for us too as the response was not more than a day or a week compared to asking an appointment and going in and out of the office for questions that could be sent by e-mail. And also the managers are usually busy with their own schedules and meetings.

Date	Name of Interviewer	Position
11-11-2013	Sandvik and Toralf Rein	Production and Lean Project Managers
14-11-2013	VidarAndreassen	Senior Logistics Consultant
26-11-2013	VidarAndreassen	Senior Logistics Consultant
15-01-2014	VidarAndreassen	Senior Logistics Consultant
06-02-2014	Toralf Rein	Lean Project Manager
07-02-2014	VidarAndreassen	Senior Logistics Consultant
13-03-2014	VidarAndreassen	Senior Logistics Consultant
24-03-2014	Helge Ottar	Planning Chief
27-03-2014	Helge Ottar	Planning Cheif
24-04-2014	Toralf Rein	Lean Project Manager
24-04-2014	Interview with the Workers	Louver Department
25-04-2014	Bjarne Lie	Maintenance Department Leader
25-04-2014	Robert	Louver Department Leader

Table 3.3: Personal Interview/E-mail Interview at Glamox Company

3.2.2. *Reliability and Validity*

The quality of the research can be evaluated through validity and reliability of the observation study. Reliability is "the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable (Golafshani 2003, 598)" While the debate between the quantitative and qualitative research method for evaluating reliability of the data is misleading, Golafshani (2003) claims that reliabilty in qualititative paradigms can be evaluated in terms of credibility, neutrality or confirmability, consistency or dependability and applicability. More specifically "dependability" is closely linked with "reliability" in qualitative reseach.

The interviews with the senior managers in Glamox company was the major sources of data in our master thesis. "To ensure reliability in qualitative research, examination of trustworthiness is crucial (Golafshani 2003, 601)." The datas from the archived records and from the company is also a reliable sources as it is an evidence from the past experience. Since without validity, reliability is meaningless regardless of its quality information. Validity in qualitative research is "a kind of qualifying check or measure (Golafshani 2003, 602)" to establish assurance in a research performed.

In order to provide validity and reliability in a research findings triangulation method is used. "Triangulation has risen an important methodolofical issue in natualistic and qualitative approached to evaluation [in order to] control bias and establishing valid propositions because traditional scientific techniques are incompatible with the alternative epistemology (Golafshani 2003, 603)." In our thesis, multiple sources are used for triangulation through direct observation, interviews, necessary documents provided by the company including the website as shown in table 3.4. The use of these sources has strengthen the validity of our thesis and confirmation from the reliable resources. Therefore to support our thesis we have used relevant literature reviews to establish truth and gain trustworthy research framework. We received data from 2 different types sources and exacted the data by direct observig to confirm and validate our given source.

Type of data	Sources of Data		
	Vidar Andriensen	Toralf Rein	Direct Observation
Cycle time(Body)	48 secs	55.5 secs	48 secs
Cycle Time (Bracets)	0.923 secs	2.4 secs	0.923 secs

Type of data	Sources of Data		
	Vidar Andriensen	Toralf Rein	Direct Observation
Average Demand	250 pcs	270 pcs	270 pcs

Table 3.4: Triangluation From Different Sources

4. Analysis

This section will present the analysis and discussion about the results that have been found in the project. It is divided into two parts. First section covers the discussion about the production process as well as analysis of the problem by observation and interview survey methods. The next section covers the value stream mapping, measuring the analysis of the production process.

4.1The Production process- Description and Findings

In this section first we describe briefly about production process and in section 4.2 (a) we describe briefly about processing steps. The last part of this chapter mainly focuses on the errors and types of wastes in the production process.

4.1.1. Definition and description about production process

The process is defined as a series of independent task that transforms an input (raw materials) into an output (finished goods) of higher value for the organization. The most important part in this analysis is production process analysis. The process analysis is mainly used to identify the *inefficient* task, to spot potential *effectiveness* improvement tasks, to recognize where *value* can be added. The important step is planning, the value stream mapping; we defined and maintain the range of the process. Therefore, we seek to define from the starting to finishing point of the production process flow in Section 4.2(a).

Glamox company purchase raw material and produces the goods as make to stock process to inventory, and in this thesis we are not considering about how much to purchase and what to purchase. We are not going to look in the costs, and the lead time is measured only until the goods are shipped. The focus is more about supplementary production with lower lead time utilizing minimum buffer capacity.

We have limited our research to single product item (C10-10054120) in the family of C10/C20 and disregarded other products in the company to narrow our findings in limited time plan. Even though C10-10054120 is a standard product; they also produce some special products with in the same family group like Louvers with different sizes and material according to costumer order. According to the Glamox ASA, the production of engineer to order products were adequate scheduled, therefore we have not considered these type of product in our thesis.

4.2 Integrating Theory of Constraints and Lean

We discussed earlier in Section 2.3 by integrating the Theory of Constraints and Lean we can achieve: greater through put, small reduction in operating expenses and also reduction in inventory costs. We can also observe in the earlier Section 2.2 that the Theory of Constraints mainly focus on increasing the through put, but Lean thinking brings the extra rigor and chastisement, in order to reach the goal, Lean also offers many key tools and techniques for reducing the waste. By combining the Theory of Constraints and Lean we can obtain a clear picture for improvement to ensure a systematic, organized to obtain the maximum utilization of resources to expand more profits and revenue.

4.2.1. Step 1: Identifying the Constraint

This step answers the first research question presented in this master thesis Section 1.3

"*How can production line performance be measured at Glamox?"*

We have explained in the Figure 2.9 the first focusing step in the theory of constraints is to identify the constraint. In Lean approach, the first step is to identify the Value stream of the cycle. This step is most important one, because it militaries us to mainly view and calculate the whole value stream to discover the area, strategy and process i.e. finding the constraint that prevents the organization from reaching their goals. As we explained in the Section 2.3 the first principle in Lean approach is to identify and map the value stream. The Lean approach in this step shows us the overall presentation about the Glamox Company's value stream for the product C10-10054120 and focuses resources which can be done better and are basis for the continuous improvement.

4.2.1.1. Value Stream Mapping

As we explained in the above Section 2.1.5.1 that the "value stream is defined as all the actions, including both value added and non-value added ones, that are required to receive the order, schedule it, obtain necessary raw materials, produce it and deliver it to the customer. Included in the VSM are methods for receiving orders, methods for communicating information about production requirements i.e. scheduling system, the locations and amount of inventory, the current processing and cycle times for all process steps, the distance travelled between process steps and so on (Sproull 2009, 18)." All these information presented in the value stream will help us to identify the constraint, and that constraint will be the focal point for improvement activities.

According to Value stream mapping methodology, the first step is selecting the product family and setting the boundary conditions. In terms of value stream mapping the selection of product family is including all the components of raw material receiving from suppliers to delivering the finished product to the customers in the Glamox Company. Moreover the company describes that the product C10 family belongs to A-component, where A-component is make to stock.

While discussing about the boundary conditions, we have limited our value stream mapping to the flow of materials from suppliers to customers for a single product i.e. C10-100054120. Whereas, the company receives the maximum part of the raw materials from the same suppliers and send the other products with the same orders to the customer's. But, we limited our research to the particular product, and its information and material flows.

4.2.1.1.1. Current State Map

As we explained in the Section 2.1.5.1 the current state map should reflect what happens from start to finish in the entire value stream for a particular product item C10-1005412 at Glamox Company. In the Figure 2.9 it shows clearly the first step 1(a) is to plot the value stream map, flow and inventory analysis and Performance metrics Analysis. This section covers in first part a brief explanation and pictorial representation of value stream map; the company's material and information flow and also shows the inventory at each stage. The second part shows the performance metrics and its calculations.

As mentioned above in Section 4.1 the product item that we are dealing with C10/C20 which is a type of make-to-stock product. So, the production process starts from the demand forecasting.

Production Lines	Day	Hours	Shift	Un-Paid Breaks	Paid Breaks
Brackets/Body /Louvers/Louvers Assembly	Mon-Thurs Fri	6:30-15:00 15:00-23:45 6:00-15:00	First Shift Second Shift First Shift	30mins 25mins	25mins 15mins
Final Assembly	Mon-Fri	7:30-16:00	Single Shift	30mins	25mins

Table 4.1: Working Hours in Glamox Company

i. *Demand Forecasting*

For the products like make to stock the accumulation is based on demand forecasting, which is called as anonymous production not a Make to Order system. This type of anonymous Production can be considered as push production system. The varieties in each products and their family, it is essential to forecast and schedule beforehand for simplicity and clearance to employees about what are their targeted goals in each day. The planning chief forecast the demand from the customers' perspective based on the previous orders pattern once in a month and hence the products are produced into semi-finished stocks and finished goods at a security level for 15 days. The production orders are always made no longer than 3 days ahead it also depends on the safety stock level they reached.

The Planning Chief at Glamox Company uses an MRP (Material Requirement Plan) system, to plan the semi-finished goods. This MRP system will automatically runs every 4th hour, when the production order is entered in the system, the MRP system checks for the required semi-finished goods to prepare that product and if it consumes those semi-finished goods from the safety stock, then it automatically releases a proposal for new production order. The planning chief needs to have a quick overview on the new production order and transfer it into batches per day.

The product C10-10054120 is a fast-runner, and there is always high demand to produce in each production line. The average demand for this product is 270 pieces per week. The minimum security level is 1525 pieces in warehouse or 5 weeks. So, the plan for maintenance of safety stock is done in a very beginning of every month. When the safety stock level reaches to 6.5 weeks then it's a signal for reordering point and it is automatically displayed in the system i.e. "INV control", then they plan for more two weeks of production, to maintain a balance in planning as well as controlling stock level. From the supplier's perspective, the company places an order once in a week based on planning and demand forecasting.

ii. *Receiving orders*

The second main part in the system is receiving the orders from the customer. In the Figure 4.2 below shows clearly that the Glamox Company receives orders from the customers every week and they receive the orders by Email, Fax and sometimes by phone. The sales department is responsible for entering the sales orders in the system. The company is mainly concentrating on selling their products to wholesalers (Electroskandia) instead of directly dealing with customers. The company receives approximately 70 orders per month. They also have an agreement with the sale department i.e. for the products like make- to-stock (A-item) they need to deliver within 24 hours after receiving the sales order except for the big orders that can take much more time.

iii. *Receiving raw material*

From the personnel interview we observed that they receive the raw material from their suppliers once in a week according to their demand. However, one week demand of raw materials by suppliers is not only for C10-10054120 but also for all types of products that will be manufactured within a week.

iv. *Production of body*

The punching machine of body is located at the East side of the Glamox Company as shown in Figure 1.7. This department will operate two shifts per day as shown in table 4.1. For the particular product item, C10-10054120 the coil is white-painted sheet made up of steel and its material number is 01216436, the consumption of steel in every month is about 5000 to 8000 meters and they order their suppliers twice in a month of about 2000 to 4000 meters of coil. This type of white-painted sheet coil is not only used for the C10-10054120 but also used in 40 different types of products that belong to the same family. On average they consume 430pcs of body weekly, when the stock level reaches to 200pcs then they plan to produce in a batch 540pcs in the next 3days. The machine is semi-automatic punching machine and only one person operates the machine with programming, changing of the coil, testing and internal transportation of buffers.

The time taken to place the coil on the machine is 4 minutes and change over time (restructuring) is 66 minutes, retrieving the program will take 15secs and the time take to produce one piece of body is 48sec.After installing the program the operator test one or two pieces either the punching is correct or not, if it is not he will make some adjustment in the program and it takes around 5 minutes, once the operator confirm that the punching is correct then he starts the machine. The buffer near the machine about 750 pieces of coil and the finished good buffer near the machine is 180stk and it takes 4 min for internal transportation to move the pallets from machine to the west hall where there is buffer for semi-finished goods of product. They place 90 pieces of main bodies on one pallet. In the west hall the finished goods buffer is placed as safety stock, until they receive the next order. The buffer in the final Assembly is about 750 pcs.

v. *Production of brackets*:

In Figure 4.2 it is clearly shown that the production of brackets is parallel with the production of body. The brackets punching machine is an automatline, one person operates with the machine, i.e. changing the coil and moving the finished goods. This department also operates in two shifts per day from Monday to Thursday and one shift on Friday. The type of coil they use for the preparation of end brackets is steel with a material number 01615230.The consumption of steel is about 400-800 meters per month. They place orders to their suppliers about 2 to 4 months with a volume of coil around 1500 meters. On average they consume 1000pcs weekly, when the safety stock reaches to 1000pcs it is an indication for reordering point after then they place a new production order to prepare a batch of 4000pcs.

The time taken to place the coil on the machine is 5 minutes and change over time (restructuring) is 100 minutes, retrieving the program will take 2minutes and the time take to produce one piece of body is 0.923seconds. The operator will test one or two pieces and make changes in the program, it almost takes 2 minutes. The buffer near the machine about 350 pieces of coil and the finished good buffer near the machine is 1600 pieces or one pallet, and it takes 5 minutes for internal transportation to move the pallets from machine to mid hall. The mid hall consists of semi-finished goods buffer and the buffer in the Final Assembly is 1000 pieces.

vi. *Production of louvers*

In the louvers production line, we have two different operations of louvers from the (figure 4.1 below).We can observe that the louvers cross mirror and side mirror, these two different operations are done on the same machine but the material for these two operations are different. For side mirrors they use aluminum with the material type is of 03344055, the frequency of ordering to their suppliers is about 1-2 times in a month around 20,000 meters of coil and the maximum consumption of coil is about 20,000 to 40,000 meters of coil every month. The second operation is about cross mirrors, for these cross mirrors they us the material of aluminum with a silver coating, to having a high quality of luminaries and reflection, the material type is 03344052.The ordering frequency is about 1-2 times in a month about to 20,000 meters of coil and the maximum consumption is about 30,000 to 40,000 meters per month. On average they consume 330 pieces of finished products weekly, if the safety stock level reaches to 450, then they place a new production order to prepare in a batch of 360 pieces (2 pallets).

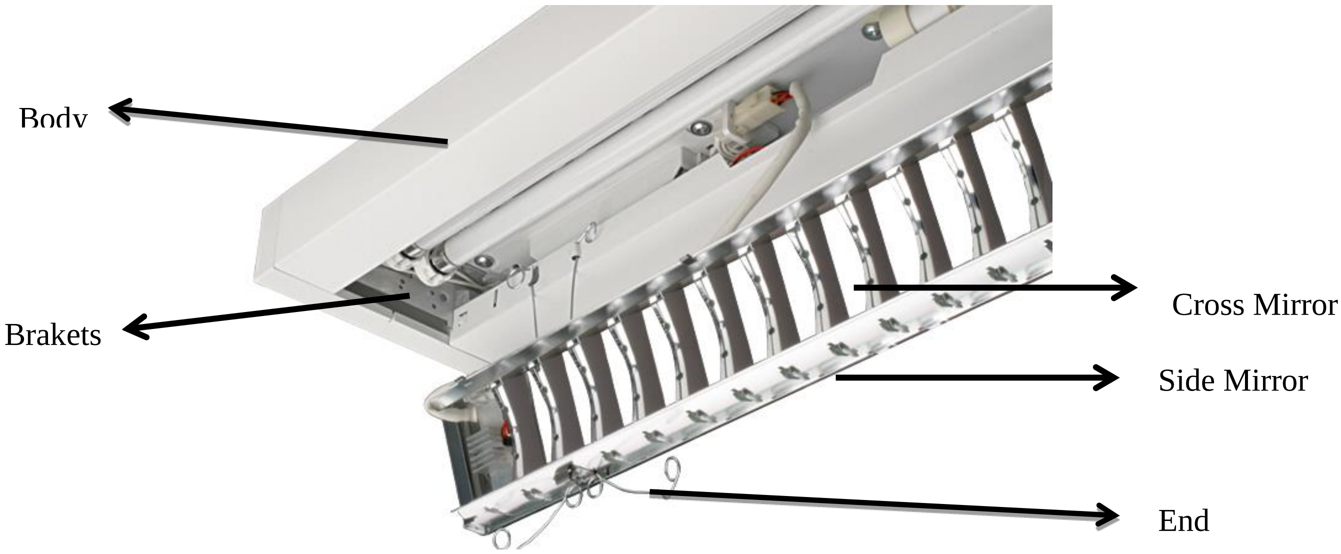


Figure 4.1: The Image of C10-S1 (Glamox 2014)

The Louver department operates two shifts per day and they consist of 4 semi-automatic machines. But for the production of C10-10054210 product they use only one machine, if the demand is high or the safety stock is less then they plan to produce it on two machines. Each machine needs one operator for programming, changing the coil, changing the plastic sheets and for testing. The time taken to place the coil on the machine is about 5 minutes and the change over time is 8 minutes. The time taken to prepare one Louver is 1.377 minutes. The buffers near the machine are about 325 pieces of raw material and semi-finished goods buffer near the machine is about 93 pieces or one pallet. The internal transportation of semi-finished goods buffer from machine to east hall will take around 5 minutes. The east hall consists of 405 pieces of buffer. From this it is send directly to assembly of louvers department.

vii. Assembly of louvers

This is the fourth production line for the particular product C10-10054120, in this assembly of louvers they operate mainly fitting with an end springs and end caps for the louvers bodies, for the products like C10-10054120 they have two lover bodies fitted together to convert into one piece, after finishing with the assembly process they add a protection film for the louvers to be secure from accidents while handling and transporting to the end customers.

The louvers assembly and production of louvers are located at the same place and in this production line they have both manual operation and machine operation. In manual operation they have four tables and four persons are required and for the machine operation one person operates the program and internal transportation of buffers. They use an aluminum material for spring of material number 03334175. The monthly consumption of this material is around 500-1500 meters and they place an order to their suppliers every 2 to 6 months around the quantity of 3000 meters. The time taken to assemble on louver by machine is around 0.024 seconds and the manual operation takes 2.428 minutes. The change over time for machine operation is about 78minutes. They place 90 louvers on one pallet. After finishing the assembly of louvers the semi-finished goods moves to the buffer in the east hall. From this east hall it is directly send to Final assembly. The final assembly holds the buffer around 350 pieces.

viii. Final assembly

In this final assembly process they receive the semi-finished goods from brackets, louvers, body departments and also the purchased products like wiring, plastic caps to hold tubes, different types of plastic caps for wiring system etc. from the buffers and they assemble it when the security level is low. In final assembly, five employees assemble the semi-finished into finished product. The first person assembles the clips and internal wiring; he then takes about 37 seconds to produce one piece. The second person operates with a side brackets, the operating time is around 37 seconds and the other 3 persons operates on fitting bulbs, wiring ,fitting with Louvers and testing, they consumes the time around 39 seconds to produce one piece. They place 64 finished products on one pallet.

From the data collected through email by the planning chief, we witnessed that the Glamox company plans to produce when the demand in security level is high not as per week and he also explained that they produce every time in batches and an average size of each batch is of 320pcs this is done almost once in a week. The time to produce one batch is around 9.32 hours including setup time. The last part of this final assembly is plastic packing; this is located near to the final assembly after finishing this part is shipped directly to the finished goods inventory.

ix. Packing

This packing machine is located next to the final assembly. It operates like a pull system, when the final assembly finishes a product they place on the roller belt and send it for packing. The packing is a semi-automatic machine and one operator is needed to place the plastic film coil on the machine and for programming. Different products have different sizes, so the person operator needs to change setting for each product that runs in a final assembly. The time taken to pack one piece is around 60 seconds and the change over time is 5 minutes. After packing is done, they place the finished goods on one pallet. One pallet consists of 64 finished products. After one pallet is full, they transport it into the warehouse and the time taken for internal transportation is around 10minutes. After it reaches to the warehouse they scan the product, it takes around 10 sec and the product is entered into the system.

x. Errors/Waste in production Processes

As we explained briefly from the Lean perspective that the Waste is nothing but the non-value added activities and there are 7+1 original wastes as described above. The focus on this value stream mapping is mostly on the physical flow of goods internally. In this Whole process flow, there are particularly three Lean Wastes are identified: 1) Excess Inventory 2) Over Production 3) Unnecessary Moment of Materials

1) Excess Inventory

The first Lean Wastage consistently identified in the whole production process is Excess inventory. As we described in the above section, the excess inventory shows that having an additional inventory in advance before it required for production. Lean Philosophy clearly explains that the excess inventory leads to increase in the Lead time of the Production Process and also increase the space necessity. These two major factors lead to increase in the inventory holding cost.

The Glamox Company looks at buffers as a stock to fulfill day-to-day needs and safety stock to avoid the variation in the supply chain. From value stream mapping Figure 4.2 below, we can identify the inventory status. Since the product is make-to-stock item, therefore we can conclude that the Company holds maximum inventory in each production line. The buffers of semi-finished product remain at least for 2 weeks and the buffers in warehouse are 5 weeks with minimum security level 1525 pieces. Kiron Shastry, an associate partner in Accenture's supply chain management line, states that, "The amount of safety stock an enterprise allows for similarly depends on two factors: how accurate the company is in forecasting demand, and how well its suppliers meet inventory needs (O'Reilly 2005)." Through our direct observation the unnecessary holding of inventory before and after the machinery makes working place quite congested and improper. In our interview, we comprehended that the company pursuits to reduce buffer in each production line. However since it is a fast runner product, the buffers are built because of variations in speed and reliability.

2) Over Production

The second lean wastage is identified as *over production*. As we discussed in above, the over production refers to storing an extra products even though which is not necessary in time. Lean philosophy suggests that the over production tends to increase the lead time, increase in inventory space and lead to wastage of energy.

The worker plan to finish one coil at a time when the machine is on, as the setup time is high and keeping a coil is inconvenient and time consuming for the next time. Therefore in order to finish the coil in use, the company will have to keep at least one extra pallet in the stock. The extra pallet is the result of overproduction which is rise in cost of inventory and storage space requirement. The re-order level is 6 weeks i.e. when the stock reaches to 6 weeks they place a new order.

3) Unnecessary Movement of Materials/Transportation

The third Lean waste is considerably identified in the whole production process as transportation. As described above, *the transportation refers to unnecessary movement of materials between the processes.* Lean philosophy suggests that the unnecessary *transportation tend to increase the material handling equipment charges, and space for transportation.* The Lean philosophy also says that the main causes of unnecessary transportation are due to over production, excess inventory, multiple storage Locations. Excess transportation then what is required is a waste. Also the damages in transit, reliability of delivery schedule and accessibility of information can add cost in long run.

It is important to restate that the product we are dealing with is a fast runner and delivery time is within 24 hours after receiving an order. Moreover we can say it contradicts the traditional large lot size based cost efficient way of moving goods. The Glamox Company delivers in smaller batches according to demand of the customer as the delivery time is too short to wait for the truck to be full.

From the direct observation and interview method, we know that inventories in each production line exist for quick accessibility. However on the other hand it increases cost for moving smaller quantities more frequently as it adds to labor as well as transportation cost. Further in depth discussion, while walking around on the company floor we observed that from the raw material location to machinery, they have at least two locations. One location is for keeping all received raw materials of coils at one place. Second location is near the machinery. Similarly, in final assembly production line, first the semi-finished goods are placed near the machine. The workers use around 8 pallets for body, 1 pallet for brackets, and 1 pallet for louvers. After the assembly of required pieces, the operator transfers it to another location. For example brackets are transferred to east hall; louvers are transferred to west hall and bodies are transferred to mid hall. The remaining buffers or semi-finished products are assembled again within next week according to the requirement.

4.2.1.2. Performance Calculations

The above part provides a brief description about the production process and its operating times, buffer capacity etc. at Glamox Company for the product C10-10045120. This part shows the calculations that are required to plot the Current state map and also shows the value added and non-value added time. The formulas that we use here are:

$$Uptime = \frac{Available\ production\ time - change\ over\ time}{Available\ Production\ time}$$

The Number of days that WIP in hand between two processes

$$= \frac{WIP\ on\ hand\ (\ inv\ between\ two\ processes)}{No\ of\ pieces\ shipped\ per\ day}$$

Average Demand	270 pieces per week
Shipping Month	20 days or 5days per week
Number of pieces shipped per day	54 pieces
Takt Time	8.42 minutes

Table 4.2: Calculation of Takt time

- *Available Production time:*

First shift:

$$8.5\ hours * 60\ minutes = 510\ minutesminus\ one\ 30\ minutes\ Lunch\ Break$$
$$= 30\ minutes$$
$$minus\ \ two\ 10\ minutes\ and\ one\ 5\ minutes\ break = 25\ minutes$$
$$Total = 510 - 55 = 455\ minutes\ /shift$$

= 27,300 *seconds /shift*

Second Shift:

$$8hours + 45\ minutes * 60\ minutes = 525\ minutes$$
$$minus\ 20 \min lunch\ break = 25\ minutes$$
$$minus\ 15\ minutes\ breaks = 15\ minutes$$
$$Total = 525 - 40 = 485\ minutes$$

= 29,100 *seconds/shift*

- *Shipping/ warehouse:*

- Frequency of Shipping: Daily
- Finished goods inventory: 979 pieces

- *Flow of Information and Material:*

- All communication between Glamox Company and their customers or supplier are electronic.
- Manufacturing Management performs demand forecasting monthly and receives weekly orders from customers (Electroskandia).
- Manufacturing Management performs demand forecasting monthly and transmits weekly orders to their Suppliers.
- They have 3 days orders release to production supervisor.
- The orders are released daily for Brackets, Body, Louvers, Assembly Louvers and Final Assembly.
- All materials are pushed between processes, so there is a push icon between each process.
- In reality the packing and final assembly is together, for convenience of understanding we made the packing as different line. The material is pulled between packing and final assembly so, there is a pull symbol between these two processes.

Contents	Body	Bracket	Louvers	Louvers Assembly	Final Assembly	Packing
Cycle Time	48 seconds	0.923 seconds	82.62 seconds	0.024 seconds	37 seconds	60 Seconds
Change Over Time	3960secs	3000secs	37 min/2226 sec	4680secs	600secs	300secs
Availability	27,300secs	27,300secs	27,300secs	27,300secs	27,300secs	27,300secs
Uptime	85%	89%	92%	82%	98%	98%
Number of Operators	1	1	1	1	5	1
Number of Shifts	2	2	2	2	1	1
Work in Progress	750pcs	350pcs	325pcs	405pcs	350pcs +750pcs +1000pcs	Pull System
Time Between two Processes	Raw material and Body 14 days	Raw material and brackets is 6.5	Raw material and louvers is 6 days	Louvers and Louvers assembly is 7.5	3production lines to final assembly is 18.5days	Final Assembly and Packing is 0 days

Table 4.3: Performance Calculation for each production line.

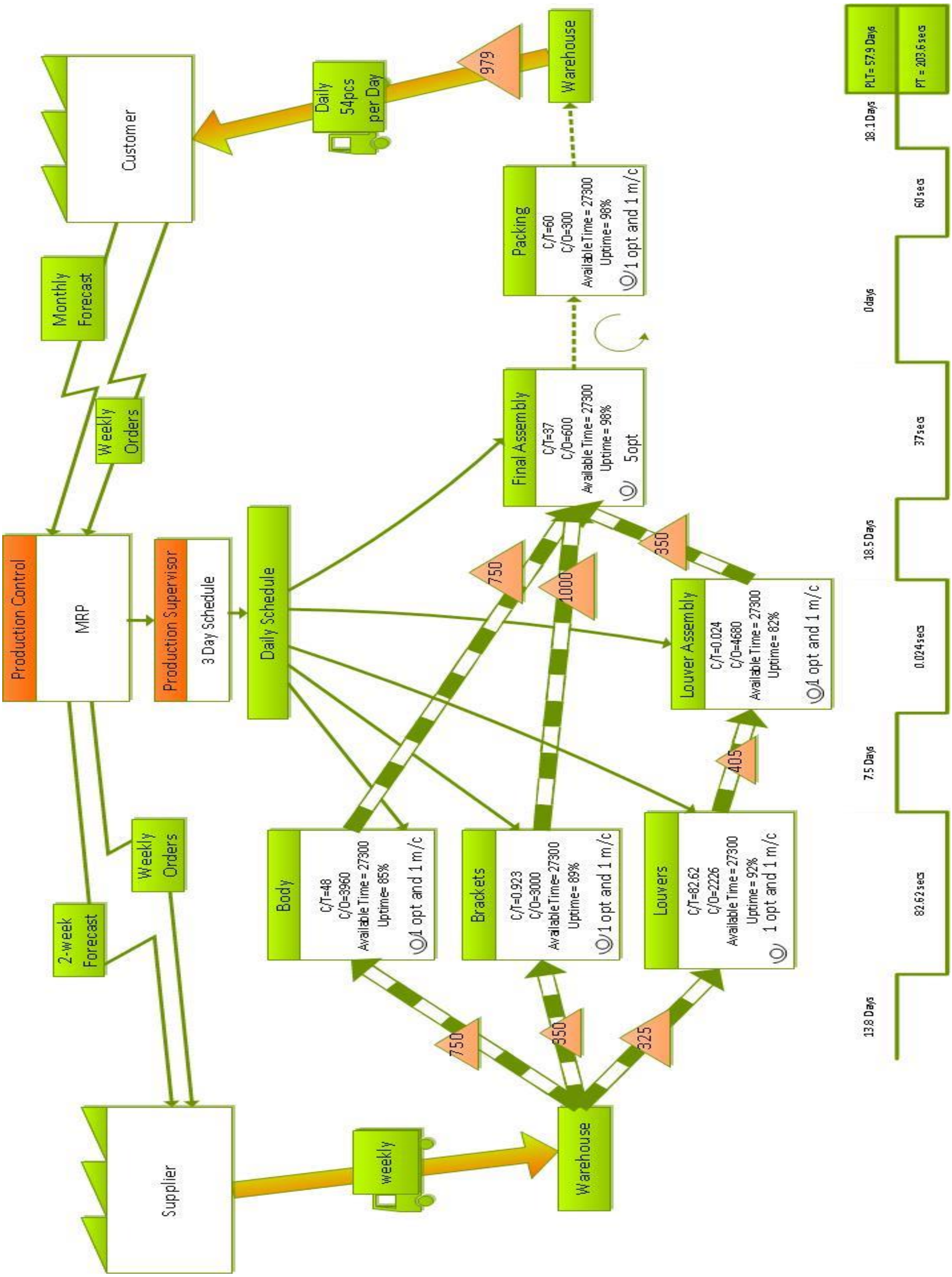


Figure 4.2: Current State Map of Glamox Company

4.2.1.3. Lean Metrics

In the above sections we documented the values for current state and plotted it, now we are going to identify the Lean metrics that will help us to identify the constraint and give some suggestions on the future state. "Lean metrics provide such a tool, and help to drive continuous improvement and waste elimination. Eliminating the waste makes companies stronger and more competitive and it results in cost reductions" (Tapping, Luyster and Shuker 2002, 95).

- Total value stream WIP (Work in Process) inventory:

  The total value stream WIP is done by adding the amount of WIP-inventory on hand between each process.

  - Raw material to Body:750pcs
  - Raw Material to Brackets: 350pcs
  - Raw Material to Louvers: 325pcs
  - Louvers to Louvers Assembly: 405pcs
  - Louvers Assembly to Final Assembly: 350 pcs
  - From Brackets to Final Assembly: 1000pcs
  - From Body to Final Assembly: 750pcs

  Total WIP Inventory is = 3930pcs

- Total Number of finished product item required per day:54pieces

- Number of days that WIP on Hand:
  - Between Raw material to Body is 13.8 days
  - Between Raw material to Brackets is 6.5 days
  - Between Raw Material to Louvers is 6 days
  - Between Louvers to Louvers Assembly is 7.5days
  - Brackets to final Assembly is 18.5days
  - Between ware house and shipping finished goods 18 days

  Total Inventory (in days) = 13.8+6.5+6+7.5+18.5+18 = 70.3 days on hand

- Total Product Cycle Time:
  - Body: 48 seconds
  - Brackets: 0.923 seconds
  - Louvers: 82.62 seconds
  - Louvers Assembly: 0.024 seconds
  - Final Assembly: 37 seconds
  - Packing: 60 seconds

  Total cycle time is = 228.567 seconds =3.8 minutes

➢ Total Value stream Lead time:

- Between Raw material to Body is 13.8 days
- Between Louvers to Louvers Assembly is 7.5days
- Brackets to final Assembly is 18.5days
- Between ware house and shipping finished goods 18 days
  Total Cycle Time is = 13.8+7.5+18.5+18 = 57.8 days

➢ UP time:

- Body: 85%
- Brackets: 89%
- Louvers: 92%
- Louvers Assembly:82%
- Final Assembly:98%
- Packing: 98%
  $0.85 * 0.89 * 0.92 * 0.82 * 0.98 * 0.98 = 0.548 = 54.8\% \approx 55\%$
  45 % of machine is not available for processing because of breakdown, waiting or exchange of tools.

4.2.1.4. Identifying the Constraint

As we discussed in the above Section 2.2.1 the identification of the constraint in the system process can be done by observing the system capacity and "Look for large accumulations of work-in-process on the plant floor. Review equipment performance data to determine which equipment has the longest average cycle time (Vorne 2010)". With reference to these points and from the value stream mapping figure 4.2, we can observe that Glamox Company receives orders from the customers as well as demand order from suppliers both in weekly basis. We can also note that since this product is make to stock and the company always maintains the safety stock at minimal, the delivery of goods are within 24 hours from the time when orders are received till goods are delivered to customer.

Process	Cycle time	Raw material	
		Pieces	Meters
Body	48 seconds	750	900
Brackets	0.923 seconds	350	38
Louvers	82.62 seconds	325	780

Table 4.4: Comparing Three Production Lines

First we take into consideration about the WIP and the Cycle time, from the Figure 4.2 we can observe that the three production lines are operating in parallel but if we compare the

processing time and the raw material in the 3 production processes as shown in Table 4.4, the longest average cycle time of 82.62 seconds is taken by the Louvers machine. However, the bracket holds raw material as maximum inventory. Moreover, if we look in the overall process the inventory is highest between Brackets Machinery and Final Assembly i.e. 1000 pieces.
Second, we take into consideration the capacity and utilization of machinery. While walking on the floor, we observed the daily production of each machine. All of the machines maximum capacity and their utilization are shown in Table 4.6 below.

a) Calculations

Now we take into consideration to calculate the OEE (Overall Equipment Effectiveness) and performance of the machinery. As we explained before the "OEE quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run (Gulati 2008, 182)" and performance of the machinery explains about the speed loss occurred in the machinery, the speed losses includes the loss of production assets. As we explained before the six big losses affects the OEE, in that the idling & minor stops and slow speed are performance metrics.

Formula:

$$Availability = {}^{Operating\ Time}\!/_{PLanned\ Production\ Time}$$

$$Performance = \frac{Actual\ Out\ Put}{Theoritical\ Out\ Put}$$

$$Quality\ = {}^{Good\ Pieces}\!/_{Total\ Pieces}$$

After multiplying all these three together the OEE equation transfers to

$$OEE = Availability * Performance * quality$$

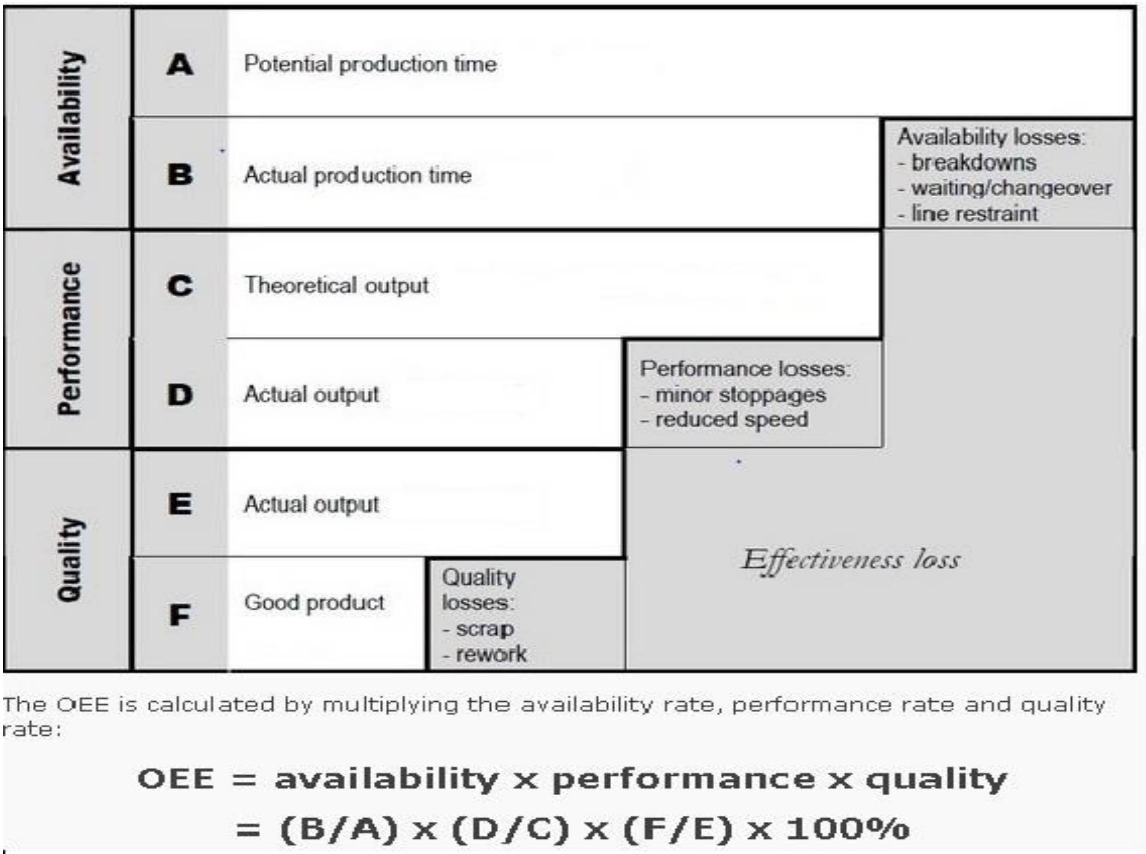


Figure 4.3: Calculations for OEE (Koch 2001)

Planned Production Time (average for two shifts) = Shift Length – Breaks

= 980-(55+40)

= 885 minutes = 885/2 = 442.5 minutes = 7.3 hours

We calculated everything by taking 7 hours i.e. 420 minutes into consideration

DATA (Louvers)	
Shift Length	8.5 hours = 510 min
Short Breaks	25 min
Meal Breaks	30 min
Down Time	112,6min
Ideal Cycle time	1.377 min
Total Pieces	750
Total Produced pieces	657
Good Pieces	536

Operating Time = Planned Production Time – Down Time

= 420 – 112.6

= 307.4 minutes = 5.12 hours

DATA(Body)	
Shift Length	8.5 hours = 510 min
Short Breaks	25 min
Meal Breaks	30 min
Down Time	76 min
Ideal Cycle time	0,8 min
Total Pieces	455/ shift
Total Produced pieces	450.4
Good Pieces	440/shift

1% loss in defects and scrap

Planned Production Time = Shift Length – Breaks

= 455 minutes

= 7.5 hours

Operating Time = Planned Production Time – Down Time

= 455 – 76

= 379 minutes =6.31 hours

DATA(Brackets)	
Shift Length	8.5 hours = 510 min
Short Breaks	25 min
Meal Breaks	30 min
Down Time	60 min
Ideal Cycle time	0.015 min
Total Pieces	10,500/ shift
Total Produced pieces	10.395
Good Pieces	10,000/shift

Operating Time = Planned Production Time – Down Time

= 450– 76

= 374 minutes =6.23 hours

Production Department	Availability	Performance	Quality	OEE
Louver	73.1%	87.6%	71.4%	45.7%
Body	83%	99%	92%	75.5%
Brackets	83%	99%	95%	78.1%

Table 4.5: Availability, performance, quality and OEE calculation

The bracket machine operates 37.5 hours per week and its utilization of machine is 78.1 % approx. In the same way, the body machine operates 72 hours per week and its utilization also 75.5% as shown in Table 4.6. The Louver machine operates 72 hours per week but the utilization of machine is 45.7%.

Machine	Max Capacity	OEE	Operating time(Hours/week)
Body 2 shifts	80%	75.5%	36*2=72
Brackets 1 shift	80%	78.1%	37.5
Louvers 2 shifts	65%	45.7%	36*2=72

Table 4.6: Maximum Capacity and Utilization of machinery

After reviewing the first consideration i.e. *WIP and Cycle time*; and second consideration i.e. *capacity and utilization of machinery*, it's clearly shows the Louvers department as the first constraint and Body department as the second Constraint.

If we take Brackets Department as the second constraint since it has the highest buffer i.e. 1000 pieces however the utilization of capacity of the machinery is high, but the inventory cycle time is low i.e. 0.923 seconds. Therefore Body department is taken as second constraint. We can also look into Final assembly department which is s type of pull system. When an order is placed they pull the material from the different parts and assemble them so, all these WIP were located near the machinery. In conclusion, the company is not even able to utilize 50% capacity from its Louver machine. We also observed the daily production of the louver department to analyze the results and make a graph shown in Appendix 6.3. The summary of the PL5 machinery shows that there exist some errors in the machinery and its utilization. The next section covers the errors and root cause of PL5 machine.

4.2.1.5. Operations Included in Preparation of Louvers

After finding the first constraint in the above section, now we focus on that constraint. In this section first we explain briefly about the operations included in production of louvers and in next section we briefly discusses about the errors occurring in the production of Louvers. As we explained in the Section 4.2(vi) the production of Louvers starts first from putting the coil into the machine, and then putting the plastic cover into the machine and rubber bands. This plastic cover helps to protect the frame of louvers from bending, because the louvers material is thin sheet plate of aluminum as shown in Figure 4.4 below. So, when the plates are inserted into the machine for punching, the chances of bending and scratches on the sheet is likely. These rubber bands help to hold with the punching machine for correct operation.

Figure 4.4: PL5 Louver Machinery

Once you built up everything with coils, plastic covers and rubber bands the machine starts and programming of the machine takes at least 8 minutes. The coil of the side mirror will transfer into the stamping machine, then the machine formulate the stamp, passes it on the belt and reaches to forming machine. At this time we have the plastic sheet placed under the stamping sheet; this forming machine presses the stamping into the correct curved shape and passes it to observer. Further he takes two stamped sheets and places it in the cross mirror machine. Then the cross mirror machine places the cross mirrors into the correct holes of the stamped sheets and send it to the observer. This whole process takes

1.377 minutes. The overall process is shown in appendix 6.3. The worker checks the pieces after starting the machine whether the side mirror machine operate well i.e. placing the holes in the right place and the cross mirrors fits in the place. The worker checks at least 5 to 6 pieces to ensure if something is wrong then the operator makes some adjustments in the program which may take more 5 minutes.

4.2.1.6. Errors/Waste in production of Louvers

In the above Section 2.1.2 (b) “Waste is described as anything that consumes resources but doesn’t add value to the customers (Gopalakrishnan.N 2010, 6)”. There are 7 + 1 unique sources of waste in Lean thinking. They are 1) Over production, 2) Defects 3) Inventory 4) Transportation 5) Waiting 6) Motion 7) Correction (rework) and 8) Talent, this 8 waste is included in the Glamox Company. However, the focus on the C10-10054120 product value stream is mainly on the physical flow of materials, so the terms of waste in this product flow is mainly related to the activities and processes that may be the root cause of delays or stoppages of the flow of material.

In this case study, mainly four wastes are identified as the basic wastes considering only production line of Louvers: 1) Waiting 2) Motion 3) Defects or inappropriate processing 4) Talent. But all these wastes are mainly interrelated with the efficiency and performance of machinery and workers.

4.2.1.6.1. Waiting Time

Henry Ford wrote, “The easiest of all waste, and the hardest to correct, is this Waste of Time because it does not litter the floor like wastes material (O'Reilly 2005).” The Lean theories mainly specify to reduce the waiting time, as the waiting time is considered as non-value added to the customers. The observational study shows that the PL5 Louver Machinery has maximum 2 or 3 interruptions in one shift as shown in appendix Figure 6.6. In other words, these interruptions mean idle time for workers including waiting time for other process concurrently.

While going through detail consideration about the interruptions, the first interruption was due to maintenance of the machine and tools. From the data received, the direct measure from the last five months shows that the maintenance of machinery is also characterized into different operations they are repairing tools, cleaning of beam, greasing of the tools and maintenance. The interview revealed that the maintenance of the machinery takes long time, is about 10373 minutes. As shown in Appendix 6.4, the details about these kinds of maintenance are the repairing of tools takes 3300 minutes, primary maintenance takes 2937 minutes, greasing the tools consumes 2387 minutes, cleaning of beam consumes 1749 minutes.

4.2.1.6.2. Motion

The second waste identified in Louvers Production Process is Motion. As we explained in the above, Motion is any unnecessary physical movement of machine and workers which can direct to addition cost of waste. The Lean philosophy recommends that the waste of motion tend to decrease in the work efficiency and the increase in sick leaves for the workers.

While going into the detailed description about the interruptions, we first consider change over time. When the worker wants to change the coil they need to stop the machine at least 8 to 10 minutes. The detail description about the operation included in changing the coil is: first to spin the coil from warehouse then place it on pallet truck and disassemble the old coil on the machinery, mount the new coil taken with the help of the pallet truck, then the worker checks the production plan and install the program according to the production plan. This whole process is operated by one operator but mounting the coil is done by two operators and it takes 565 seconds as shown in appendix 6.5. Programming the machine consumes 44 seconds but testing the machinery and changing according to production plan takes more time. The whole operations included with testing and programming with time schedule was shown in Appendix 6.5.

Only one operator consumes more time to program and test the machine. The Glamox Company made an analysis in this PL5 machine and which is shown in the spaghetti diagram Figure 4.5 below; the number of times the operator rotates near the machine to make corrections. It clearly shows that the red lines are the movements done by the one operator from placing the coil to the programming and testing of the outcome according to the production plan. From the data collected from the company shows that the programming and preparation consumed the maximum waiting time and is around 5236 minutes in last five months.

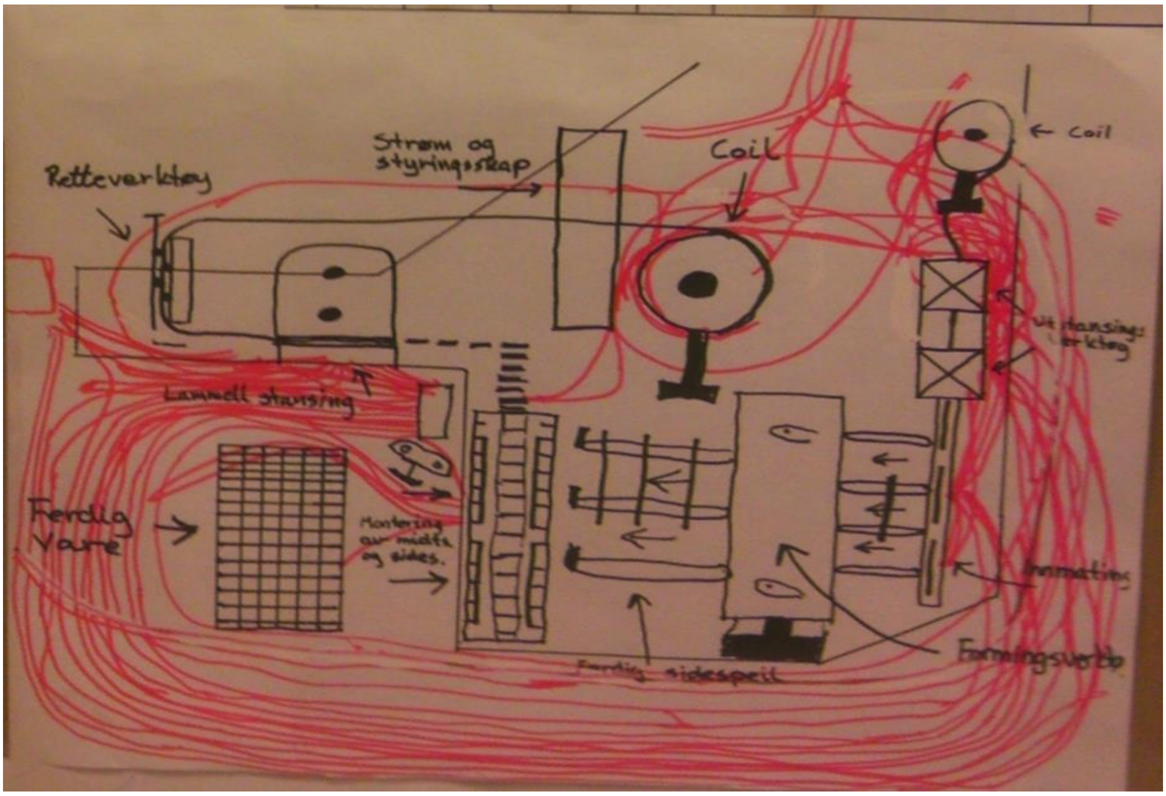


Figure 4.5: Spaghetti diagram of the Programming and testing of the Louver department using one operator

The second consideration is searching for tools and equipment. The maintenance department is responsible for holding tools and other equipment's for minor repairing. At the time when we started writing this thesis the maintenance department had not implemented 5s. However since March 2013 the maintenance department implemented 5s. Even though before March there was a problem for workers to search for the right tools or bits for minor maintenance. This also committed to waiting time and non-value added cost. Third consideration is about excessive inventory and transportation is interrelated with the waste of motion. The time taken to locate the items inclines analogously to information flow. The system with control of information and better accuracy on inventory can help to cut down the unnecessary motion.

4.2.1.6.3. Defects or inappropriate processing

The third Lean wastage is identified as defects. As described above section 2.1.3 the defects is defined as the waste of correction cause by the in adequate training and shortage of skills. "The rectification of parts consumes more time and directly affects the output. Moreover, it consumes capacity, resulting in overtime of workers to meet the customer's demand (Gopalakrishnan.N 2010, 7)." The Lean theory proposes that the in appropriate processing tends to increase in lead time. So, the Lean aims to reduce the in appropriate processing or defects.

Here the first consideration is about failure in testing. In the process of material flow, when the Louvers comes out from the machinery the workers need to monitor very carefully, if they have any scratches. If any defect found, they need to stop the machine and make some primary cleaning and start machine again. From the interview study it revealed that more than 25% of the machine interruption is due to failure in monitoring. In depth discussion we found from the data collection of the company shows 3872 minutes of waiting time due to failure in monitoring or failure in testing the pieces.

Second consideration is about coil without plastic. When the coil is not placed on the plastic sheet the chance of bending and appearance of scratches of the coil is expected. The workers should monitor the plastic coil, if the plastic sheet is almost empty and whether the coil is in right place with plastic sheet. From the interview it revealed that the coil without plastic consume 20% of or 555 minutes in a week of waiting time.

4.2.1.6.4. Talent

The third Lean waste is considered as Talent, where talent is eighth waste introduced in the Glamox Company. As we described in the above Section 2.1.3 the talent is described as motivating and guiding the workers about design and development of their workplace. They should be adequate trained by the company how to work smarter and get the continuous feedback about the process and development. Lean theory suggests that the underutilized talent tend to increase the lead time and prevent fast identification of errors.

If we take in to consideration about our errors in the previous sections like, maintenance, programming and preparations, and identification of defects. These all wastes are interrelated to the talent. These types of wastes were mainly due to the lack of training about the work place, machinery operations and failure to involve the work force in development of workplace.

4.2.1.7. Root Cause Analysis for Wastes

After reviewing the type of waste held in Louvers department from available data of 2013, we decided to carry out informal and formal interviews with the employers working at Louvers PL5 machinery. The interviews were held with two of the employee’s working at Louver machinery; one employee working with the machinery and another Manager of the department. We decided to use these interviews as a data collection method because with the initiation from the employees in the Louver department we could find a root cause of the problem. The interviews held with them would be entitled as informal and unstructured interviews because of the time and we did not particularly meet and inquire the questionnaire however it was most as a discussion among us. Moreover, we presented different type of errors but our main aim is to find the cause for reducing the machinery utilization efficiency and expected their opinion about the cause of errors. By asking a flexible and open questions to the employees, we desired to give a chance for the employers to come up with new ideas, which we can use as the foundation for our exploration. During our conversation with the employers, we tried to apply the 5 why analysis technique to go into deeper and find the root cause of the errors as mentioned above. Depending on the answers that we received from the employers we made our 5why analysis chat and cause and effect diagram. Although for the waste of motion, the company made an analysis, and attempted to solve them but we inspected more from the employers.

One type of waste that records as maximum time consumed in the past years analysis is waste of motion. Although for the waste of motion, the company made an analysis of spaghetti diagram, and attempted to solve them. When we had a conversation about the change over time with the employees, we found interesting factors from the employees. They had to walk around the machine several time, check and fix the rubber bands in the machine and when they walk around the machine the sensor gets activated and machine stops, this was the problem. This sensor is mainly used for the security purpose. In the process of changing the machine, for instance, changing the coil they would have to lift the coil with the machinery like cranes and keep on the pallet and move it near to the machine, they felt stress and exhausted.

The second type of waste here we mainly observe is with Maintenance. From the records of 2013 the maintenance of the machinery occupies the second place in the errors list. The interview from the employers reveals that longer time was taken to find the particular tool to repair or clean the machine and also another more interesting part was the leakage of oil from the machine wasted time of worker in cleaning and every time if they had more leakage then the machine break down was severe as shown in Figure 4.6 below. Although, the company considered this leakage of oil as a waste and implemented kaizen event in a way of handling the problem.

Figure 4.6: The Leakage of Oil near PL5 machinery and its primary solution

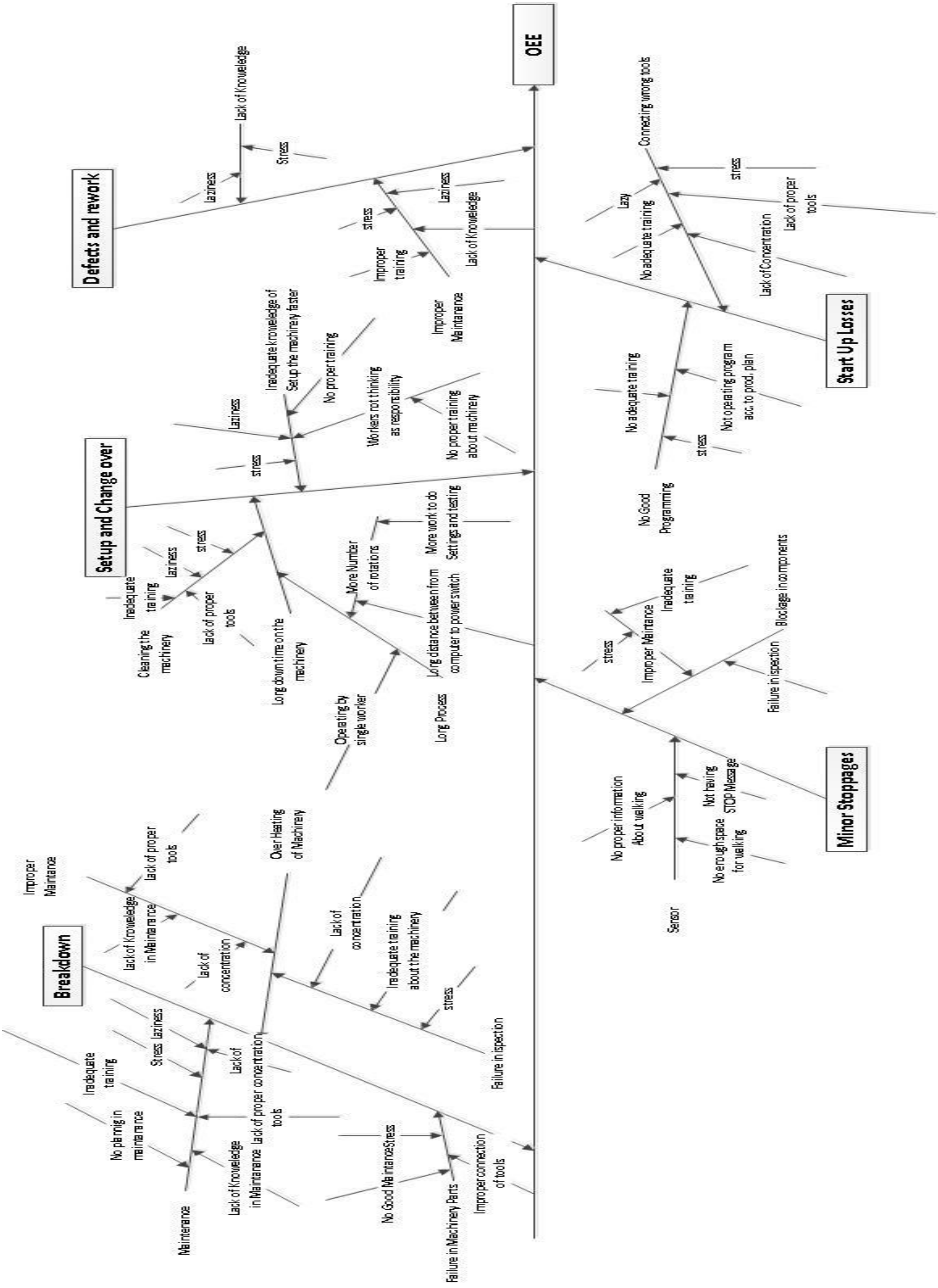


Figure 4.7: Cause and Effect Diagram for OEE

The third type of waste that records maximum is defects/inappropriate processing. The employee thinks that the defects occur due to stress, and problems with concentration are lost. The worker near the machinery says that the problems in defects occur due to inappropriate maintenance of the machine, lack of concentration and inadequate training about the errors. But the manager of the department claims that workers doesn't concentrate on the cleaning the machinery very much, they thinks that the "machine is running smoothly now why to clean and we can clean that whenever the errors occurs", so because of this type of judgment the machine gets major breakdown and stops for at least 15 to 20 minutes. Sometimes, if the workers don't take good consideration about cleaning then it might be huge breakdown and the machine might stop at least for a week. Even though the maintenance department has the spare tool, but for fixing it to the machinery always takes time. From the interviews held with the production managers, it revealed that the machine breakdowns were thrice in last six months of 2013.

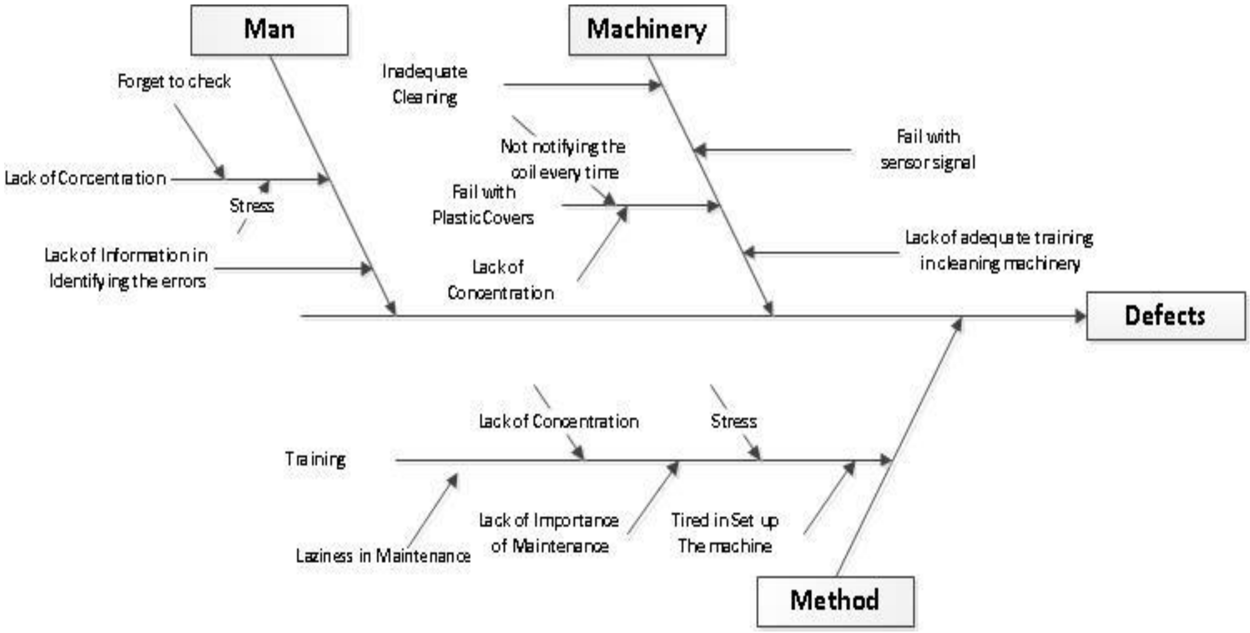


Figure 4.8: Cause and Effect Diagram for Defects

We prepared a five why analysis, by observing through walk on the plant floor. The machine stopped for at least fifteen minutes. So, we asked the workers "why" it happened, they replied these answers. From the answers that we got we assumed lack of training for the workers.

1. Why machine stop for 15 minutes?
   a. Because of scratches.
2. Why scratches appeared on side coil?
   b. Because of the existence of rust or dust in the form side
3. Why dust appears on the form side beam?
   c. Lack of good cleaning.
4. Why the beam is not cleaned?

d. We cleaned but still it's dirty , because of no availability of particular tool

The final answer is lack of adequate training about machinery and its cleaning, and also about using the tools presenting with them.

Our aim is to identify the root cause of the problem and try to exploit it by using the available resources.

4.2.2. Step 2: Exploiting the Constraint

This step will provide the answer for our second research question i.e.

"How can the lead time be reduced or the production performance be increased and how can we find the root cause of delays in production?"

In the second research question finding the root cause of the system is done in the above Section 4.2.1.7. From the Figure 2.9 we can observe that the second step in the theory of constraints is to exploit the constraint, and in Lean perspective the second step is to make the value flow. After discovery of the system constraint, we try to exploit the identified system constraint by using the available resources. As we explained above, the second principle in the Lean approach is to make the value flow, after identifying the wastes from the value stream mapping; we examine to reduce the wastes (non-value added activities) by using Lean tools like 5s and kaizen event.

4.2.2.1. Implementation of 5S at Glamox Company

At the time of writing this thesis the implementation of Lean 5s in the Louver Department was still in process, therefore this case study might not consist of a complete follow up of the implementation of 5s and the consequential results. However, it presents the background behind the implementation of Lean 5s and possible improvements of it. We also will go one phase in advance with more focus on sustainability of the process.

By maintaining the clean safe and well organized environment, which will recover the production process by adding value, the company has initiated the implementation of Lean 5s. During the visits on the production floor and from the interviews, it is clearly shown that the company implemented Sorting and Setting in order for Louver department. They also have already initiated and planned how to implement the Lean 5S in Louver Department. With the help of TPM Team Company, there are total five staffs involved in 5s implementation among which three belongs to TPM group. In an interview method, we got to know that the team concerned is to identify the difficulties of employees in the Louver Department.

The interviews with the management of the Company show that the road map of the implementation of Lean 5s that started in the year 2013 and is still in progress with the dead line of June 2014 for completion. The first phase was to plan the implementation of 5s and motivate the workers for the upcoming changes. The company also conducts the 5s workshops for the workers to understand and get awareness about 5s to involve all employees in this transition phase. It has been influential to involve all the employees in this process, particularly some of the employees are working since 30 years in the company, as they also express cynicism on the road to the success of the final results. However TPM extended their deadline in the implementation of the process from their initial plan.

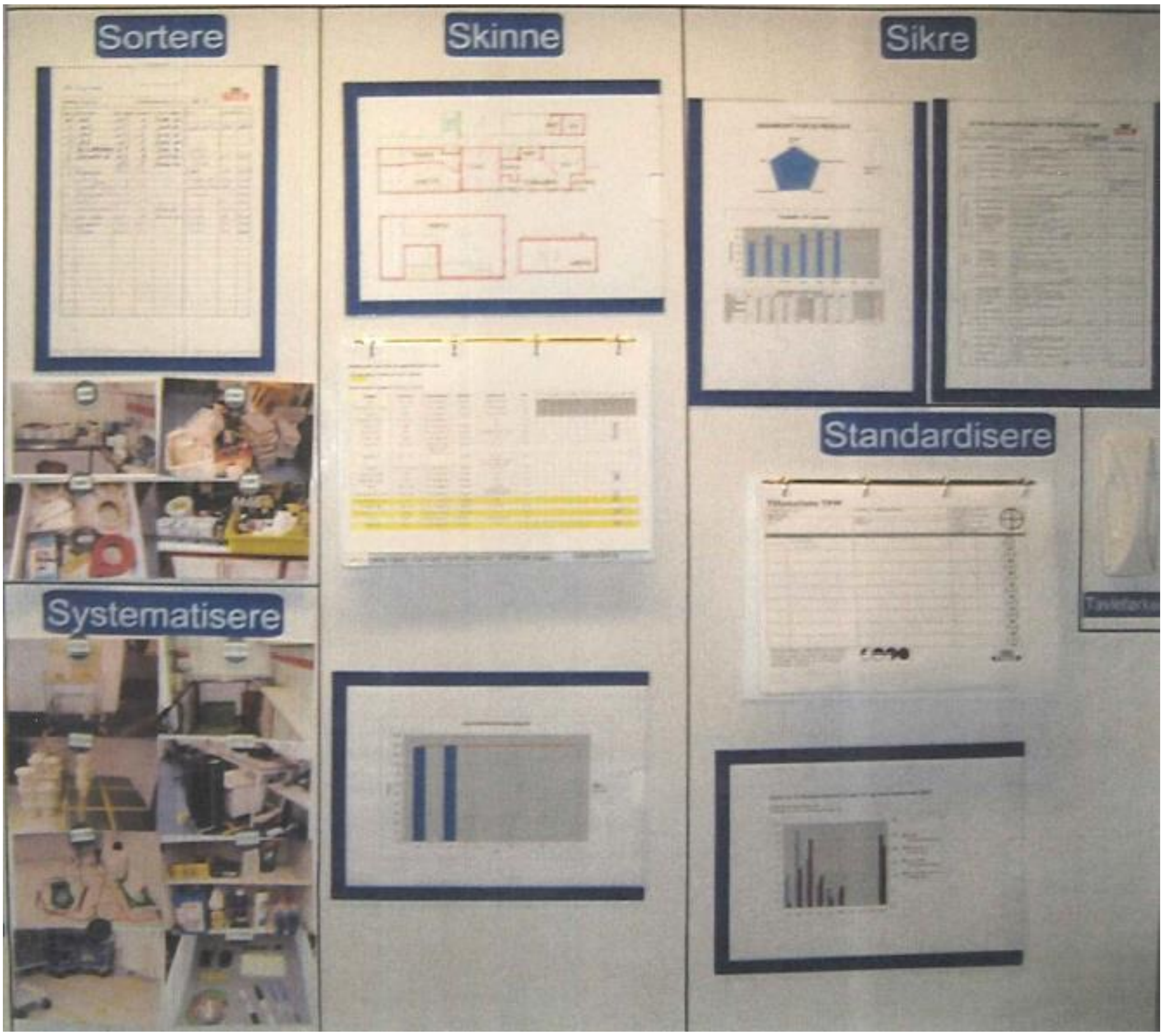


Figure 4.9: 5S Boards in Glamox Company

They divided the Louver department into three section for implementation of 5s i.e. maintenance, warehouse and machinery. However the implementation of 5s is in following order. The company pursues 5s to achieve an organized and safer working environment, increased effectiveness and raise awareness by changing attitudes of the workers. With the notion of “Prevention is better than the cure”, the company seeks for rectifying the hazards before accidents could happen. A hygiene working environment and believing the first impression as the last impression, the workers are facilitated with secure work environment. The goal is to set standards and create pride and discipline among employees and provide a structured co-operation and training to achieve improvement.

1. Sort

In all section of the Louver Department, the implementation of sorting is done by using red tagging. First the company took the pictures, where to be changed? Red tag it as shown in Figure 4.10 if it needs to be changed, and then perform sorting the system. The company also considers finding the place for sorting and keeping the goods.

- What to change?
  - ✓ Remove all unnecessary material
- Why change?
  - ✓ Clear location
  - ✓ For security
  - ✓ Easier to work
  - ✓ Easier to keep clean
- Where to change?
  - ✓ Take picture of the area before sorting
  - ✓ Create red-tag site
  - ✓ Make a list of red-tag and find a location for safety reasons.

Figure 4.10: Sorting at Glamox Company

2. Set in Order/systemize

In the above the company placed all red tagged places in the Louver department. In this step the company ought to the place all the red tag products in order. This system is planned in October 2013, but it came into phase of implementation in January 2014. The main purpose of systemizing is to get rid of unproductive time for searching and unnecessary movement. The material which is placed in red tags is sorted out further by keeping the only needed materials and throwing the ones which are useless.

Figure 4.11: Maintenance and Warehouse before and after

The shelves and desks have been changed according to size of the materials and fixed places. They also placed the notes on the shelves of the tool; this helps the employees with the accessibility of the required tool. The availability of resources of right thing at right place is systemizing. All floors are marked to clearly show where to place the tools and materials as shown in figure below. Fixed and marked spaces, order of tools and materials makes it impossible to load any tray than what should be there.

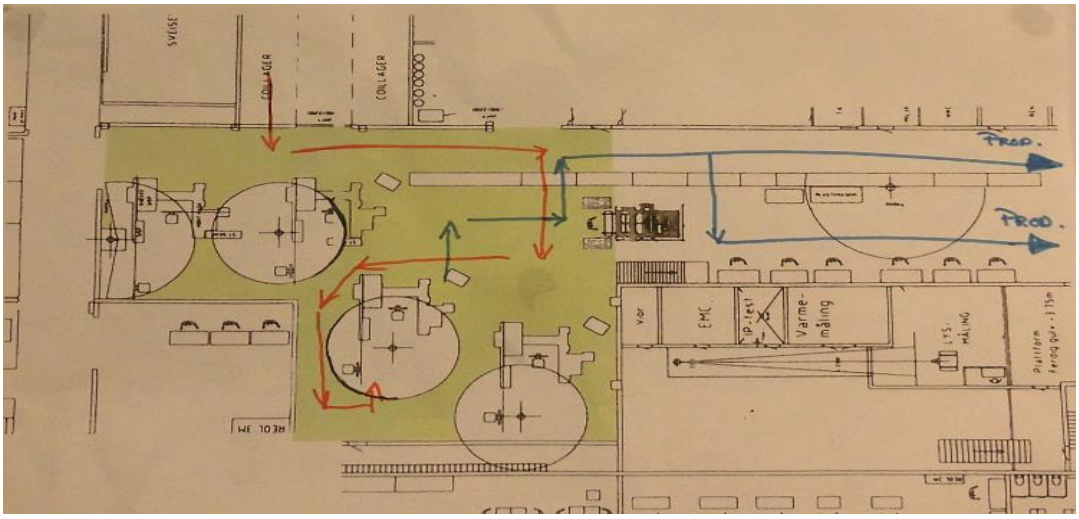


Figure 4.12: Systemized product flow (red line is coil into the machine and blue line is semi-finished product going into buffers) at Glamox Company

Figure 4.13: Fixed and Marked spaces at Glamox Company

Figure 4.14: Order of materials in the marked floors at Glamox Company

3. Shine

Shining means keeping clean and hygiene workplace to avoid possible accidents and make a good impression for visitors. Cleaning workplace and things helps to see unnecessary and unused materials and tools. The sink is kept clean, inspect equipment to avoid failure and learn to maintain the same cleanliness. The company gave responsibility to each worker working in material and tools about 5-15 minutes only for cleaning time. The main purpose is to inspect whether the workers have met the standards and kept clean.

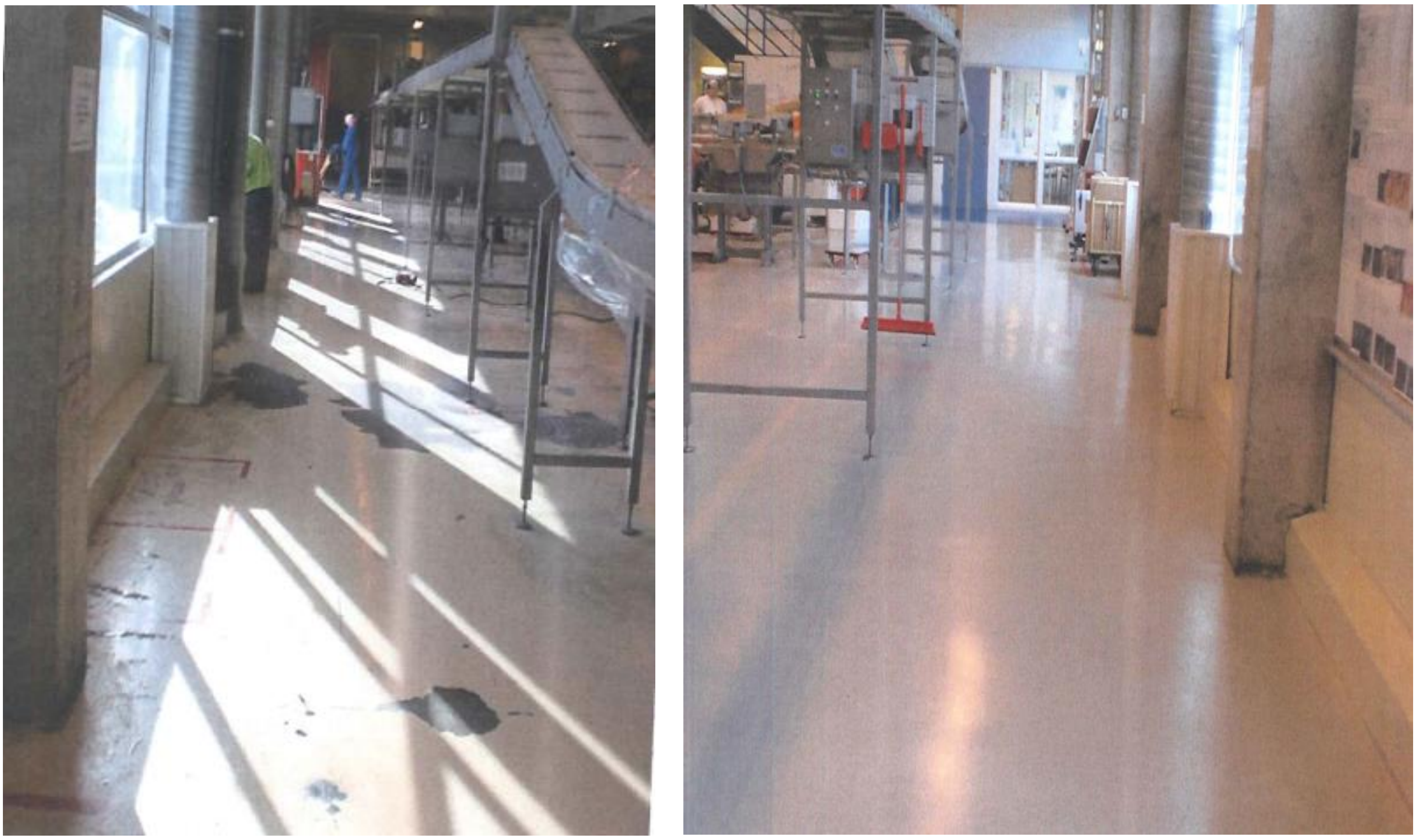


Figure 4.15: Clean Floors at Glamox Company

Figure 4.16: Before and after cleaning of the sink at Glamox Company

From the interview, the manger explained, “It is not only about cleaning but saving money from waste.” For instance, if there is leakage of oil in the floor, the employees clean as well as look for the cause and notify to technicians. The product on the floor means money on the floor and utilizing the best of what they have is what the company strives for. Shine, therefore, is checking for errors and keeping clean working environment.

4. Standardize

Standardize is finding the best solution from utilizing the available materials. Through interview method, we got to know that each worker are given roles and responsibilities to ensure the use of 5s techniques. The managers and supervisors are committed and have appointed leader in a group of employees to develop and implement 5s change. The leader guides his co-workers and supports them in an effort to grow and embrace 5s in working areas. Standardizing is the basis for continuous improvement and seeking for perfection.

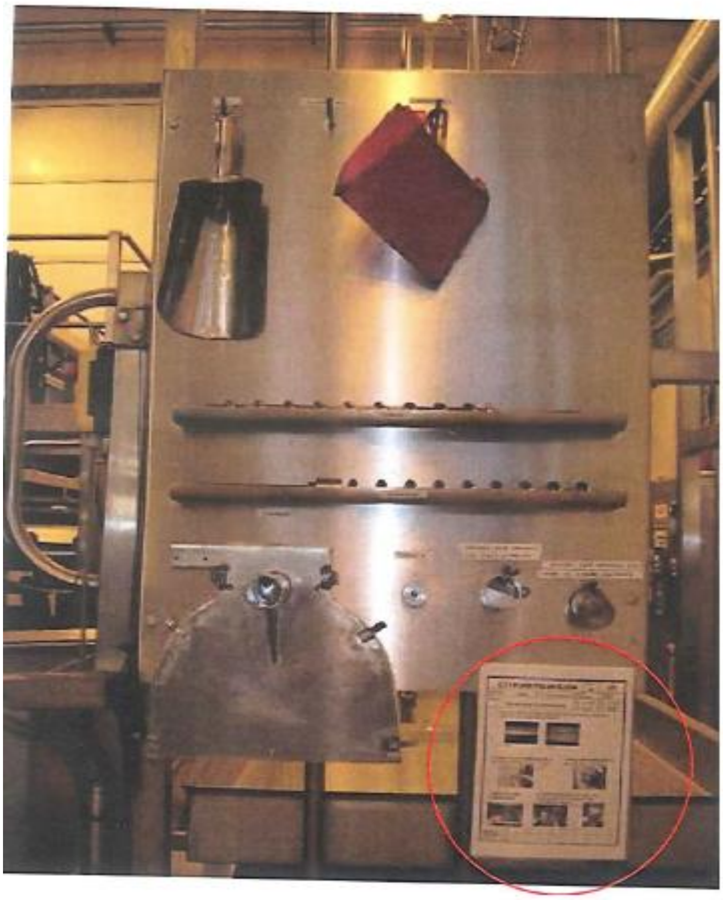


Figure 4.17: Standardizing by self-explanatory points supported by figures and pictures at Glamox Company

The brief instruction of list of process posted near the machine and materials help employees to understand and follow the standard way of doing things. This saves time and effort of employees. Doing exactly as visual checklist, labeling or color-coding is the best practice way to get everyone anywhere and anytime. The time spent for communicating and training everyone is saved.

5. Sustain

The last step in 5s is to sustain or make arrangements to ensure the new standards are respected and further developed. The old habits of falling back are kept intact and revised to avoid in future. Basically it is ongoing process for improvement by visual communication (boards, goal management, and visual standards). By interview method, the manager told us that after going through all the 5s phase: sorting, setting, shining and standardizing, sustaining is the most difficult of all. It requires continuous involvement of all the employees and awareness of what and why 5s is implemented. Roles and responsibilities of each employee must be clear and requires a dedicated and committed leader to create a standard and safer working environment. Each step above should be monitored and tapping the ideas for improvement can help sustain and benefit from this Lean tool in long run. Immediate solution to the problem that could be implemented could easily bring a possible change in old habits.

4.2.3. Step3: Subordinate

This step will provide the further answers to our second research question:

“How can the lead time be reduced or the production performance be increased and how can we find the root cause of delays in production?”

As we explained in the above step how to exploit the constraint by available resources and execute maximum efficiency, even though the planning for exploiting the constraint was done by the company, now we are moving one step ahead and developing the road map in order to subordinate the constraint. From the Figure 2.9, we can observe that the third step in the theory of constraints is to subordinate the constraint, and in Lean perspective the third step is pull to customer demand. As we explained above, after identifying the wastes from the value stream mapping and exploiting it, we examine the ways to increase the OEE (Operating Equipment Effectiveness) by using Lean tools like TPM, SMED etc.
Although we calculated the metrics for OEE in the step1: identifying the constraint, the OEE for Louver Department is of 45%, now we use some Lean tools to increase the OEE of the machinery.

4.2.3.1. TPM

As we explained in above about implementation of 5s in the exploiting step of the constraint, the foundation of TPM is 5s, and also OEE is considered as one of the key factors for TPM. The main purpose of TPM is to boost the productivity of the plant or machinery by eliminating the six big losses. These six losses will directly affect the OEE of the machinery. The six losses are Breakdowns, Setup and Change over, Idling and Minor stoppages, Reduced speed, Defects and Rework and Startup Losses. Now we elaborate these six big Losses and provide an effective suggestion for those losses using Lean Tools.

4.2.3.1.1. Break Downs

The main cause of occurrence of a breakdown in PL5 machinery is due to heating of beam, motor failure, and damage of tools. These all three causes depend on the unplanned maintenance. The maintenance is like a medicine for the machinery to live longer. The good maintenance of machinery will increase the performance of the machinery and decreases the breakdown rate or down time losses. This breakdown comes under the first pillar of the TPM tools i.e. *autonomous maintenance*. Before going to start the autonomous maintenance, first we will collect the relevant information about break downs in the PL5 machinery. The maintenance department in the Glamox Company is responsible for all the machinery in all departments. So, when the demand rate goes up, the maintenance department delays the machine maintenance. When the breakdown occurs, the workers try to understand what the cause is or why it occurred, than the maintenance department looks over to that problem and makes some changes in it. This type of repairing or changing only the breakdown part is known as corrective maintenance. The corrective maintenance focuses on removal of broken part and also focus on studying the cause.

When we analyze the case study of the company, we observed that the company uses only the corrective maintenance, but we are going one step ahead by using the autonomous maintenance system for achieving zero breakdowns, which is considered as the ultimate goal for increasing the OEE and decrease Lead-time. Before going to an autonomous maintenance, first we need to understand about the preventive maintenance. The preventive maintenance is defined as “to avoid a breakdown of any resource while keeping maintenance cost as low as possible, it includes two types of actions, Inspections and Revisions” (Santos, Wysk and Torres 2006, 106). In order to implement preventive maintenance the company should plan for daily, weekly and monthly maintenance. This maintenance plan should not affect the production plan of the machinery, so we visualize that the company should start daily, weekly and monthly cleaning maintenance with workers and maintenance department people. These preventive maintenance tasks are also known as PM orders. These PM orders should be based on a study of cause and equipment.

Although the company provides an adequate training for the workers about the machinery and cleaning when the new machine arrives, they are also responsible for inspections and revisions about the working capability of the workers. For instance, the way they follow up cleaning and maintaining the machine. From interview data collection, workers feel more responsible and excited to clean new machine than old machines and old machines have more problems.

Once the PM orders are through, the group of these types of orders is known as user maintenance orders. This user maintenance is the key in development of autonomous maintenance. In this autonomous maintenance the inspection should be carried out every day from the company's higher department employers and need to place comments on the form, or after daily cleaning the workers should enter the comments about the machine on the paper. So, the maintenance department will have adequate information about the errors in the machinery and its problem and also causes of the problem. The maintenance department will further focus on the errors and fix the problem easily. Sometimes it may take more time to fix the problems, but they obtain speedy measure to fix them with an available resource.

The autonomous maintenance includes the daily cleaning tasks like cleaning, checking the coolant oil and lubricating. The security of the workers at time of cleaning is more important in autonomous maintenance. The company should train the workers about daily cleaning and how should they perform it and its safety measures when they are working in cleaning of the machinery. If there is any major and risky cleaning of the machinery, the maintenance department works on it. The simple, easy and safe maintenance should be allotted to the workers.

Workers usually don't want to perform the extra task of cleaning and they also fail to consider the maintenance of the machinery as their responsibility. Moreover, the company should motivate and also conduct some courses for the employees about the importance of the maintenance of the machinery. Also conducting an inspection every day until the workers make the maintenance as a habit, the leader should be responsible. The maintenance department should perform an autonomous supervision on the workers and their responsibilities of maintenance and cleaning.

4.2.3.1.2. Setup and Change Over

From the Lean perspective in order to reduce the setup time the company uses the Kaizen event with including PDCA cycle, as we go into further details before implementation of Lean Kaizen the company uses 33 lists of operations shown in Appendix 6.6 and done by only one operator. The spaghetti diagram in Figure 4.5 also shows that the number of rotations one operator does in order to setup the machinery. The operator first place the machine into an idle state, bring all tools and coils near the machine then mount them and program the machine according to the production plan.

After the kaizen implementation, they divided the overall operations and made an operational plan and its changes in Appendix 6.5. This figure gives an overall overview of the operations that is done and changes that may be done. The overall review of that figure in Appendix 6.5 shows that some of the operations were divided and done by two people and the team leader of the department review the next production plan and places the coils near the machinery when machinery is running.

Plan:

The Company made a kaizen plan to reduce the setup time up to 1 min 30 seconds. By planning activities, for example the loss of time in retrieving the coil and machine down time, what is the next action to be taken to reduce the time in restructuring?

Do:

The Company also planned for activities working in parallel with machinery in order to reduce the time. First they considered the pallets are not placed in right place i.e. near the coil or the machinery. So, the workers had to search for the pallets to bring the coil from the warehouse. They also made an action that the coil should be retrieved and placed near the machinery so that the space near the machinery should be enough to place the coil before setup time. And also planned to use of machine cranes to lift and mount the coil which was easier process for the employees.

Check:

By obtaining these changes the company would benefit around 7050 NOK per year and they can save around 15 minutes.

Act:

In this step they define use of crane machinery for lifting the coil and placing on the machinery.

4.2.3.1.3. Idling and Minor Stoppages

This idling and minor stoppage occurred due to blockage in component, adjustments in machinery, blocked with sensor, blocked with delivery, cleaning and checking and helping with another machine. These stops take five minutes or less than that, as we already explained in bottlenecks/wastes in louver department. The blockage of sensor occurred due to safety reasons, if one person's passes from that sensor the machine stops for safety reasons. The company although implemented the standardize method and drew the border lines, but they should also maintain the gaps for this sensor while walking near the machinery. The Help with another person also consumes more wastage, this is occurred due to the person near the machine doesn't know how to operate or isn't able to fix the problem on the machine. At this time, another experienced operator would have to stop the machine and help the operator. From the Appendix 6.7 we observe the time that the Louver department consumes at least 20 minutes per day in one machine for helping with another machine. Sometimes it may take about 5 to 10 minutes and sometimes more than 60 minutes. These minor stoppages doesn't count more wastage in time if it is once or twice, but the stoppage of the machinery is about 25% in one week's shown in Appendix 6.7, the plan for standardization will improve the time for stoppages and reduce the number of stoppages. The standardization should be planned according that the space between the sensor and the machinery.

The standardization process should be clearly explained to the workers who walk around the sensors then the company can reduce the minor stoppages of the machine and have good and safe standard production. For instance, the Team Leader of the department can help the minor stoppage in the machine instead of going to another operator. Therefore they can reduce the time of helping another machine or they should provide a good training for the employees. As a result, both the machines will be running to save time and effort.

Kaizen or continuous improvement is the second pillar of TPM as a focused improvement. As we discussed earlier TPM as a proactive approach, continuous improvements are done with the help of all talented employees in equipment operations. Cross-functional teams can perform better than any single department working alone. “Machines do only what people make them do – right or wrong – and can only perform better if the people taking care of them acquire new knowledge and skills regarding equipment care (Leflar 2001, 6).”

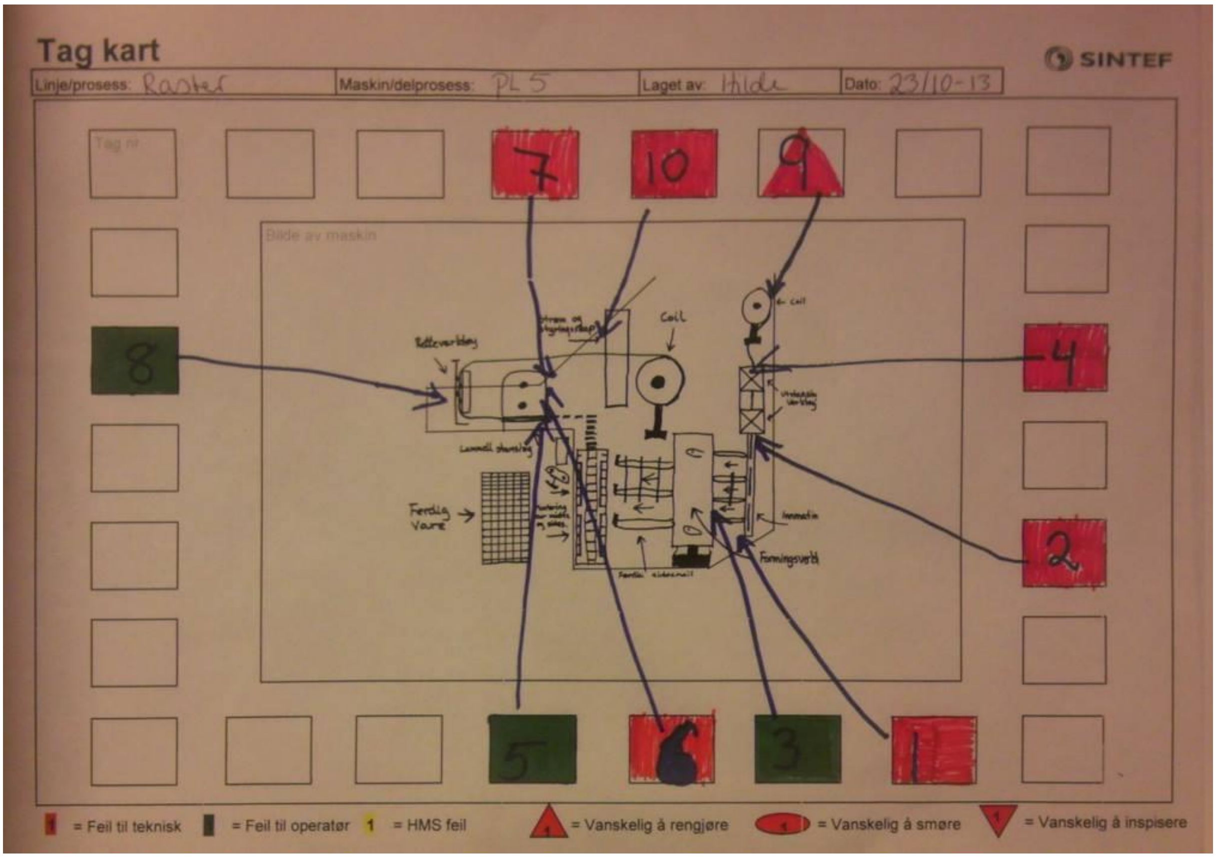


Figure 4.18: Implementation of Kaizen in PL5 machine at Glamox Company

In the above figure, the company implemented Kaizen event in order to increase the efficiency of the louver machine. The red square box with numbers 1, 2, 3, 6, 7, and 10 indicates the technical failure; the red triangular shape with number 9 indicated the difficulty in cleaning; and the green square box with numbers 3, 5 and 8 indicates the operation failure. It was further investigated with the help PDCA cycle by a group of leaders to eliminate the problem from the system process in a given period of time.

1. Loose wires
2. Coil with wires
3. Tape and rubber bands placed on punching machine of side mirrors
4. Red strip holds with gears

5. Oil leakage on the tool in cross mirror machine
6. Cable or reel placed on the floor with punching machine
7. Preventing from doing something wrong
8. Hanging the jacket in wrong place
9. Inaccessible area for cleaning
10. Cables hanging outside cabinet impossible for closing

From the data collected and through direct observation, we observed that the company had already finished implementing PDCA cycle in 3, 4, 6 and 9 problems. Therefore, we attempt to explain the given problems in details further in our research work to obtain a continuous improvement in the company.

Problem 3: Tape and rubber bands placed on punching machine of side mirrors

Figure 4.19: Picture of punching machine of side mirrors at Glamox Company

Plan:

In order to find a permanent solution, the group investigated to remove the old machine parts into new tape or rubbers. It was estimated that it takes 15 minutes per week and 11 hours per year with the expense of 6600 NOK per year.

Do:

Conveyor belt joints was not satisfactory because side mirrors hit the joystick, misplaced and malfunction of joystick, malfunction of trek rolls and their design.

Check:

Problem considered cost is estimated saving of 6600 NOK per year with 11 hours per year

Act:

Develop a standard plan for controlling the rollers and joystick. Need for regular inspection to ensure operator's maintenance.

Problem 4: Red strip holds with gears

Figure 4.20: Picture of gears at Glamox Company

Plan:

Time consuming for cleaning. To remove the unnecessary cleaning and save time, permanent solution is to clean with red spirit and use of box on the floor to collect oil. We can also attach a device and seal the leakage. This will take 30 minutes in each shift and cost 300 NOK per shift.

Do:

The leakage can be fixed with tape creating standard fixture for holding sealing leaks. Also ask 5 why to solve the problem.

Check:

Check the loose items, leakage, and get 100% solution in cleaning. Save 60 minutes per day and 13200 NOK in a year.

Act:

Visual checking daily of cabling and tubing. See how and what needs to be checked daily with all machinery.

Problem 6: Cable or reel placed on the floor with punching machine

Figure 4.21: Cables near punching machine at Glamox Company

Plan:
Large cable coil on the floor prevents cleaning. Time consuming for about 20 minutes extra time.
Do:
Cut the cable in exact length and remove the extra length of the cable.
Check:
The cable is cut in right length and hung up from the floor. Cleaning is reduced to 20 minutes per week.
Act:
Routinely checking the cables by fitting or removing. Get it right first time.

Problem 9: Inaccessible area for cleaning

Figure 4.22: Picture of inaccessible cleaning area at Glamox Company

Plan:
Haspel cleaning time = 2 hours. New dirt, oiling and dust remain in the machine.
Do:
Reason to measure

1. Bad plan for cleaning: Create a detailed plan for regular cleaning
2. Plan not followed up: Make a system with cards that can be easily checked
3. Plan not visible (panel facing the wall): One-Point Lesson prepared and display
5. Engineers not focus on cleaning when there is stock in machines: Requirements cured by acquisition updating to include a focus content and user friendliness.

Check:

Routine implementation and meetings held with the checklist for all new installation positions where user friendliness, easy maintenance and good inspection opportunities

Act:

Plan every week for cleaning and maintenance.

4.2.3.1.4. Defects and Rework

The defects or reworks is a cause of error in steady state production, these defects are very problematic to identify, while machine is in operation. As we explained in the above regarding the wastes/bottlenecks in the company the second reason for stoppage of machinery is due to defects and rework. If we go into consideration about values from the Appendix 6.7 we can observe that the maximum time taken was 70 minutes to clean the machine when defects occurred. The company is motivating the workers and identifying the causes and finding the ways to improve wastes. But now we are going into one step ahead and try to find the root cause of the problem as in the Figure 4.8 as we explained about the root cause analysis about the defects. From the interviews and direct observation data collection we observed that the main cause for this type of waste is due to improper maintenance and due to employee's laziness.

After finding the root cause we once again held an interview with the team leaders and employees we identified that the workers feel the minor maintenance of the machinery is not their responsibility and allege it on the maintenance department for it. The maintenance department and leader of the department should take care about these issues keeping in mind to motivate the workers and designate their responsibilities to avoid large breakdowns. After analyzing all categories we mentioned to implement planned maintenance. This planned maintenance will reduce the chances of defects and rework rate and also prevents from long term break downs.

As we explained in the above, the eight pillars of TPM the third pillar is about planned maintenance. "The properly planned maintenance routines can prevent almost all sporadic equipment failure. In Agilent's manufacturing terms, well maintained machines make many wafers. Poorly maintained machinery makes fewer wafers. Broken-down machine makes none. Scheduled maintenance is the foundation for TPM activities (Leflar 2001, 6)." From the above definition we move one step ahead and interview the maintenance department employees about their plans for cleaning and maintenance of the machinery.

The interviews from the maintenance department leader, we got to know that the maintenance department in Glamox Company was outsourced by the AMEKA Company.

This maintenance department was only responsible for the new arrivals of machinery and provides service for the machinery for 6 months to 1 year. They also take major problems of machinery into consideration like breakdown of tools and also had some spare tools for machines and they fix them whenever the problems couldn't be managed by the operator. They also provide an adequate training for the people about the new machinery and its cleaning, but they are not responsible for cleaning the machinery like weekly and monthly. They told us that the workers near the machinery were responsible for cleaning and the leader of the Louver department is responsible for the small and daily problems. Then we interviewed a Louver Department leader, he explained that when the workers start their first shift they should operate minor cleaning for 15 min, and then they start the machine. But they don't have any planned maintenance for the machine, if the defects occur, they stop the machine and clean it and again start the machine. The maintenance department leader told us now they were thinking to plan and implement maintenance task for workers to get a good results for machines. From the interviews and direct observation from the plant floor we deliver a planned maintenance task for the Louver department.

We divided the whole maintenance task into two categories one is primarily done by the employees who works on the machinery and the second one is for the maintenance department. If we go into further details about the first task, this task should be held with the employees near the machinery every day. The task include in daily maintenance are cleaning the beam, checking the coolant oil and checking with plastic cover. These operations should be done every day, and this maintenance also prevents the scratches on Louvers. This must be done thrice per shift once when they are starting the shift for 5 to 10 min and then for 5 minutes before going to lunch and another for 10 minutes before finishing the shift, or it can also be handled when they are placing on another coil on the machinery like set up and the company should provide an adequate training for the workers, i.e. to perform cleaning in an easy and fast way and they also should provide a cleaning manuals and how to perform it in visuals near the machine. The Leader of the Louver department should check workers performance in cleaning whether they performed well or not if not the leader should show how to perform it, in this way the workers will learn sooner.

Further we move on to the second task, this task should be held by the maintenance department. We divided this task into two types: weekly and monthly maintenance. Now focusing on the weekly cleaning, on Friday the company operates only one shift i.e. up to 3:30, the maintenance department should start cleaning the machinery on Friday after the first shift is over. The main tasks for them are to grease the tools and check if all the tools of the machinery are operating well and good. If the tools are not good enough so they need to change into spare tools. Now focusing on Monthly task, the maintenance department should operate once in a month and clean the whole machinery. The maintenance department should also take care about the training for the maintenance and team leader should supervise the workers every day. If the company follows these suggestions there is a chance of decreasing the break down and rate of defects. As we explained before that the Maintenance is like a medicine to the machinery so as often as we carry out maintenance, the output is always effective operation.

As explained before the company implemented 5s with the aim of employee's convenience to find the tools and have quick operation. Some authors suggest that the 5S is focused on autonomous maintenance. But these "Planned maintenance tasks are usually beyond the scope of the autonomous maintenance program. They require special skills, significant disassembly, and special measuring techniques and tools etc. as the equipment operators improve their skills, the maintenance groups performs fewer and fewer planned maintenance activities and start focusing their effort instead on improvements that are designed to reduce the maintenance requirement of the equipment, thus reducing overall maintenance work." (Gulati 2008, 178)

4.2.3.1.5. Startup Losses

The startup defects occurred when the machine after set up of new programming. These losses also occurred during warm up the machine. From the interviews it's revealed that the root cause for the startup defects occurred due use of improper tools and problems in programming. These types of defects can be reduced by proper training of employees about the way to setup the machine and clearance about the required tools. Also placing an instruction chat near the machine explaining the details about the setup and required tools could boost up the confidence in workers. These suggestions would help the company to reduce the startup defects rate and have a good production system.

4.2.3.1.6. Reduced Speed

This type of defect occurs due to in appropriate processing of the setup, problem in tools. The reduced speed while running the machine signifies sooner breakdown in the machinery. These types of errors can be reduced only by good maintenance plan, precise setup of the machinery, and use the accurate tools.
Our main aim in this section is to improve the performance of our constraint, and increase the lead time of the whole process. From above analysis of the problem, the company has implemented few maintenance and plan to implement some more. But after analyzing the problem according to our ideas, we used the appropriate Lean tools for the problem and made some suggestions for the company to operate and analyze them and benefit from better improvement in production.

5. Suggestions and Conclusion

This chapter represents the suggestions of our research paper, our findings and recommendation to further analyze the problem in the company.

5.1. Suggestions

In the course of writing this research paper, we still have our last research question left which we discuss as suggestions. Since the implementation of Lean in Glamox Company is still in progress therefore we could not further analyze our third question. Our suggestions may or may not be applied that is another question however we have tried our best to understand and further try to reduce the inventory stock using Lean tools.

5.1.1. Reducing inventory

This step will provide an answer for our third research question:

> *"How can the buffer capacity utilization be reduced?"*

As we explained above in the seven wastes of Lean Philosophy, the major type of wastage is inventory. The increase in inventory causes the space reduction, high inventory holding costs, increase in internal transportation of goods and increase in unnecessary motion. From the figure 1.8 and through the direct observation and interviews it's revealed that the company utilizes more space for buffers and more internal transportation of materials. In the process of writing this thesis the company has not yet focused on the reduction of inventory plan but we made some suggestions for the company to reduce the inventory and its locations.

Once again if we go back and revise, the product we are dealing with is make-to-stock product where delivery must be within 24 hours after receiving the orders. So, in this perspective we were not able to make the production into one piece flow of goods taking into consideration of minimum amount of inventory of finished goods inventory and semi-finished goods inventory. Although the company uses MRP for production planning, they increase their safety stock level in this year compared to last year. In the above sections we explained about reordering points and safety stock levels in each and every production line. "A Lean Inventory reduction program is therefore complementary to a company's inventory control strategy, since the Lean techniques focuses on the inventory with in the production system as well as the finished goods inventory" (Basem and Raid 2006, 46).

From the interview held with the planning chief, we acknowledged that the demand is variable and not same all the time. He also informed us that all the 4 production lines are open capacity on machinery which means the machinery are available every time for the production whereas final assembly is not open capacity and should be planned.

According to the authors (Black and Hunter 2003, 40) “The minimum level of inventory that can be achieved is a function of the quality level, probability of machine break down, length of the setups, variability in the manual operation, number of workers in the cell, parts shortages, transportation distances and other factors”. In order to have smooth flow of materials in the production process we need to decrease the inventory levels. In any manufacturing system maintaining a zero inventory is impossible, so the only way to maintain minimum inventory is by achieving zero defects in production process.

By using the Kanban Lean tool, we can reduce the inventory levels and maintain balance inventory in the manufacturing process. As we explained in the above, the kanban is an ultimate tool to reduce the inventory and access to pull system in the production process. But here in our case we are not obtaining the pull system but reducing the inventory level.

From the data collection we analysed that the company places the production plan 3 days ahead and holds 5 weeks finished goods buffer as safety stock, 5weeks of buffer near the brackets, 3 weeks buffers with louvers assembly and 2 weeks buffer near the body assembly. The average weekly demand is 270 and produce 320 pieces in final assembly on average in one week. After reviewing the above data we plan reduction in inventory by using the kanban cards and its links from body to final assembly.

For instance in Body production line, currently we have around 6 pallets (1 week production) with extra 2 weeks buffer. By placing Kanban cards on each pallet, the final assembly line proceeds to withdraw one pallet at the time they require from the feeding subassembly line. These subassembly lines triggers the need for the replacement of the pallet that has been removed on the production plan and made immediately within 3 days i.e. 430 pieces. In this way, we can decrease buffer of 1 week from the subassembly lines.

By this way using Kanban card, we produce only before usage of material and keeping one week buffer ahead for any major problems. The company can reduce the buffer capacity, costs and space. The safety stock level in the ware house of finished assembly is 5 weeks buffer and reorder point is 6 weeks but they produce every week in final assembly. We suggest the company to reduce their inventory level in ware house to 2 weeks and reordering point to 3 weeks. Although they produce goods every week around 320 pieces and makes them to stock, therefore to maintain minimum stock level and decrease holding cost is our suggestion.

If the company reduces the buffers between the production lines and final assembly it could reduce to 8.3 days WIP with only one week semi-finished products in stock. If they reduce the finished goods inventory, from 6 weeks to 2 weeks, than they could reduce from 18.1 days to 11. 8 days since 2 weeks is reorder point for finished goods inventory. For example if the customer places an order of 1000 pieces, then the shipment will be every week of 54 to 60 pieces, they won’t send all 1000 pieces in one lot. So, in total the company can reduce its WIP to (13.8+7.5+8.3+11.8 = 41.4 days), from previous 57.5 days of WIP.

By following these suggestions the company reduces their WIP inventory and lead time, reduces the costs and also decreases the internal transportation of goods and space reduction. If there is any problem with the machinery, they can hold one week buffer of semi-finished goods and two weeks buffer of finished products in hand until they resolve the problem.

5.1.2. SMED

From the Lean perspective in order to reduce the set up time or change over time by using SMED (single Minute Die Exchange). Here we consider SMED to reduce the set up time in Louver Department PL5 machinery. As we explained in the above section the primary step included in the SMED methodology is to study and analyze the current setup process, the current set up process given by the company is shown in appendix 6.5 and also the appendix 6.5 shows the set up required and activities obtain in setup the coil according to the production plan. Although the company planned to implement kaizen for reducing the setup time but we are going ahead and analyzing the activities and dividing the activities into external and internal activities and also removing the activities those are not necessary.

Separating internal and external setup activities:

As we explained in the above section the external setup activities includes those operations that can be runs parallel when the machine is running, But the internal setup activities are operated only when the machine in idle state. In the table we explained the activities those held for set up the machine. Now we are separating all the activities into internal and external. The 1, 2, 3, 7, 9, 25, 26, 27, 28, and 29 operations can be done in parallel when machine is running, and the other activities is done when the machine is in idle state. The separation of internal and external operations was shown in Appendix 6.6.1 and 6.6.2.

Converting internal setup process into external setup:

From the internal process as we described in Appendix 6.6.1, all internal process is held only when the machine is in idle state, like mounting the coil and disassemble the coil mounting the plastic coil programming the machinery according to the production plan. Actually before implementation of Lean at Glamox all the internal setup and external setup is done by one operator the spaghetti diagram for the one person is also shown in the Figure 4.4. Some of these internal setups like the tools to mount the coil and tools to disassemble and plastic should be converted into the external setup. Moreover if one person operates the all the internal operations they may take too much time so, we suggest two workers helping each other when they place these operation and reduce the setup time with same amount of quality of work. Also the Leader of the department should help the worker with setup of the machine.

If we observe in Appendix 6.6.1 shows the internal process should be done when the machine is in ideal stage. In order to test the piece they should stop the machine and start again these are like start up defects. The company has divided some external and internal activities. As shown on Appendix 6.5.

Here we suggest company that if the operations like 10 and 11 should also done by using two operations so we can decrease the set up time to some extent, and also we suggest that the when there is set up of the coil and programming the Team leader should help the workers with programming and setting so, they can reduce the time in testing and programming the machine and chances to reduce the set up time.

5.1.3. Planned Maintenance

As we explained in the above section about planned maintenance, those suggestions will provide a decrease in the reduction of time in defects rate, help with another machine and coil without plastic. These regular maintenance methods will provide a 50% reduction of time difference in stoppage of machine time. If the company follows these methods there is a minor chances of defects and stoppage due that also reduces and reduces the large breakdown chances.

5.1.4. Delays in Production

From the interview held by the Team Leader of Louver department and the production plan for that department on that day showed they scheduled production of louvers however the machines was in ideal stage without production, so we asked why isn't the machine running as it is supposed to be as scheduled? He answered "As the final assembly was two days delay according to production plan so we stop our production in order to reduce the buffer capacity." Then we asked again what about the workers on that machinery? He replied "We assigned them for assembly of louvers." The delay in final assembly could be due to sick leaves, absenteeism, lack of required parts, lack of people and waiting for the parts to be assembled.

If the reason is due to lack of manpower then it is a big problem for the assembly as it is operated by 5 people and one shift per day. So, if one person takes leave there is a big loss in production and plan will be delayed from the actual plan. Although the company produces the production plan only for three days ahead, they are the bottle necks for the production line for now. And the leader of the Louver department and Assembly department has an internal co-ordination that's why the Louver department leader keeps their information intact to avoid overproduction. But what about the production plan for the production manager? Here they explained that the production manager decides the orders but they don't know about the capacity of the people and department. So, the Louver department leader delayed the production for one day. Here we can observe the communication with the higher departments is not so good enough. They are producing the production plan but not supervising it whether it was produced or not, if not they should update their next three days production plan and provide minor changes for the next three days.

We suggest the company to reduce the lack of man power by taking a group of people from each department and train them with all the work in the company about machinery in each department and final assembly. If any department fails to catch up with the production plan then those trained people can shift and place to work at any time. So, doing this they can be updated with a production plan, on-time and other department may also run freely. If there is any problem with availability of material, then the system should check before planning about that product whether there is an enough goods in the ware house or not.

Here we also suggest the company that when each department finishes the production plan according to planned, they should enter in the system when they finished the goods so that the system may check the availability and plan for the next. For instance, in the company most of the times the operators plan to finish the coil if in case of standard product and kept them as buffer. When this buffer is entered in the system, the next time when they need material the operators can take from this buffer, instead of producing a new production plan. Here we suggest they should make some changes in proper updated production plan and plan according to the working efficiency.

Here we also suggest the company that when the workers takes leave, it also should be entered into the system and check where the production runs smoothly so from there one person can come and operate for the assembly for one day or two days. So, this is the safest way to have a smooth production flow.

When we were walking on the production flow, we observed that the employees in the production flow were a bit lazy in working. We also observed that they are active when they start the work and after lunch the work is bit slower. So, we ask this question to the higher managers they replied that the workers don’t know about the production plan. So to avoid this type of errors and motivate the workers about their work there should be a goal in each day for every production line so workers know how much work is completed and how much they need to finish. The display board indicating what is the max production for now and how much they produced until now and how many more number of pieces should the workers need to produce more makes work more efficient and smooth flow. If they place a sensor in the machine when they enter one piece into the pallet it reads and display what is left.

By following the above mentioned suggestions the company may decrease the time in production system and reduction in WIP, reduction in setup time, reduction in helping with another machine time, and reduction delay of products according to production plan and have a smooth production flow.

5.2 Limitations and Further Research

5.2.1. Limitations

There always exist some certain limitations which cannot be avoided. The availability of resources, time and knowledge can limit our understanding and knowledge in case study method.

The main limitation of thesis was changing data, figures and information in regard to the Glamox Company. The implementation of Lean is on-going process and the company is generating values to understand Lean culture which were not measured before. Getting information from the company took longer period and translating the documents in English was time consuming. Some of the given information is estimation based on the available resources. Therefore reliability and validity of data should be checked if possible. However we have tried to justify the research with the reference papers.

Another limitation was our study is not related to cost reduction. The cost-benefit that Glamox Company can get is not illustrated as our focus was reducing lead time and buffer capacity where time is also another crucial factor as being a student. And also the different varieties of product in each family gave complex outcomes. So focus in only one product was complicated and challenging.

5.2.2. Further research

During our thesis and certain time limitations, some issues and topics can be further analyzed for research in future.

- As we discussed earlier the cost saving in numbers can be a research work for further studies. How much the company can save from implementation of Lean is the primary goal for managers. Reducing buffer is not seen as value as reducing the actual cost of the product.

- Production process layout is another area for further research in Glamox Company. The layout of production process is also the reason for increase in motion of inventory and people. The U-shaped production process and flow of material is efficient and a leaner process.

- The further analysis on elevating the constraint can also be the research work by implementing Lean tools and getting the exact values of reduction of Lead Time.

5.3. Conclusion

The journey of Lean is an on-going process and will continue to improve efficiency by engaging employees in the process of change. The motivated employees, flexible working environment, training and opportunities, clear goals and expectation, and better relationship with managers are Lean practices. Contribution of employees in creating more value embarks success in Glamox Company. The concept is extremely simple, building a mindset of continual pursuit for perfection and when we stop doing the wrong things and start making it right than the outcome is simple.

In this thesis we use focusing power of the Theory of Constraints and Lean tools to concentrate on priority areas and improve the overall performance of the company. The use of right tool and application of TOC methodology provides strategic advantage of continuous process improvement and flow management.

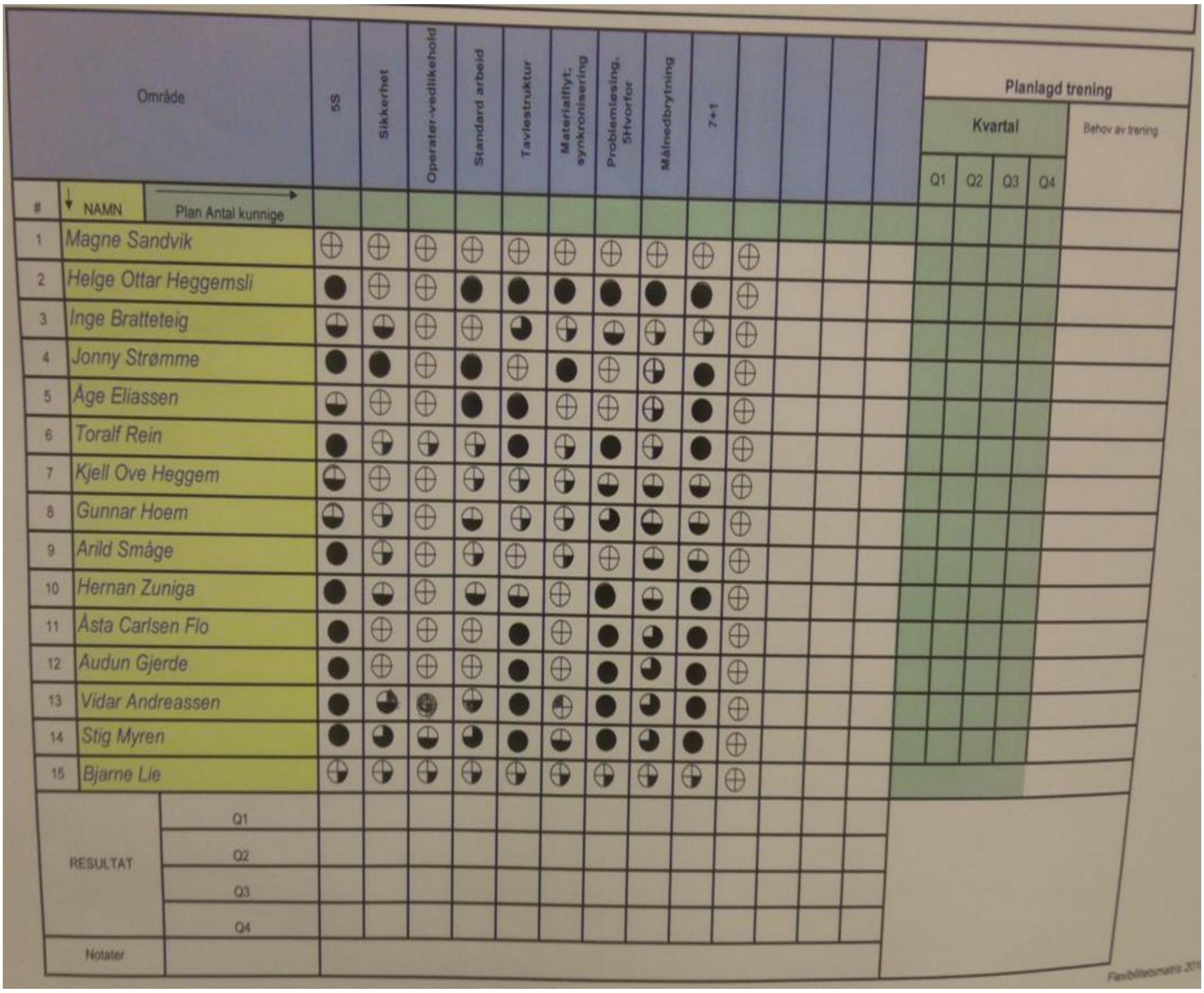
The main aim in this case study is to reduce the lead time, increase the performance of production and reduce the buffer capacity. So, we have limited our research to C10 product flow to analyze the production performance, findings for the root cause and using appropriate tools to resolve the problems in the production line. But the cost of the production and also suppliers or customers is not analyzed as a part of our thesis because of time limitation and broad discussion.

The use of Value Stream mapping guides us to seek answer for our first research question. The performance of each production department is measured in order to find the system constraint and remove the non-value added waste. From the performance calculation and research, Louver Department was the main area of focus to improve the machine efficiency because of the lower machine performance and longer lead time. The 5-Why analysis and Cause and effect diagram is implemented to provide the root cause of the problem to analyze further.

After identifying the constraint in the process of exploiting we use 5s tools to make the most of what exists or best possible way to utilize the resources. This step not only focused on the preventive measures but also safety of the employees, the major concern of the company. Kaizen event or continuous improvement using PDCA cycle served as practice of Lean culture and employee involvement in the company. TPM offers an insight to subordinate the constraint and lead time by obtaining the zero defects and zero breakdowns. The use of SMED tool for further suggestions to the company is for the reduction of setup and change over time which is insight for the reduction of Lead time; these tools answer our second research question. The use of Kanban tool is also further suggestion to the company to answer the third question of what our thesis aims for i.e. reduce buffer and lead time.

6. Appendices

6.1. Knowledge about Lean in Glamox Company



6.2. Data Received

We received this data on 14,03,2014 from the logistic chief Mr. Vidar Anderrensen.

1. *For Brackets:*

4548410021 Brakett ende

											100							0,923											
																													0
Lossing av bil				Ankomst stålager	Innmelding lager 112	1001M WH112	520m/mnd		Lager slitteområde 1400m	Coil settes på stanselinje = 5 min	Omstilling	50 min		oppstartskontroll = 2 min	Hente program = 1 min	Kjøre test = 2 min	justere program	Stansing	Buffer stansemaskin = 6400m	Interntransport = 5 min				Bufferlager midt hall = ca 1400m	Hentes til montering				Bufferlager ved Ads/reol = 1670m

Material brakett (01615230):
Leveranse stål: ca 1500 mtr hver 2. - 4. måned
Stålforbruk: 4-800 mtr pr måned

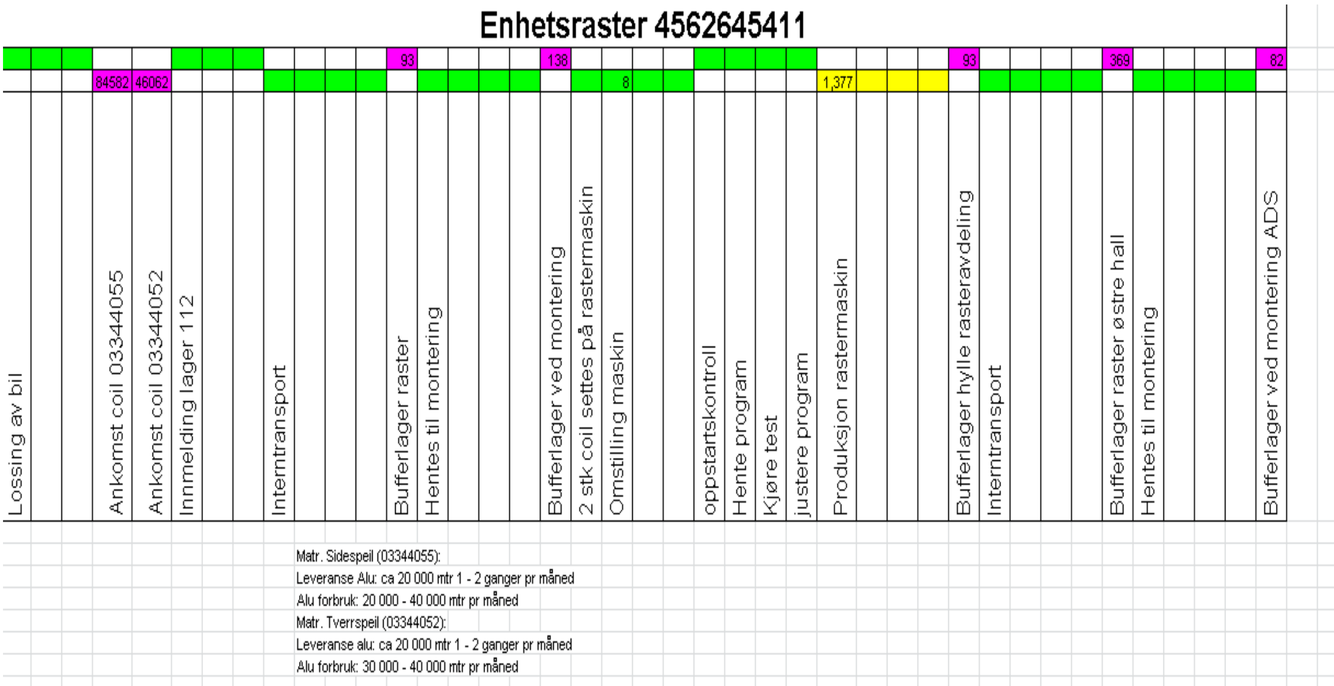
2. *For Body:*

4633700010 OV C10-S1 225/54 HVIT

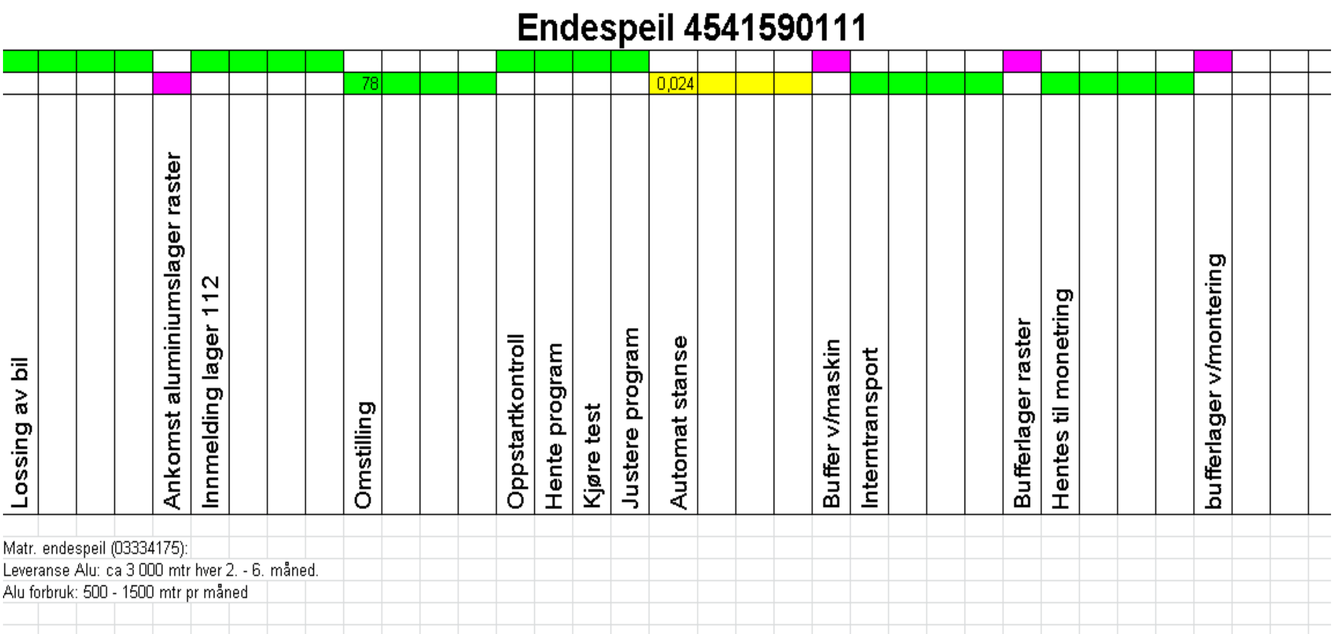
											66							0,04														
																						180					1035					1440
Lossing av bil				Ankomst stålager	Innmelding lager 112	4642m WH112	Gjennomsnitt 6774m/mnd		Lager pivatic = 9366m	Coil hektes på maskin = 4min	Omstilling			oppstartskontroll	Hente program = 15 sek	Kjøre test = 48 sek	kontrollere/justere program = 5 min	Pivatic 1 kjører	48 sek/stk			Bufferlager Pivatic 1 = 180stk i bure	Interntransport	flytting ut av buret = 4 min			Bufferlager vestre hall = 1035 stk	Hentes til montering				Bufferlager ved Ads

Material overdel (01216436):
Leveranse stål: ca 2 000 - 4 000 mtr 2 ganger pr måned
Stålforbruk: 5000 - 8 000 mtr pr måned

3. *For Louvers:*



4. *For Louvers Assembly:*



5. For Final Assembly:

C10054120 C10S

Innkjøpte deler rekvirert fra lager	Hente deler 114	Hente overdeler	Hente raster	Hente braketter	Sluttmontere ADS	Sluttmontør 1	Sluttmontør 2	Plastring/pakking		Buffer montasje		Intern transport		Buffer plastring	Intern transport til lagermottak
	242	164	156	236		37	39	108							
					235					0				0	
Syklustid					34	37	39	108							
Antall pers.					1	1	3	1							

6. For Warehouse:

Ferdig produkt 10054120

Innlagringspunkt fra produksjon	Scanne innlagring	Finne plass til produktet	Scanne lokasjon og lagre inn	Lager	Printe spocliste og fordele	Sjekke confirm sales order	Bekrefte dato til grossist / kunde	Printe ut og sortere plukklister	Scanning av plukklister og plukking	Avslutte og releese plukklista	pakking/ embalering og merking	Sette godset på felt / reol	Melde mengde og eventuelt avvik	Booke transporter	Eventuell fortolling	Klargjøre transportdokument	EDI overføring	Printe godsliste	Lagre pl.lister og kvitterte transp. Dok
					10	10	7						10	180			30	10	320
0				979								0							

7. *Data received from Toralf Rein about production of Body and Brackets:*

Produksjon av C10 2-rørs overdel art 4633700010		
Antall pr ordre	**Intervall for produksjon**	**Syklustid**
540 stk = 6 paller a 90 prod.	En gang hver 14. dag	65 stk/time (55,5 sek/stk)
	Ordre ved minimum lager	

Produksjon av Brakett for C10 2rørs art 454841002		
Antall/ordre	**Intervall**	**Syklustid**
ca 8000 stk (avhenger av coil)	ca en gang hver mnd	1500 stk/time (2,4 sek pr stk)
	Ordre ved minimum lager	

8. *Last Year's Production for Each and Every Department*

Art. Nr	Type	Antall 2013	minste seriestr.	Sikkerh. Lager
c10054120	C10S1251LLA228HGW99	12442	512	1525
4633700010	OV C10-S1 225 228/54	21256	540	200
4548410021	BRAK ENDE C20-S/P1	98354	8000	2000
4562676411	LOUVRE C10 LL2 1225	15937	360	450
4562645411	ENHETSRASTER C10 LL	34796	1080	0
4541590111	ENDESPEIL C20 SL2/DL2/LL2	181220	6000	2000

Art. Nr	Type	Antall 2013	Pr mnd	Pr dag
c10054120	C10S1251LLA228HGW99	12442	1036,8	54,1
4633700010	OV C10-S1 225 228/54	21256	1771,3	92,4
4548410021	BRAK ENDE C20-S/P1	98354	8196,2	427,6
4562676411	LOUVRE C10 LL2 1225	15937	1328,1	69,3
4562645411	ENHETSRASTER C10 LL	34796	2899,7	151,3
4541590111	ENDESPEIL C20 SL2/DL2/LL2	181220	15101,7	787,9

9. Daily production chart for Louvers Department

UKE 3 Louvers.

	Mandag 1 skift	2 skift	Tirsdag 1 skift	2 skift	Onsdag 1 skift	2 skift	Torsdag 1 skift	2 skift	Fredag 1 skift	2 skift
					Gjennomsnittsantall PL maskiner					
PL 3	497	810	760	131	440	593	650	924	720	
PL 4		618.5	884	784	346	685	930	338		
PL 5	325	850		837						
PL 6	840	630	470			480	618	390	640	
MÅL	750	750	750	750	750	750	750	750	750	

UKE 4

	Mandag 1 skift	2 skift	Tirsdag 1 skift	2 skift	Onsdag 1 skift	2 skift	Torsdag 1 skift	2 skift	Fredag 1 skift	2 skift
					Gjennomsnittsantall PL maskiner					
PL 3	671	310	730	448	722	712	628	774		
PL 4	691	972	555	524	800	980	689	869	687	
PL 5				465	329	702	567.5	57		
PL 6	601	148		[illegible]				525		
MÅL	750	750	750	750	750	750	750	750	750	

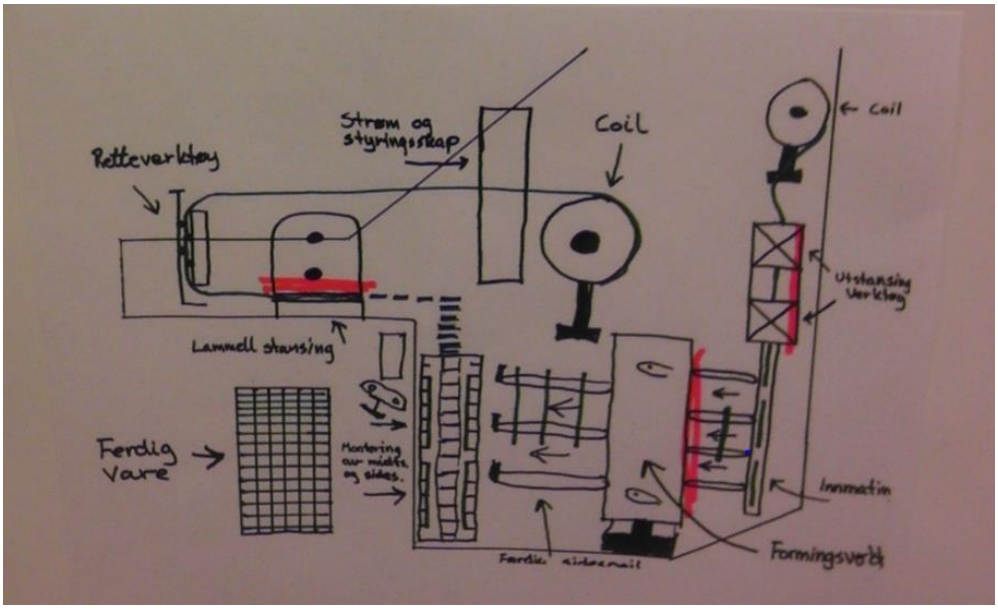
UKE 5

	Mandag 1 skift	2 skift	Tirsdag 1 skift	2 skift	Onsdag 1 skift	2 skift	Torsdag 1 skift	2 skift	Fredag 1 skift	2 skift
					Gjennomsnittsantall PL maskiner					
PL 3	670		700	660	515		597	790	800	
PL 4	930	840	908	826	820	818	858	666	820	
PL 5	495	833	925		860	917	400		756	
PL 6		700		650				722	~~[illegible]~~ 740	
MÅL	750	750	750	750	750	750	750	750	750	

UKE 6

	Mandag 1 skift	2 skift	Tirsdag 1 skift	2 skift	Onsdag 1 skift	2 skift	Torsdag 1 skift	2 skift	Fredag 1 skift	2 skift
					Gjennomsnittsantall PL maskiner					
PL 3	912	785	940	635	720	700				
PL 4	740		841		780					
PL 5		612		744		710				
PL 6	680			700	680					
MÅL	750	750	750	750	750	750	750	750	750	

6.3. Louvers Department:

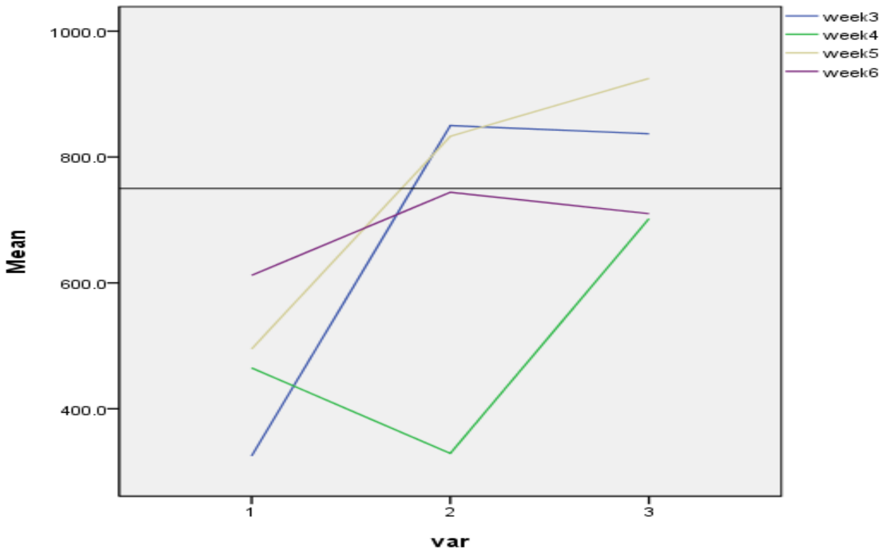


PL5 machine and its operation

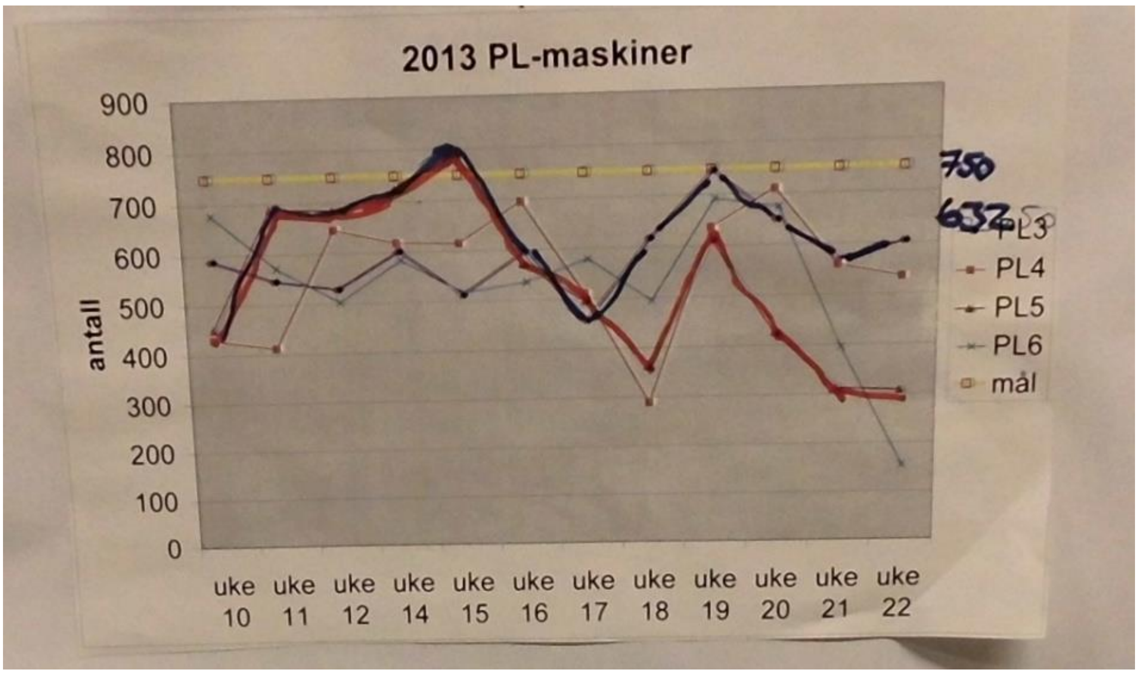
6.3.1. Production of PL5 Louver machine:

Week	Monday		Tuesday		Wednesday		Thursday		Friday
	1 shift	2 shift	1 shift	2 shift	1 shift	2 shift	1shift	2 shift	1 shift
3	325	850		837					
4				465	329	702	567,5	57	
5	495	833	925		860	917	400		756
6		612		744		710			

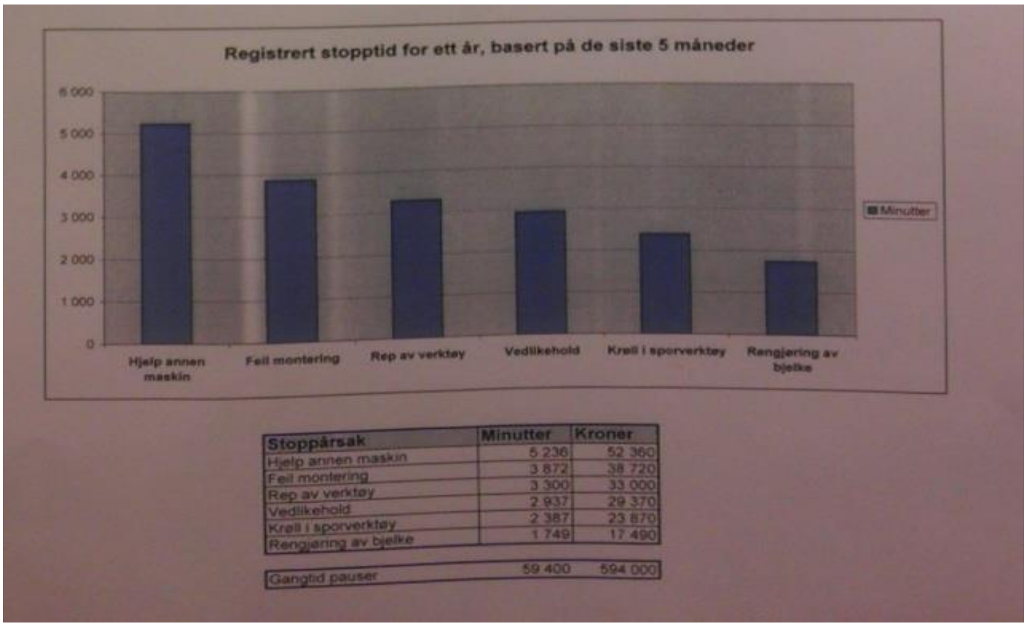
6.3.2. Graph about the Performance of Louver Machine from week 3 to week 6



6.3.3. Performance of Louver machinery's in 2013

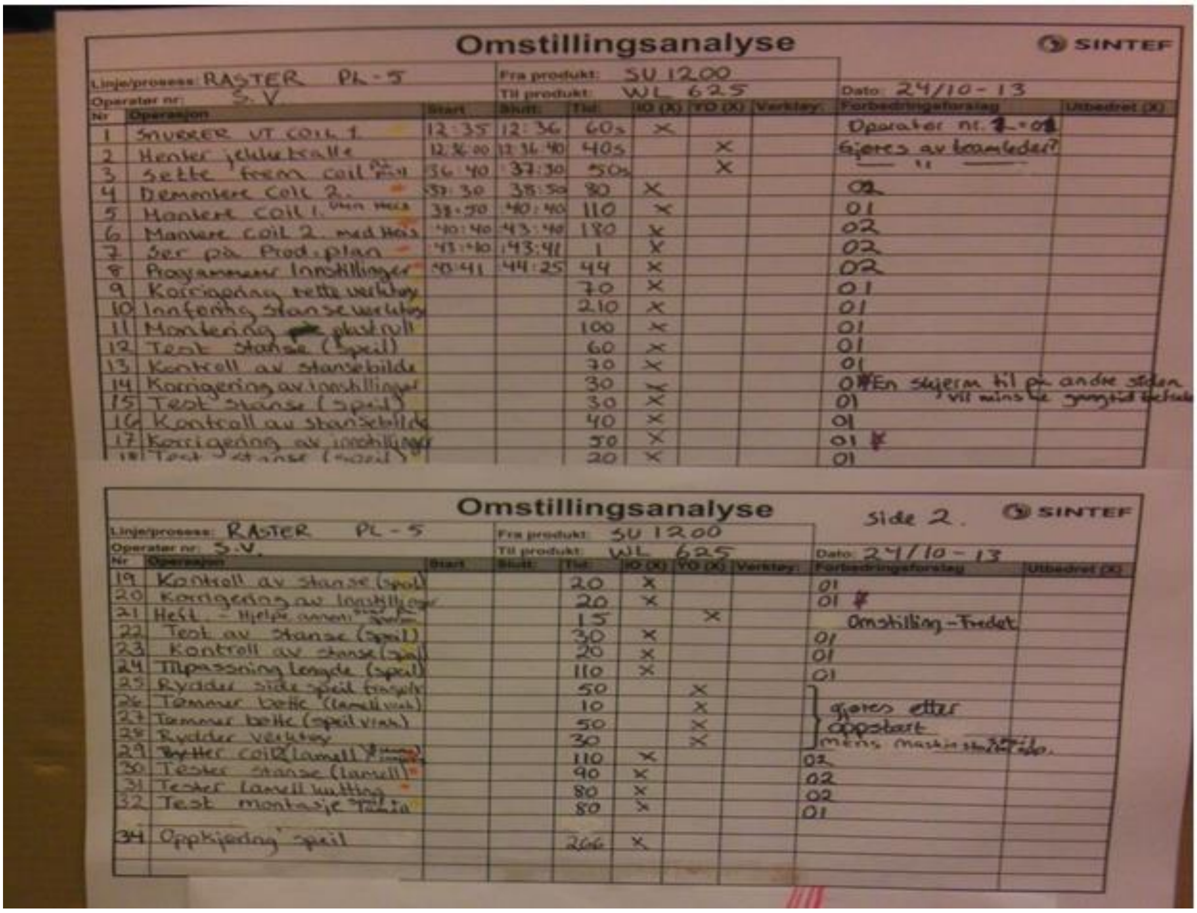


6.4. Errors in Louver Department



Stoppårsak	Minutter	Kroner
Hjelp annen maskin	5 236	52 360
Feil montering	3 872	38 720
Rep av verktøy	3 300	33 000
Vedlikehold	2 937	29 370
Krøll i sporverktøy	2 387	23 870
Rengjøring av bjelke	1 749	17 490
Gangtid pauser	59 400	594 000

6.5. The operations included in mounting the coil and programming the machinery



6.6. The activities and time taken by the PL5 machinery

Sl No	Activity	Time(s)
1	spin the coil 1	60
2	retrieves pallet truck	40
3	put the coil on the pull	50
4	disassemble the coil 2	80
5	mount coil 1 without lift	110
6	Mounting Coil 2 with elevator	180
7	looks at production level	1
8	applications settings	44
9	correction right tools	70
10	introduction stop watch tool	210
11	mounting plastic pull	100
12	test stop (mirror)	60
13	control of halting picture	70
14	correction settings	30
15	test stop (mirror)	30
16	control of halting picture	40
17	correction settings	50
18	test stop (mirror)	20
19	control of stopping (mirror)	20
20	correction settings	20
21	tack will help other pa	15
22	test stop (mirror)	30
23	control of stopping (mirror)	20
24	adaptation length (mirror)	110
25	paving side mirrors fragulr	50
26	inch bucket (the discs elections)	10
27	inch bucket (mirrors elections)	50
28	paving tools	30
29	replacing coil 2 Slat	110
30	tests stop Solder pads	90
31	tests Solder pads	80
32	test vane assembly mirror	80
33	ramp-up mirror	266

6.6.1. Table about internal setup process

Sl. no.	Activity	Time(s)
1	spin the coil 1	60
2	disassemble the coil 2	80
3	mount coil 1 without lift	110
4	Mounting Coil 2 with elevator	180
5	looks at production level	1
6	applications settings	44
7	correction right tools	70
8	introduction stop watch tool	210
9	mounting plastic pull	100
10	test stop (mirror)	60
11	control of halting picture	70
12	correction settings	30
13	test stop (mirror)	30

Sl.no	Activity	Time(s)
14	control of halting picture	40
15	correction settings	50
16	test stop (mirror)	20
17	control of stopping (mirror)	20
18	correction settings	20
19	test stop (mirror)	30
20	control of stopping (mirror)	20
21	adaptation length (mirror)	110
22	replacing coil 2 Slat	110
23	tests stop Solder pads	90
24	tests Solder pads	80
25	test vane assembly mirror	80
26	ramp-up mirror	266

6.6.2. Table about External setup process:

Sl.no.	Activity	Time(s)
1	retrieves pallet truck	40
2	put the coil on the pull	50
3	tack will help other pa	15
4	paving side mirrors fragulr	50
5	inch bucket (the discs elections)	10
6	inch bucket (mirrors elections)	50
7	paving tools	30

6.7. Waste of Time in Louver department

Strekskjema NIVÅ 1 og 2 GLAMOX P24

Linje/område/maskin: Gruppe 7

UKE: 17

	Problem nummer (Beskrivelse under)					Sum	Sum
Produksjons-tid	Mandag	Tirsdag	Onsdag	Torsdag	Fredag	Nivå 2	Nivå 1
Transport 1							
Omarbeiding 2							
Lager 3							
Overprod 4							
Venting/Leting 5							
Krøll i lamellverktøy							
Plastframtrekk							
Rengjøring av bjelke							
Rusk / Bulk i lameller							
Side speil ikke ute							
Krøll i sporverktøy							
Hjelp annen maskin							
Varierende matelengde							
Coil uten plast							
Rengjøre karusell							
Verktøybytte							
Vedlikehold							
Sidespeil fast i saks							
Rusk i sidespeil							
Tett avsug							
Reparasjon maskindel							
Sidespeil ikke fremme							
Utstøter							
Saks							
Monteringsbord							
Bytte gul fjær							
Krøll i saks							
Rengjøre lamellverktøy for olje							
Bevegelser 6							
Overarbeid 7							
SUM minutter/dag							

Strekskjema NIVÅ 1 og 2

GLAMOX

Linje/område/maskin: Gruppe 7

UKE: 14

	Problem nummer (Beskrivelse under)					Sum	Sum
Produksjons-tid	Mandag	Tirsdag	Onsdag	Torsdag	Fredag	**Nivå 2**	**Nivå 1**
Transport 1							
Omarbeiding 2							
Lager 3							
Overprod 4							
Venting/Leting 5							
Krøll i lamellverktøy	5	30	5	[illegible]			
Plastframtrekk		5		10			
Rengjøring av bjelke	10	15	25	35			
Rusk / Bulk i lameller	35	65	45	20			
Side speil ikke ute	5	5	10				
Krøll i sporverktøy		5	10	5			
Hjelp annen maskin				25			
Varierende matelengde							
Coil uten plast	20	10	25	30			
Rengjøre karusell			30	15			
Verktøybytte							
Vedlikehold							
Sidespeil fast i saks							
Rusk i sidespeil	15						
Tett avsug							
Reparasjo maskindel				50			
Sidespeil ikke fremme	5	10	10	15			
Utstøter							
Saks	90						
Monteringsbord	20	20	20	15			
Bytte gul fjær	10						
Krøll i saks							
BYTTE AVSUGSLANGE	20	Switch hose component					
BREMSE HASPEL 1	10	Brake haspel					
Bevegelser 6							
PROBLEM. LAMELLER		300					
Overarbeid 7							
PROBLEM. KARUSELL				25			
SUM minutter/dag	245	465	180	245			

Strekskjema NIVÅ 1 og 2 GLAMOX

Linje/område/maskin: Gruppe 7
UKE: 15

	Problem nummer (Beskrivelse under)					Sum	Sum
Produksjons-tid	Mandag	Tirsdag	Onsdag	Torsdag	Fredag	Nivå 2	Nivå 1
Transport 1							
Omarbeiding 2							
Lager 3							
Overprod 4							
Venting/Leting 5							
Krøll i lamellverktøy	5	5	15	10	curling of louvers tools		
Plastframtrekk		5	10	10	Plastic conveyor		
Rengjøring av bjelke	25	15	15	15	cleaning of beam.		
Rusk / Bulk i lameller	20	70	40	20	defects in louvers.		
Side speil ikke ute	35	30	40	15	side mirrors not out		
Krøll i sporverktøy	5	5	10	10	curling of track tools		
Hjelp annen maskin	15	60		5	Help other Machine		
Varierende matelengde							
Coil uten plast	10	10	15	15	coil without plastic		
Rengjøre karusell		45			cleaning carousel (revolving).		
Verktøybytte							
Vedlikehold	maintenance	30					
Sidespeil fast i saks							
Rusk i sidespeil	defects in side mirrors		15	25			
Tett avsug	cloged suction.			5			
Reparasjon maskindel		90	5	50	repair of machinery -		
Sidespeil ikke fremme	20	20	15	10	side mirrors not in good position		
Utstøter	15	expelling (to force to live)					
Saks	10	scissors.					
Monteringsbord	5	20	mounting board.				
Bytte gul fjær	switch yellow feathers		15				
Krøll i saks	curling of scissors	5.					
Rettevrek sidespeil	40		just works side mirrors				
Innskyver		195	inserts				
Bevegelser 6							
Overarbeid 7							
SUM minutter/dag	205	605	195	190			

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