ASSEMBLY LINE IMPROVEMENT WITHIN THE AUTOMOTIVE INDUSTRY: APPLICATION OF SOFT SYSTEMS METHODOLOGY TO MANUFACTURING FIELD

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Abstract

In today’s manufacturing industry there is an increased focus to produce the right product at right time and in the automotive sector the pressure on suppliers in order to deliver is high. In this matter the organization has to have clear and reachable goals together with a production system that can meet these goals.

The aim of this study was to observe and discover improvements in an assembly line called EUCD 1 at a company working in the automotive industry. The task was from a third party perspective to identify bottlenecks and put forth recommendations for the future as to how the improvement work should be carried out at the line. The production flow has been mapped out by the use observations, interviews with personnel working on the line, qualitative and quantitative data along with System Soft methodology. The interview questions were based on Porras’ and Robertson’s Organizational framework which is divided into four sections namely technology, social factors, physical settings and organizational arrangement.

The line assembles three types of gearboxes consisting of different models which make this line very complex. This case study also includes literature studies in order to support the results found in this thesis.

This report includes a rich picture of the current state at the line for understanding how the line operates. Along with this observation and interviews have been made. Observations are supported by quantitative data and analyses to justify the problematic situation in the production line. The current state has been analysed with the help of the theories used and it revealed a distinct gap between the actual production and desired goals for the organization. The company used a methodology of solving the everyday problematic issues by temporary solutions which led to the reappearance of problems again.

The analyses conducted have resulted in general recommendation as to how the organization should be working to eliminate the different bottlenecks permanently. A desired state has been put forward that includes how the company should operate in a long term future to make the EUCD 1 assembly line more stable with less variation in standstill situations.

The report ends with a discussion of the methodology used along with the findings obtained. The three research questions are answered along with discussions regarding how we could have done this thesis in a different manner. The reports sums up with a section for reliability of the data collected and what future studies can be conducted in the area.
Keywords
Organizational development, Production development, Lean production, Soft systems methodology (SSM), Overall Equipment Efficiency (OEE), TPM
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I Introduction

This chapter describes a brief background of the automotive manufacturing industry and the importance of maintaining high quality production. Further it relates to our specific study and leads to our problem formulation and aim. Furthermore research questions, delimitations and outline of the thesis are presented.

1.1 Background

In today’s fierce competition, productivity is an important factor for a company’s success and particularly Sweden is known for its “world class” development and productivity (Almstrom & Kinnander, 2007). On a national level the capacity utilization level is close to 100% but we see that this is mostly measured by economic figures and not on what’s actually happening at the shop floor. Furthermore, market variations and powerful customers require assembly stations to frequently change to deal with the demand in order to quickly adapt new products and variants (Bruch, Karlton & Dencker, 2008). Bruch et al. (2008) argues that workplace settings that are characterized by uncertainty needs to change, with knowledge based behavior, work roles and proactive behavior in order to contribute to competitive advantages. Further lean thinking is a set of tools to improve a business and an organization needs to manage business enterprises as it works towards lean. It is therefore important that businesses also focus on the accounting system and measurement methods to change from traditional thinking to lean thinking by accessing data and reports that supports lean manufacturing (Maskell & Kennedy, 2007). It is very clear that the automotive industry has created higher pressure to solve problems in terms of switching from traditional mass production to lean production (Sturgeon & Florida, 2000) whilst producing higher quantity products with improved quality. The case study has been performed on a company within the automotive industry that supplies parts for the leading automotive companies. The company showed that it was working with lean manufacturing since long time and has made relevant progress in the area, with development of cells, monitoring the performance and continuous improvements. The challenge however was to find the next step towards making the company a lean enterprise in the true sense whilst finding solutions to the distinct problems faced at cellular level. At the company our project has focused on the assembly section of the plastic division. We have analyzed a production line called EUCD 1 assembly line which produces gear shifters for Volvo, Land Rover and Ford. The assembly line has 12 stations divided into 3 cells namely Body shell assembly, Electronic assembly and Final test. The company used lean tools such as kanban, 5S, kaizen and standardized work instructions and products were produced 2 days in advance of delivery. Previously the company has implemented certain Kaizen projects on the ECUD line, but there were some issues that still remained and therefore resulted in insufficient outcomes. Thus we were provided with this opportunity to
observethese issues from a thirdperson perspective, to follow methodologies and theories learnt during our academic program.

## 1.2 Problem formulation

As a first part of the thesis project we conducted a pre study in order to understand the assembly process better and to find possible issues affecting the productivity performance of the line. Variability occurs in all production systems and affects performance (Hopp & Spearman, 2001). We found that the following reasons could be possible causes for variation in the processes.

i. Unplanned outages (Machine breakdowns) - The first problem was related to machine area i.e. the last station at the assembly namely the End of the line (EOL). The station had high frequency of stoppage which was accountable for creating disruption in production.

ii. Operator variation (Absenteeism) - The second problem we encountered during the pre-study was absenteeism among operators. The lack of manpower affected the distribution of workload affecting the overall performance of the line.

We came to the conclusion that technical and human related organizational problems would be our main areas and focus of interest. Along with these distinct problems, we have considered a more overall approach of implementing long term solutions whilst balancing the everyday production problems at EUCD 1.

## 1.3 Aim

The main aim of this thesis project was to identify the root causes behind the problems causing disruption in the flow of EUCD 1 and suggest suitable improvements and recommendations. Furthermore to design a structured process to solve the everyday routine problems at the assembly line along with generalizing the findings to an overall production development strategy for the company.

## 1.4 Research Questions

Based on the problems observed and our aim we established three essential research questions to be answered in the thesis where question 1 and 2 are practical following question 3 to be more theoretical.

Q1: Why are the current productivity output targets not met at EUCD 1?

Q2: Which process of improvement and methods should be followed to increase the consistency of the manufacturing processes?
Q3: How can the suggested methods be used and adapted for the development of similar/future production cells?

### 1.5 Delimitations

The thesis project does not consider quality issues related to the product design. Rather quality that’s addressed in the production process is taken into account. Furthermore technical and design issues for the automated robotic system were excluded but maintenance i.e. working of the robot was studied and considered. We moreover did not consider the changeover time and tasks between the products since moreover all the products follow a similar assembly process.

### 1.6 Outline

The thesis project is divided into four main chapters of content. After this introduction chapter follows a theoretical background which includes the relevant theory for the case. In this chapter there is an in-depth description of the concepts used. Further the chapter was re-written a number of times as the project took a different direction.

Following the theoretical background a presentation of the methods used during the project is presented. This chapter included how different data e.g. qualitative and quantitative data was collected.

In the next chapter in this thesis we present the result and analysis of the problematic situation at the company, following with general recommendation for them.

The final chapter in this report is the discussion and conclusions where the discussion is based on the process by which the project was carried out with reference to the methodology and findings. Besides this the chapter reveals the reliability of the data and what future research can be made in order to make the project more enhanced.

Except the four main chapters this report also includes an appendix section that can be of interest for the readers.
2 Theoretical background

This section gives the reader the background information in the problem area from a theoretical point of view. The theory described was used both for establishing a current picture of the line as well as in the analysis phase. Further the choice of theories was based on the findings from pre-study conducted and alignment of the three research questions. The following Table 2.1 provides information about the theories where they were applied during the project. We thereby begin by system thinking and further narrowing down to lean production and TPM.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Theory</th>
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2.1 System thinking

Senge (1990) defines systems as a complex network of different elements whose interactions are interdependent. Systems consist of variables whose functioning is interdependent. Systems can be observed in everyday situations e.g. an ecosystem; human organisms are composed of different systems like circulatory, respiratory, nervous etc. Social systems like families, design systems in airplane etc. Thus in all walks of life systems are observed. Similarly, organizations are also systems where the complete effect of different interacting processes takes a long time to observe. In addition to this, these interactions being complex in nature, the control over them becomes an intangible and unclear process (Kirsch, 1996). Most often, there is immense complexity in organization since there are more number of variables involved. It is mostly hard for employees and managers to observe the whole pattern of change, being part of such systems, and thus the tendency is developed to focus on individual events (isolated parts of the system) instead of the pattern developed (Senge, 1990 pg. 7). Due to this most organizations get stuck in the vicious circle of focusing on the temporary solutions instead of solving the fundamental problems. Furthermore this failure of getting stuck with this approach can be due to many reasons, one of which being failure in recognizing systems development due to limitations in organizational learning, design of organization or educational barriers (Lyytinen & Robey, 1999).
Thus systems thinking approach is a framework which allows managers to make these patterns visible and help us to manage the changes and complexity effectively. One reason that also needs to be considered in viewing the organization management from a systems point of view is that human beings involved in the system are capable of generating their own purposes making the systems more complex and purposeful (Senge, 1990 pg. 10). In order to understand constraints and elements of a system we need to recognize Mental models and Boundaries. As stated by (Senge, 1990 pg. 8) “Mental models are deeply ingrained assumptions, generalizations or even pictures or images that influence how we understand the world and how we take action.” Boundaries to systems are the limiting factors that hinder the development process. This ideology is the base of the organizational development model developed by Porras and Robertson and will be explained further in the upcoming chapter. Further if change is contemplated with the existing mental model it leads to first order learning, whereas if change is contemplated by radically changing the existing mental models to fit the patterns of change, it leads to effective second order learning. In a single variable the boundary can be easily visible, e.g. in case of machine, organism but in a system, identification of boundary is not precisely apparent. The second order learning is important to realize the actual boundaries of the system.

Senge (1990 pg. 69) says that “Systems thinking offers a language by restructuring how we think”. Systems are based on two components (Balancing and Regenerative processes) and are explained in the next sections. Systems thinking begins with understanding the concept named “feedback” that is based on cause and effect of actions. In simple terms it involves learning the structures that manifest an archetypal pattern of escalation. In order to develop these patterns which are based on cycle of events, there are mainly 2 types of feedback processes namely reinforcing and balancing processes.

### 2.1.1 Reinforcement process

Reinforcing feedback types of processes manifest as amplifying processes either generating growth or decline. These processes are observed when relationship between cause and effect starts to amplify e.g. increased sales or decreased sales of a product due to mouth-to-mouth publicity of the quality of the product (Senge, 1990 p. 79).

### 2.1.2 Balancing process

A balancing feedback process is goal oriented, and it takes place when a gap between the desired goal and actual state is observed. A balancing system requires stability (Senge, 1990 pg. 83). Effective planning creates a balancing process, which is satisfied only if either, enough efforts are generated or goal is weakened. Most of the time, this process goes unnoticed in reality. In addition to these processes there are often “delays, interruptions in the flow of
influence which makes the consequences of the actions occur gradually” (Senge, 1990 pg. 79).

### 2.2 Organizational development

Organizational development (OD) focuses on planned change and follows Kurt Lewis statement “In order to truly understand something, try changing it” (Porras & Robertson, 1992). Even if organizations know how to do things, like building automobiles, what does it really mean? (Dosi, Nelson & Winter, 2000). Although many contributions have been established to OD the field still has its problems. The purpose of this section is to view the change associated with organizational development by the use of Porras and Robertson’s organizational framework that focuses on the technical and social aspects of the system. Porras and Robertson develop this framework because they believe that focusing on identifying the key factors influences the on the job behavior will give a picture how the current working conditions are in an organization. These work setting factors have been divided into four categories according to Porras and Robertson (1992) and can be seen in Figure 2.1.

![Figure 2.1 Factors Constituting the Organizational Work Setting](image)
2.2.1 Organizational arrangement

The organizational arrangement consists of underlying categories as seen in Figure 2.1 above, where it explains the formal elements by which the organization has to coordinate the people and their behavior. Usually consist in written format for all employees to know but not necessarily be adopted by each single individual. One of the strongest strategic points is to clarify the organizations goals and strategy in order to reach the goals. The goals and strategies are closely linked to each other and the strategies specify how the goals will be achieved. The question is which pattern to follow and how the environment needs to interact in order for the organization to achieve its company goal (Porras & Robertson, 1992). But the process to achieve goals and set strategies will be dependent on the formal structure which refers to the formal work roles and responsible tasks for each individual (Porras & Robertson, 1992). Furthermore the formal structure defines the different subsystems and the relationship amongst them and how the information flow combines these to each other (Friedkin, 1982). In an organization, different reward systems can be applied and Gerhart & Bretz (1994) argue that workers tend to respond if only there is some kind of reciprocal obligation e.g. a sense where managers notice the value of skilled workers and are willing to delegate responsibility.

2.2.2 Social factors

The social factor covers the individual factors such as groups, interaction, patterns etc. Draft & Lengel (1983) explain that in both confusing environments and internal differences, organizations must create an acceptable level of order where managers explain structure and clarity for the individuals in order to get right data and information from the participants. This will form social norms and procedures along with establishing an organizational culture. The culture in an organization has been a topic of much interest over the years yet it is hard to understand, as it is a complex phenomenon including many elements that need to fit in order to have a positive environment (Edgar, 1990). Training of individuals has become vital during the past decades and it is the supervisors e.g. managers responsibility to train workers accordingly. Thus there is a lack in industries to improve the work as to how it is being conducted after training (Robinson & Schroeder, 1993).

2.2.3 Physical settings

The physical setting explains the external factors that affect individual, both positively and negatively for them to perform their responsible tasks. The settings don’t take into account non-technical/non-social part of the work environment (Porras & Robertson, 1992). The physical ambiance affects performance and behavior at work. Tyre & Hippel (1997) explain that each setting represents a mix of resources that can be used to solve different
problems in a non-formal way which generates confidence and a feeling of being noticed. Secondly a learning organization will be dependent on the physical settings in order to establish a comfortable environment for example problem solving and decision making.

2.2.4 Technology

This final category in Porras & Robertson’s organizational framework explains the technology and encompasses all the factors that transform the organizations input to output (Porras & Robertson, 1992). There are a number of different aspects that need attention. First of all, the tools, equipment and machinery are important as they produce product output and refer to any physical objective that creates an object, product or service (Porras & Robertson, 1992). The size and time taken in order to produce the right object can vary from complex and large to simple and small with and estimated variation of time. According to Peters & O'Connor (1980) much progress has been made to identify the variance in terms of individual ability and motivation, but variance in performance needs a complete understanding so that the interaction together with the measurement variables such as preparation, tools and equipment can be established and decrease the performance variance. The machinery determines the takttime e.g. work flow design and in a production line, jobs determine the creation of a specific flow and are co-dependent on knowledge in the process for it to produce the right products/goods (Porras & Robertson, 1992). Ballard (1999) states that 100% capacity is possible if it can be predicted accurately. However due to high production variance, the work flow is not highly reliable. Manufacturing is a segment with high variance in order to control this; the job design acquires critical knowledge, skill and ability in order to perform jobs in terms of select, place and train workers for a specific job task. The requirement objective is to fulfill the current job design but also to generate new job designs or redesign existing ones (Ilgen & Hollenbeck, 1990). Moreover the job design combines a series of tasks which are performed by individuals to control work processes, get feedback, and to use the variance of skilled possessed and continuous interaction with other members (Porras & Robertson, 1992). To establish a preset of job design the methods for performing tasks in the transformations input to output are to be described. These are very briefly described and they directly relate to the transformation process (Porras & Robertson, 1992). Moreover it takes into account the specific task that requests to be performed in a specific way. A supporting tool is to have a technical system that provides the status of different features. It can include variance in different systems in real time control for example inventory system, maintenance system etc. (Porras & Robertson, 1992.). The persons responsible for maintaining the system are the technical expertise that includes individual level of skill and knowledge that will allow them to conduct different types of task that requires special skills (Ballard, 1999). The system can be used to plan and carry out maintenance activities and to have an effective maintenance system is critical as it extends equipment life with proper condition (Swanson, 2001).
2.3 Production development

Production development is a term more traditional than production engineering (Bellgran & Säfsten, 2005 p. 2) and it describes the need for long term actions in production system development. With the ongoing increasing competition, the focus on production has a more or less value for every manufacturing company, not only in Sweden but the rest of the Western world (Bellgran & Säfsten, 2005 p. 2). One way of improving the current production system is by the use of tools and methods supporting the way of working within the production cell. The ongoing condition of industrial change on a regular basis and as the company is a major factor in the market it comes with opportunities as much as change of requirements (Bellgran & Säfsten, 2005 p. 3). Nowadays, customer expects much more than low prices for e.g. high quality products and on time delivery. Factors such as delivery at right price along with requiring suppliers with continuous development of new products, companies tend to give more attention towards outsourcing and production is instead moved to low wages countries such as China. One main reason for this move is that companies in Sweden see the world as a big factory and are maximizing profit when facilities are located in a different place of the world (Bellgran & Säfsten, 2005 p. 4). The accepted traditional concept of mass production practiced in the automotive industry was challenged by lean production in the 1990’s and has led to changes in the manufacturing industry (Holweg, 2007). One aspect that has been historically separate is productivity and quality (Gunasekaran, Korukonda, Virtanen & Yli-Olli, 1993). This is due to the fact that quality has not been given the equal amount of importance compared to productivity. Nowadays right quality goods eliminate unnecessary costs and reworks whilst improving productivity. The next session explains the basics of lean along with Toyota production systems that has become a global phenomenon to think lean.

2.3.1 Lean production

Lean production is a foundation practiced in order to reduce waste transactions and has a customer focus along with continuous improvements (Liker & Morgan, 2006 pg. 5). Most of the manufacturing companies today have started with lean initiatives and it is spread across diverse range of industries. But in spite of implementing lean tools companies have learned that selective application of lean doesn’t lead to sustainable improvements. (Liker & Morgan, 2006 pg. 5). Liker et al. (2006) argues that companies are required to have some sort of lean program/tool in order to stay competitive as mass production has been replaced by lean production. Lean production, often referred as Toyota system is an “ideal state” through simplification and contains several different concepts (Fujimoto & Takeishi, 2001). One of the concepts is the elimination of the seven wastes which is described more in detailed in upcoming section.
2.3.2 The seven wastes

One of the first steps in lean is to understand what customer value is and in order to do so identification of necessary activities and resources is required (Poppendieck, 2002). When this is understood, the rest are wastes and non-value adding activities towards customer. There are seven different wastes (Muda) identified by the master himself, Taiichi Ohno which are;

- Overproduction
- Inventory
- Extra processing steps
- Motion (Movement)
- Defects*
- Waiting*
- Transportation

In our thesis project, defects and waiting are the two essential identified waste activities. Defects relates to problems such as frequent errors, product quality problems or poor delivery performance (Hines & Taylor, 2000). The bottom line is that defects are a cause of direct costs. With reference to Toyota production system, defects should be seen as opportunity to improve rather than something traded off, which instead is poor management (Hines & Rich, 1997). Waiting refers to activities where people are inactive (Hines et al, 2000). The waiting among people can occur for example when machinery breaks down and it leads to a poor flow along with longer lead times. Waiting can also occur when goods are not moving or if the previous production cell is not operating (Hines et al, 1997). An ideal state should be a one piece flow which leads to faster and more consistent produced products with minimum defects. The waiting time is seen as a non-value adding activity and should be used for training, maintenance activities etc.

2.3.3 Work group as focal point for problem solving

One of the principles of Lean is developing exceptional people and teams. According to this principle the focal point of problem solving activities are the work groups or teams at the shop floor who are responsible for value added activities. It is however also a challenge to accommodate the problem solving activities in between the process of maintaining daily production. (Liker et. al 2006) In lean thinking these value adding people find themselves at the top of the hierarchy while the rest of the members in the hierarchy are to provide support to the operators. The next in line after the team members or operators is the team leader. The team leader is a person who has spent a considerable time on the line and has gained enough knowledge about it. The next in line is the group leader or supervisor who is responsible for coordinating different groups.
2.4 Box Score

In visual management box score is an efficient tool for weekly measurements and keeping track of how the value stream is performing. Box score helps to monitor how a value stream is performing with measurement figures etc. As company works towards lean manufacturing and overlook the entire flow of the production instead of each single production cells, it has become more important for an organization to present the stream in a better way (Maskell & Baggaley, 2004 p. 146). Box score enables one to present in a consistent way, different types of lean targets for example FTT (first time though), OEE (Overall Equipment Efficiency) It helps a team to keep a track on key information and keeps everyone informed about the current state, to keep tracks of the efforts being taken to improve the value stream in order to meet the long and short term goals. The benefit of box score is that it can be applied throughout the organization which makes it understandable for everyone (Maskell & Baggaley, 2004 p. 147). Within a lean organization, all personal have a common view and language in order to talk about how the production line is performing.

2.4.1 First time through (FTT)

The first time through is a measurement of quality and has the purpose of monitoring if the right product is produced the first time (Salomon, 2003 p. 33). Even though it keeps track on scrap-, rework-, and repair rate it’s more a measurement of the effectiveness of the standardized work which is an important feature in lean production. Standardized work will more or less guarantee that the right products are produced the first time. In a FTT report, percentage of products produced without any rework or scrap in the first attempt is calculated. In simple terms percentage of products which are accepted as first time through in terms of quality are calculated as given by the following formula:

\[ \text{FTT} = \frac{\text{Total Units Processed} - \text{Rej. or rework}}{\text{Total Units Processed}} \]

2.4.2 Overall Equipment Efficiency (OEE)

Another performance measure is Overall Equipment Efficiency (OEE) which is a time and quality based measure (Bellgran & Säfsten, 2010). Furthermore OEE is a support tool for total productive maintenance since it monitors the production capability in the machine. OEE is used to monitor the efficiency of automatic and semiautomatic production systems (Bellgran & Säfsten, 2010). OEE is addressed to the machines within the cells (Solomon, 2003 p. 37) and tracks the machines ability to produces right products in right quality. In cells the total cycle time is dependent on the machine and requires tracking of three measurements; downtime, production rate and FTT. It’s important to use the
OEE for the right machines e.g. the bottleneck as calculating OEE is time consuming.

OEE requires three types of data; machine availability, machine performance and quality of products and is calculated as:

\[ \text{OEE} = \text{Availability} \times \text{Performance efficiency} \times \text{Quality} \]

Each of these measurements below is calculated as follows:

- **Availability** = \frac{\text{total machine time available} – \text{downtime}}{\text{Total time}}
- **Performance efficiency** = \frac{\text{Actual run rate}}{\text{ideal run rate}}
- **Quality** = \frac{\text{total quantity manufactured} – \text{Number rejected}}{\text{Total quantity manufactured}}

### 2.5 TPM

In order to achieve high quality performance companies tend to improve productivity and reduce cost as much as possible. In order to do so, an efficient maintenance system is required. It will not only extend equipment lifetime but also produce right products at the first time (Swanson, 2001).

Traditionally manufacturing companies tend to use reactive maintenance e.g. fixing machinery problems when it happens. Assembly lines consisting of machinery need attention to maintenance activities in order to prevent breakdowns and establishing high quality products. Total productive maintenance (TPM) is one system that can increase the consistency of a line in order to maintain a high level of productivity (Borris, 2006). According to Bellgran & Säfsten (2010) maintenance is defined as technical and administrative actions that include maintaining or restoring a unit to the condition where it allows the function desired. TPM consists of not only maintenance activities and machineries but also leads the organization towards improvement activities of equipment. Moreover according to Bellgran et al. (2010) TPM has its base in three corner stone’s namely follow up of operational disturbances e.g. by the means of measurement tools such as OEE which will help in finding the factors limiting the production. The second corner stone is to have an operator maintenance that will be of use to suggest how maintenance and production should work as one unit. The final stone in TPM is the environment e.g. enhancing a climate that provides the production with the support and resources needed to continuous improvement.

Similar to the wastes included in the Lean theory, there are 7 wastes included in the TPM theory. They are mentioned as follows (Sekine & Arai, 1998).
1) Minor stoppages, major stoppages: Waste due to minor stoppages occurs when certain equipment keeps stopping and starting causing disruptions in the rhythm of the process. The timing of stoppages last up to 4 minutes. It can be caused due to a work piece getting caught in machine parts, jamming of parts, work getting crushed or damaged during assembly, parts not being grasped properly or sensors of the machine giving wrong readings, computer display malfunctioning and even due to shortage of material supply. Waste due to medium or major stoppage occurs when the equipment stops functioning causing the entire line to stop. Medium stoppages last from 4 to 30 minutes whereas major stoppages last for more than half an hour. They usually occur during production start-up. These occur due to not understanding the weak points of the machinery or due to severely deteriorated parts.

2) Lengthy set up times: This waste occurs when changeover goes wrong and changeover process is not standardized. This can also be a result due to not recognizing deviations from standards.

3) Manual rework, defects, faulty products and low yields: This waste is resulted due to chronic problems with machinery and equipment consequently leading to a lower FTT and lower yield. The problems with machinery can occur due to chronic abnormalities, haphazard setups, frequent changeovers and strenuous work.

4) Planned downtime: These wastes occur due to the capacity of the equipment exceeding the demand from the equipment or insufficient skill among older operators for operating advanced equipment or untrained operators.

5) Incomplete 5 S application: This occurs when the last 2 S’s (standardize and sustain) of 5 S are not implemented. This waste is resulted due to poor maintenance of the working environment which can cause hazards to the equipment, tools or fixtures.

6) Overproduction by large equipment: This waste occurs due to production of unfinished or finished inventory. This occurs because large equipment tends to have a more complex changeover process resulting in less frequent changeovers.

7) Equipment problems at production startup: This waste occurs when the machine designers and users lack exchange of ideas which can result in equipment problems in the initial phases.
3 Method approach and implementation

This section explains the case description, the chosen research method and techniques that were used during the thesis work. It also gives explanations as to why these methods were appropriate and supported by the theory.

3.1 Case study

Case study research helps to develop an understanding of a scientific phenomenon in its natural setting (Williamson, 2002). This allowed deeper understanding of the issues related to the organization and increased the relevancy of the recommendations for the line. It enabled us to find possible root causes for the production problems encountered. The delimitation of a case study approach is that the data collection analysis will be heavily dependent on researcher’s previous experience and interpretations (Williamson, 2002). In order to improve the reliability during the project, the measures were repeated during a long period of time e.g. absenteeism statistics, time studies etc. To handle the delimitations external supervision was helpful to broaden the perspective.

3.1.1 Case description

The project was been carried out at Kongsberg Automotive AB located in Mullsjö, Sweden. The company manufactures driveline system components for automobiles like cable systems, throttle controls and transmission shift control systems. The area chosen for improvement was EUCD 1 which manufactures gear shifters for the companies’ key customers Volvo, Ford and Land Rover. Previously, many Kaizen events had been carried out on this line, but without any sustainable results. The production manager wanted to investigate what were the exact causes for the production variance and therefore we were given the project. Thus according to our research questions we started with identifying the factors that affect productivity targets and later to find improvements for the same.

3.2 Data collection

The data gathered during the thesis project were both qualitative and quantitative. According to Williamson (2000) by the use of multiple sources of data collection can be used in case studies such as observations, interviews and questionnaires. When deciding the data collection techniques the researchers should have in mind the two types of data e.g. primary and secondary data. Primary data refers to data collected for the first time whilst secondary refers to data collected by someone else which can be used for further analysis (Kothari, 2004).
3.3 Primary data

The following section gives the source of the primary data used during this project.

3.3.1 Observation

Observation is a data collection technique in which the researcher observes processes and behaviors over a specific period of time (Thietart et al. 2001). In this thesis project we have observed the individual work stations at EUCD 1. Observations have been a primary data source for identification of problems in the line. The observation of each individual work station has been helpful for the basic understanding of the assembly line.

3.3.2 Measurements

Time measurement was used for finding the timings of different activities at the individual work stations at EUCD 1 in order to check the flow and the balance the line. Further this detailed time study was used to prepare the activity chart. During the pre-study we measured the actual process times at the different stations in the line to compare them with the actual overall takt time.

3.3.3 Interviews

For this thesis interviews were conducted with production and quality technicians, operator and line supervisor. The questions can be found in appendix and were based on Porras and Robertson’s organization framework. The interviews were also recorded so that no information was lost. During the interviews Thietart et al. (2001) recommend to tape the interview in order to not to miss out on any information. The interview was conducted with line supervisor, maintenance manager, production manager, quality technician, production technician, maintenance operator and four assembly line operators.

3.4 Secondary data

This section contains the data we obtained from other sources at the company.

3.4.1 Measurements

Data was collected from different departments within the company to assist our findings and suggestions. We had taken data from control sheets to find deviations in quality of the products and studied the maintenance activities from shift records. Furthermore a closer look into statistical data e.g. FTT. From the shift records we also took daily productivity data and absenteeism.
3.5 Soft systems methodology (SSM)

SSM is a cyclic process of learning which takes place from identifying a problematic situation to defining or taking action to improve it. (Checkland & Poulter, 2010). Soft systems methodology (SSM) is a tool to handle complexity in real-life problem situations (Checkland, 1999, pg. 11). It is a framework used to address chaotic situations which lack in proper root definition. One important advantage of using SSM is to constrain the extent of the situation and thereafter expand it in detail (Williams, 2005). Thus the unstructured problem gets a moreover structured model and enables the researcher to evaluate different developed models corresponding to the goals. SSM is based on core elements of worldview and human actions involved in everyday situations (Checkland & Poulter, 2010). Therefore SSM can have wide range applications ranging from service sectors to information sectors. It enables of perceive an overall view by means of linear step-by-step approach. (Ison, 2008) SSM follows 7 steps of implementation mentioned as follows (Lester, 2008) and can be seen in the following Figure 3.1.

1. Identifying the problematic situation.
2. Building a rich picture of the situation.
3. Formulating root definitions of relevant systems (Key processes that need to take place within the desired system).
5. Comparing the models with the real world situation.
6. Defining changes that are desirable and feasible.
7. Taking action.

3.5.1 Stage 1 &2: The problem defined

This stage doesn’t mean defining the problem directly but identifying the area of general interest to improve. The definitions and organizational boundaries are not fixed, making the framework more flexible and enabling changes in the boundaries at a later stage. It is a starting point which can shift as different aspects get involved with the existing situation (Ison, 2008). The boundaries get shifted because of the fact that each person has different perspective and interest, thereby different judgments are made based on the same situation. (Ison, 2008). As stated by Checkland (1999) the second stage is characterized as “Building a rich picture”; since a rich picture helps to understand and formalize existing situations better. The purpose of the second step is to build a deep presentation of the current situation (Lester, 2008 pg. 1). The picture should be constructed by considering criteria such as structure, processes, climate, issues expressed by people and conflicts (Williams, 2005).
Figure 3.1 Seven steps in Soft System Methodology (SSM)
3.5.2 Stage 3: Modelling and formatting root definitions

Modelling involves “moving away from the “real world” into the world of systems” (Williams, 2005). A purposeful model is one that is a linkage of activities which together forms a purposeful whole (Checkland & Poulter, 2010). A clear definition of the purposeful activity to be modelled is required to build a complex situation model. This stage is the most challenging stage and involves understanding of different perspectives that influence a situation. SSM tries to address all these perspectives that have an impact on the nature of the purposeful activity (Checkland, 2010). It is carried out by selecting a perspective and putting it through CATWOE analysis (Customers, Actors, Transformation, Worldview, Owner and Environment).

- **Customers** are the ones who benefit from this transformation
- **Actors** are those who facilitate the transformation these customers and people involved in transformation activities.
- **Transformation** refers to the process from “start” to “finish” and what is changed.
- **Worldview** gives the transformation a meaningful perspective.
- **Owner** is the one that controls the transformation.
- **Environment** refers to that which influences but does not control the system e.g. constraints outside the system.

3.5.3 Stage 4 & 5: Building conceptual models and comparing with real world situations

A purposeful model provides a structure for discussion bringing out some of the important worldviews that may require making changes or alterations to perform improvements. (Checkland & Poulter, 2010) The model has processes which are governed by an equation of “PQR”. Where P= what should be done, Q= how it is carried out and R= for achieving what type of result (Lester, 2008). This equation is primarily used in building conceptual models. Thereafter, this conceptual model is compared with real-life scenarios, where feasibility of the model is confirmed.

3.5.4 Stage 6: Defining changes that are desirable and feasible

Assessment of existing resources is carried out and all possible constraints are identified to make appropriate changes in the model. It also involves discussions to identify changes that are not only desirable but also culturally feasible i.e. it is required that everyone agrees for a common platform and even the conflicting worldviews are addressed (Checkland & Poulter, 2010). This results in making the formulation of models and implementation plans in a generalized manner (Checkland, 2005).
3.5.5 Stage 7: Taking action

This stage involves physically starting the implementation process of addressing the problematic situation. The evaluation of the model is done by conforming that the model is compatible to the real life situation. The effect is monitored after implementation and further improvement possibilities are identified. It is a continuous learning cycle which focuses on rigorous analytical process. (Checkland & Poulter, 2010). This learning cycle takes place on account of a conscious reflective process which takes place before, after or during the real life problem situation. (Checkland & Poulter, 2010).

3.6 Research Quality

3.6.1 Reliability

According to Williamson (2002) achieving the same results and findings with a repetitive study or experiment will determine the reliability of the study. Our research was a case study performed within the automotive industry and leaves a question as to how reliable our study was. If future studies with similar approach to the specific line will be conducted, we believe that the result will vary.

3.6.2 Validity

A research has two types of validity, internal and external (Yin, 1994). Internal is the quality of the work whereas external explains the generalization level of findings. In this study the internal validity comes from the method we had chosen with the use of data collection techniques along with our approach. For our external validity we have used research methods from previous researchers but from another field e.g. SSM is used within the IT sector. With this we have established research questions. We thereafter stated different pictures about our findings and result to illustrate the current state at the company.
4 Analysis and Result

This chapter gives an overview of the assembly process along with detailed analysis of current working condition at EUCD 1.

4.1 Description of layout

As seen in the layout Figure 4.1, the assembly line EUCD 1 is divided into 3 cells. The first cell is named as Body shell Assembly, second cell is called as Electronic Assembly and the third cell is called as Final test. The details such as number of operators, raw material storage, material transfer, operator movement, station details and throughput times are shown in Figure 4.1 and Table 4.1. The description of the 3 cells is described in the upcoming sections. Each section explains a detailed description of work process, impressions from our observations supported by quantitative data and ending with concluding statement about the overall view of the cell.

Figure 4.1 Layout of Assembly cell EUCD1
<table>
<thead>
<tr>
<th>Cell No.</th>
<th>Station No.</th>
<th>Description of Stations</th>
<th>Throughput time(Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Manual pre-assembly</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Manual pre-assembly</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Manual infeed of material</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Manual infeed of material</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Manual infeed of material</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Robot cell</td>
<td>Automated Assembly of raw shifter</td>
<td>65</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>Manual electronic assembly</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Semi-automatic knob and panel assembly</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>Manual cable assembly and testing</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>End of line (EOL) automatic final testing</td>
<td>70</td>
</tr>
</tbody>
</table>

The table 4.1 above shows the three areas and their substations. Throughput time for each individual station is also provided. These are shown graphically in the following Figure 4.2.
4.1.1 Cell 1

This cell had the objective to assemble the main body shell which formed the foundation of the gear shifter. Around this component other parts were assembled. This core component was assembled in the robot cell which received sub-assemblies of other components from stations 1, 2, and in feed material from stations 9, 10 and 11. Station 2 carried out these tasks of assembling the basic components of the main body shell and placing the semi-finished assembly on the conveyor for further processes. Station 1 supplied another semi-finished assembly of release rod. Individual work stations were designed ergonomically but had restrictions due to space and material storage of raw materials. Therefore operators faced some uncomfortable movement activities at station 1 such as picking up body shell parts due to inconvenient material storage in the pallets. Moreover cell 1 was designed for 2 operators where one operator worked between stations 1 and 9 and another operator worked between 2, 10 and 11. All the work stations were designed according to principles of 5S where standardization was practiced at a great extent. All the activities were performed by standard operating procedures. In case when there was a lack of operators, the stations were managed by single operator, but this resulted mostly in batch production due to buffers instead of desired one piece flow. The station with frequent breakdown causing variation in production was the robot cell consisting of two robot arms. We therefore conducted an OEE for the same which is displayed in the Figure 4.3 below.
As seen in Figure 4.3 there is a high variation in the OEE values with an average taken for 16 weeks as 55.81%. This is an important reason affecting productivity figures. Along with the OEE we can observe the following Figure 4.4 of machine downtime during 17 weeks.

Thus we observed in Figure 4.4 that the robot cell is rather complex in nature and were a major bottleneck which needs to be focused on. Further other stations in cell 2 and 3 were dependent on the robot cell. Moreover the other stations consist
of more manual activities which can be improved. Considering these reasons, the primary concern should be robot cell. The total downtime observed during the 17 weeks comes out to be 110.5 hours and the average downtime per week comes out as 1.3 hours. We took a closer look at the weeks with higher downtime (2, 4 and 8) and found common category of problems displayed in Figure 4.5 below.

![Problem category Robot cell](image)

**Figure 4.5 Categories of problems in Robot cell**

### 4.1.2 Cell 2

The main body shell assembled in the cell 1 entered this electronic assembly cell. The operator took the main body shell and assembled electronic parts such as solenoid, PCB box and detection pin. This operation was followed by knob and panel assembly after which the assembled shifter was finally placed on a conveyor for the final cell. The operators followed a standard way of working with the assembly process. There was one operator working between stations 12 and 13. We observed during the time study that these stations followed a balanced work flow with least disruptions in the assembly process. The productivity was mostly affected due to lack of resources and the operators found it difficult to balance these stations since they had most of the manual operations in this cell. The conveyor after station 13 had a buffer capacity of 6-7 units which was suitable for maintaining low a WIP. Thus we saw that the stations were designed in such a way that very low WIP was allowed so that problems could be brought to surface.

### 4.1.3 Cell 3

This cell included 2 stations for final inspection and testing. Station 14 activities included assembling of final electronic elements, tightening and connection of wires and springs. This was followed by a manual test by the operator to check the
smoothness of manual operating movements of the shifter. After the manual test was completed, the finished gear shifter was put in End of line (EOL) station which performed a thorough check of working of the shifter by applying specific standard pressures and forces while performing all the visual checks. One operator was responsible for managing the work at both these stations. The End of the line governed the takt time of the entire assembly process since it had the highest cycle time than all the other stations since there was always a waiting time of around 50-60 seconds observed at this station. This was due to the design constraints of the machine. The machine consisted of 2 compartments with 2 fixtures. The cycle time of the testing process was approximately 70 seconds. When one shifter was undergoing the test, there was a waiting time of approximately the same for the next shifter. This was due to the previous station 14 having a lower cycle time of about 40 seconds. Thus, around 30 seconds of waiting time was observed. This waiting time can be reduced by increasing the cycle time of the EOL. However there are technical restrictions on EOL, since the speed of the robot arm cannot be increased beyond a certain limit to prevent damages on the shifter. The cycle time of EOL therefore governed the takt of all the cells and was also the same as required takt time. After the EOL, goods were packed and made ready for dispatch. Along with being the station with highest cycle time, there were many technical failures of the machine which can be observed from the OEE shown in Figure 4.6. Along with OEE, the downtimes during 17 weeks for EOL are shown in the following Figure 4.7.

![OEE EOL](image)

The OEE EOL is very similar to OEE robot cell with very similar number of downtimes observed. The average value of OEE is 55.6 % based on data collected during 16 weeks. The downtime data can be seen in the following Figure 4.7.
As seen from the graph the downtime also varied between 3 to 13 hours and the total time during the 13 weeks comes out to be 90.55 hours while the average downtime per week is 1.4 hours. We took a closer look at the weeks having the highest downtimes (4, 10, 13 and 17) to understand the basic reasons for the same. The problems are categorized and displayed in Figure 4.8.
4.2 Analysis of System Performance (2:nd Analysis)

In this following chapter, we have analyzed the entire EUCD 1 system as a whole and the analysis follows the Soft systems methodology (SSM).

4.2.1 Identifying system processes

In order to understand the current situation at the company we identified the nature of working and we derived the model seen in Figure 4.9. The model is inspired by system thinking processes (Senge, 1999). Systems generally operate by means of 2 processes, regenerative and balancing processes as described in section 2.6. We observed that the EUCD 1 as a system was operating by means of a balancing process. The parameter which was required to be balanced was productivity. The productivity parameter in this case was defined as the ratio of the number of shifters manufactured which passed from EOL to the required target. If there was rework or scrap goods they were not included in the productivity measurement. In this system, a number of external factors influenced the balancing process of maintaining consistent productivity. The nature of working of the system is described in the following Figure 4.9.

As seen in Figure 4.9, the productivity at EUCD 1 was of major concern and there was always a perceived gap between the desired goals and actual productivity. The company followed a strategy of resolving everyday production problems e.g. the acute issues at the line such as technical breakdowns, imbalance of line and quality issues with the use of temporary countermeasures. But these were symptomatic solutions whose effects wore away within a short time period and
often reappeared in future. Therefore the perceived gap was never diminished. Thus it is required to implement a more proactive approach to address these issues instead of symptomatic solutions. The proactive approach had its limitations due to certain limiting factors or constraints for e.g. resources, time etc. The proactive approach entailed a deeper understanding of root causes but due to the constraints this never took place making it difficult to implement the fundamental solutions. Therefore the company found the path of least effort and got caught in a vicious circle of symptomatic solutions. To understand the system better we developed a practical approach described in the following Figure 4.10.

4.2.2 Building a rich picture

After understanding the system processes at the line, we tried to elaborate more on the acute issues and their root causes. For the purpose of deeper understanding of the system, we differentiated the working of the system into current and required states.

a) Current state

The performance of the line was measured based on measurement of production efficiency and was displayed on the activity boards in the form of day-by-day production. In our analysis we have calculated this performance efficiency based on weekly intervals and it is shown in Figure 4.10. The data is collected from the shift records provided by the company.

![Production Efficiency Chart](image)
As seen from the above graph, the efficiency varies in the range from around lowest of 48% to highest of 93%. The variation was found high in nature and not pertaining to any specific pattern. This figure gives an overall picture but has limited use so as to understand which specific area needs to be improved. It should be further assisted with the help of other performance measurement criteria. In order to fully understand the high variation we analyzed by comparing production efficiency and downtimes of robot cell and EOL. The need of another performance parameter is justified if we observe the figure shown below. The Figure 4.11 shows a comparative graph of downtime percentages of Robot cell and EOL with the production efficiency. We chose downtime parameter since it had highest contribution from different factors that constitute OEE i.e. availability, performance efficiency and FTT.

![Figure 4.11 Comparative graph between Downtime percentages Robot cell & EOL with production efficiency.](image)

For the weeks highlighted as shown in the figure above (week number 1, 2, 5, 9, 13, 16, and 17) there was a considerable mismatch between production efficiency and downtime. If we take a closer look at week 5, it seems very strange since the production efficiency is very high as compared to the combined downtimes. According to our opinion, this was due to the fact that the efficiency can be increased by use of inventory products during the breakdown of robot cell. Buffers were created when there was a breakdown of either EOL or robot cell.
which led to batch production and therefore efficiency was increased for a certain amount of time. Thus efficiency parameter does not provide a clear picture of the performance of the system. It is therefore required to check the finished and unfinished product inventory levels. For the remaining weeks the production efficiency matched with the downtime percentages as it was considerably low when downtimes were high. As seen above, weeks 1, 5, 9 and 15 suffered from low productivity where the downtime was high followed by a low OEE. During these weeks we observed continual breakdowns of both robot cell and EOL along with a low number of operators which affected the rate of efficiency. One major issue during these weeks was that it was hard getting technicians when machinery breakdowns occurred, this resulted in standstill and the operators themselves applied the usual countermeasures such as rebooting the system (EOL). Going deeper in the weeks with high productivity with low downtime and high OEE we saw that the common problems occurred to a minor extent. This made it easier to have a continuous flow with a high level of productivity. There was no pattern in the timings for occurrence of the problems at the line but we identified the most frequently observed problems as shown in Figures 4.5 and 4.8. In order for us to fully understand the current state of the system, we developed the following Figure 4.12
The organization followed a methodology of solving the productivity problems by the means of temporary solutions. Next to the EUCD 1 line, a board of open points was displayed where they solved the everyday production problems on a temporary basis. During the meetings at the board they tried to close acute issues. The solutions proposed were countermeasures for the apparent problem with no focus on the root cause of the problem. Along with this, there was a follow up to check repetition of these points in the future. In order for us to get an in depth picture we began with categorizing the observed issues into 3 main areas of concern which are explained in upcoming sections.
4.2.3 Imbalance of line

The imbalance of line was caused by shortage of labor at the assembly line due to absenteeism. When the line operated with limited number of workers the planned “one-piece flow” was disrupted. This resulted in batch production between Body shell assembly and Electronic station. Further there was an unbalance of workload due to additional non-value adding activities required to be carried out by operators. Moreover, as stated by operator “Extra work such as getting new batch, updating activity boards etc. is our responsibility but disrupts the production and can also lead to a stoppage of production”. There were some non-value adding activities for e.g. packaging and material handling which were included in the work tasks of the operators. This came out to be in the range of 10-14 minutes in one hour. This time was directly lost from value adding production time. The material was stored in the pallets close to the work station to benefit the assembly process. However the pallets needed to be filled with new material or replaced. The frequency of moving the pallets is described in the following Table 4.2.

Table 4.2 Non-value added work tasks

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Activity</th>
<th>Time (minutes)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fetching trolley for big pallets and putting them in place</td>
<td>5</td>
<td>Once every 2 hours</td>
</tr>
<tr>
<td>2</td>
<td>Getting new pallets (small) for raw material and putting them in place</td>
<td>4</td>
<td>Once every hour</td>
</tr>
<tr>
<td>3</td>
<td>Keeping empty pallets on shelves</td>
<td>4</td>
<td>Once every hour</td>
</tr>
<tr>
<td>4</td>
<td>Dispatch of finished shifters</td>
<td>2</td>
<td>Once every hour</td>
</tr>
<tr>
<td>5</td>
<td>Discarding unwanted materials (plastics, cardboard etc.)</td>
<td>2</td>
<td>Once every 2 hours</td>
</tr>
</tbody>
</table>

Besides these, other required non-value added activities included tasks such as updating the activity boards, filling the shift records and general daily maintenance activities. These were however carried out in the last 15 minutes before shift change.

4.2.4 Technical breakdowns

When breakdowns occurred operators carried out the necessary problem solving within their scope. If it cannot be solved, maintenance personnel were called upon. According to the production technician and by our observations “The production is disrupted by continual breakdowns of the automation and EOL”. We have observed that the technical breakdowns were the major cause for disruption in the production line. Further we observed that the production efficiency doesn’t reflect the reality of the line as seen in Figure 4.112 since the downtimes for EOL and Robot cell were considerable. OEE and downtime data were not being presented visually which made it difficult to get a clear picture of production status. According to the production manager:“The activity board
should show OEE along with performance efficiency as the performance indicators reflects a better picture of the line”.

Daily maintenance activities were scheduled 15 minutes before each shift ended and the tasks were written clearly at the activity boards and mostly involved cleaning. An operator said that “We only know how our shift is carrying out the activities and there is lack in follow up and evaluation of maintenance”. Also, according to maintenance manager “There exists no proper evaluation and follow-up of daily maintenance activities and there is a lot of scope for improvement for this”. There was a list of daily maintenance activities displayed on the activity board such as cleaning fixtures, visual control of door switch of EOL, checking air exhaust, cleaning and checking of door changer etc. These tasks were not usually carried out or followed up. The general maintenance procedures as described by the production technician were that “Preventive maintenance activities are conducted 2 times a year on the machinery equipment when the fixture was to be cleaned or replaced”. Besides this the maintenance manager stated that “The company is currently lacking in proper implementation of Total Productive maintenance”. Out of the different pillars of TPM, there was no structure for implementation of autonomous, planned and quality maintenance. The everyday problems occurring on daily bases in reference to the machinery were registered in the company’s information system called TEKLA. From the information given by the maintenance personnel, we could see the current issue that needed attention. Other issues that were not recorded were fixed when they occurred at the line. As stated by maintenance manager “Currently we are not working with detailed preventive maintenance and we have a system that has scope of improving”.

4.2.5 Description of problems

When we took a closer look at Figures 4.5 and 4.8 we understood the different problem categories with their frequencies. For the robot cell, some of the frequently occurring chronic problems were dropping or throwing of parts, robot not setting the parts correctly, crashing of the robot arms with the plastic enclosure. One problem was “empty conveyor” which meant that after the body shell was assembled, the robot gets stuck and it couldn’t put the assembled body shell on the conveyor for the next cell. These were problems which led to medium and major stoppages. These issues can be related to the equipment or the design of the assembled components. According to our opinion the arms of the robot and the gripping devices needed to be checked first in order to examine the cause of the problem. The other frequently occurring problems were home runs where the robot got stuck and changes had to be made in the computer to make the robot return to its home position. The reason for this can be sensor giving error in the reading or a chronic robot issue. From our perspective these issues were serious in nature and these should occur mostly during production startup as per theory of wastes in TPM, but in reality these were found to be everyday common problems. As seen in Figure 4.8 the most common problem category for EOL were rebooting of computer, re runs and robot crash. After discussion with the operators we found that these problems were related with each other. The robot got stuck when the final tests were going on and this lead to frequent computer
hangs. Therefore it needed to be rebooted. This was also a cause for minor stoppage. According to our opinion the cause for this could again be sensor issues or maybe due to friction in the slide ways of the EOL which carried the clamping devices. There could however be other causes related to the built-in-quality from the previous stations. Since there were apparent problems in the robot cell such as not setting parts correctly, breaking of parts, etc. this could result in poor quality which made the robot arm getting stuck when it tried to pull the gear knob in different directions. Also, EOL was the final testing station and there were no quality checks after the robot cell except some visual checks for scratches. Thus, the in-process quality could be a serious issue.

4.2.6 Quality issues

In EUCD 1 line the quality measurement parameter was FTT at EOL. There were no in process quality checks carried out except visual checks for scratches. The FTT data can be seen in the Figure 4.13 as shown below.

![Figure 4.13. FTT End of Line](image)

The company had a goal to achieve 96% FTT and as seen in the 4.12, this was not accomplished. The quality issues were solved by short-term countermeasures instead of permanent solutions. The quality issues were due to constraints such as poor product design or suppliers’ performance. There were some persistent issues, e.g. noise observed after pressing the gear knob which was solved by temporary countermeasures such as applying lubricants etc. As said by the quality technician “I would like to work with long term permanent solutions but time and resources are limited”. There was less focus given on built in quality of the process which therefore gave rise to other quality issues. Some of the common quality problems and rework areas were as shown in Figure 4.14. The rework data was obtained for weeks from 9 to 13.
4.2.7 Financial Analysis

The financial analysis was carried out based on the impact due to downtimes and non-value added activities. It gives a direction to prioritize the areas and also helped us to assess the financial feasibility of improvements.

1) Loss due to non-value added work tasks: We saw that average time lost was around 14 minutes in one hour. During this time, the number of products that can be produced = Time lost/takt time for one product = 14/2 = 7
   Cost of each product is assumed approximately as 450SEK
   Therefore, total loss of product value in one hour = 450*7 = 3,150 SEK

2) Loss during equipment downtime: When the equipment is at standstill the resources such as operators and equipment were not used as expected incurring direct losses
   Thus the direct loss per hour = operator cost + maintenance personnel cost + unused machine cost = 300 + 320 + 800 = 1,420 SEK
   The amount of products that could be produced during this time = 60/takt time=60/2=30
   Production loss cost = 30*450 = 13,500SEK

3) From sections 4.1.1 and 4.1.3 we saw that average downtime of robot cell per week was 1.3 hours and average downtime of EOL per week was 1.4 hours respectively. Therefore average loss per week due to downtime is (1.3+1.4)*13500 = 36,450 SEK.

Figure 4.14 Rework problem categories during week 9,10,11,12 & 13.
4) From Table 4.2 the average loss in time due to non-value added activities comes out to be 14 minutes. Considering there are 3 shifts working for 7.5 hours and 5 days a week each, the total loss in time comes out to be as $(14/60 \times 7.5 \times 3 \times 5) = 26.25$ hours. Thus the loss in product value due to non-value adding activities per week comes out to be as $= 3150 \times 26.25 = 82,688$ SEK.

5) Thus the total loss in product value per week comes out to be $36450 + 82688 = 119,138$ SEK

There are also losses due to rework but we didn’t have sufficient data to find out exact value. Moreover, according to the Annual report of the company during the year 2011, out of the total operating cost, the raw materials constituted 43%. The general added value by the company is thus about 57%. The above cost in lost production therefore stands for lost income being 57% of the lost production value. (Kongsberg Automotive AB2011, p.4) Thus this supports our analysis and main focus for improvements which are improving equipment performance (OEE), improved work organization allocation of tasks thereby reducing wasteful activities.

### 4.2.8 Root cause definitions (point 3 SSM)

In order to understand the root causes of the apparent issues we see from Figure 4.15 that the reasons for imbalance of line were shortage of labor (operators and maintenance) and improper work task allocation or unbalanced workload. Technical breakdowns existed due to improper daily maintenance and insufficient preventive maintenance. The reasons for quality, rework and scrap problem were due to supplier, poor production technology and also due to equipment problems. The in process built in quality gets affected when the equipment did not function properly. The improved system required addressing these root causes from organization point of view. This is discussed in the next section. Prior to discussing the improvements we would also like to perform a CATWOE analysis which makes the direction for improvements more clear by identifying the different stakeholders involved in the improvement process. This analysis also identifies additional benefits of the transformation process from a world view perspective. In the CATWOE analysis for the company we identified the customers for EUCD I system as the company’s key customers (Volvo, Land Rover and Ford) and the aftermarket division. The Actors include operators, maintenance personnel, production manager, quality technician and maintenance manager. Transformation refers to the improvement process of increasing productivity performance and quality parameters. Worldview refers to starting the lean transformation process for the organization. The owner of the process is the Production manager and the environment refers to constraints in resources for the transformation. The financial and CATWOE analyses together give a systematic approach for a further improvement process and also provide an improved model of the system.
4.3 Long term recommendations

This section gives a brief description of our long term recommendations and is displayed in Figure 4.15.

![Figure 4.15 Long term recommendation](image)

4.3.1 Work group organization and work task allocation

As seen from the theory section (2.8.3) the bottom-up management and employee empowerment are important steps towards solving the everyday production problems. Since there was a high level of absenteeism, the team leader could have compensated for it and when there was an optimum level of work force available, he/she could have looked for and encouraged improvement projects. The team leader could have also collaborated with the maintenance department for improving daily maintenance activities and finding root causes of the equipment problems. Quality checks could also have been carried out by the team leader. The financial analysis showed that there was a considerable loss in sales due to non-value added activities. This loss was due to limited number of workers or resources available at the assembly line as a result of which the operators working at the assembly line were compelled to perform the non-value added activities. Moreover, during a technical breakdown, it was observed that due to absence of a team leader, the operators had no person in charge to give them directions. Thus it makes sense if a team leader was included who could have compensated for not only the 14 minutes of non-value added activities, but also taken part in a proactive approach for predicting and solving future problems. This way it could have benefited the organization as well as the employees for carrying out their activities without any disruptions.
4.3.2 TPM

As we have seen from section 4.1.1 the downtime for EOL was 110.5 hours during 17 weeks and the average OEE was 55.81% for 16 weeks. This shows that considerable waste was created in the form of waiting for recurring repairs which also reduces employee efficiency. Thus, in our opinion, one long-term strategy to be implemented should be Total Productive Maintenance. The implementation requires a strong commitment from the management and educating the operators to identify frequently occurring problems and find countermeasures as well as permanent solutions. This process can begin with initial basic monitoring of most frequently occurring critical issues that affect productivity as well as quality. After identifying these issues they should be classified into two areas Autonomous maintenance or planned maintenance. Autonomous maintenance requires addressing of these issues by operators. Planned maintenance requires addressing of these issues by skilled maintenance personnel and later on shifting the daily maintenance activities to the Autonomous maintenance team. One important tool for identifying and classifying the abnormalities is known as F-Tag (Fugui- (Japanese for abnormality or contamination)) the examples of F-tags are shown below.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of F-Tag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>White</td>
<td>Shows faults that can be fixed by autonomous maintenance</td>
</tr>
<tr>
<td>2</td>
<td>Black</td>
<td>Shows minor faults not requiring a machine shut down</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>Shows failures</td>
</tr>
<tr>
<td>4</td>
<td>Yellow</td>
<td>Shows past failures from equipment history</td>
</tr>
</tbody>
</table>

These F-tags can be recorded in a database and a log sheet can be created to monitor them. The quality maintenance in TPM begins with classifying the abnormalities into customer defects or in house defects. Moreover, these can be further classified into major/minor according to frequency. Further, specific patterns can be identified and critical problems prioritized. The progress of TPM activities can also be represented visually on the activity boards thus informing the operators and personnel about further areas for improvement.

4.3.3 Problem solving and root cause analysis

Problem solving in a manufacturing industry requires the right quality tools in order to assist the organization in analyzing and finding the root cause of the problem (Hagemeyer, Gershenson & Johnson, 2006). For example managers tend to jump to conclusions about the cause of problems, or argue over decisions (Ho, 1993). People by nature try to solve everyday problems and make decision based on the information available at the time (Ho, 1993). Although stress is a common factor, one should define the problem with a root cause (Ho, 1993). Hagemeyer et al. (2006) states that, problem solving allows the human to correctly identify the
root cause and find the problem solution. Problem solving in finding the root cause exist within both white and blue colored workers. According to Allwood and Lee (2004) problem solving efficiency at the shop floor is characterized by its run ratio e.g. the run ratio will show a general ratio how the problem solving methodology is working. Furthermore, lean thinking begins with understanding and identifying effects and determining their root cause in order to find the real factors of the specific problem (Melton, 2005). We had seen that the visual management system could be improved by displaying the performance parameters and monitoring. The operational parameters that can be further recorded were OEE, downtimes of robot cell and EOL, the rework and scrap rates, Pareto charts of problems for robot cell and EOL. Along with this to assist the TPM implementation process, training the skills of operators can also be monitored.

4.3.4 Supplier issue

We observed that common problems recorded in the shift records were faulty parts from the suppliers. A further quality check has to be carried out to ensure that these problems do not occur on a frequent basis. The supplier quality development department needs to conduct evaluation of the quality from the suppliers.
5 Discussion and conclusions

In this chapter we begin with a discussion of the methodology and the literature used. Following this, there is also a discussion of the current state at the company along with the data analyzed. We will sum up the discussion part with conclusions based on the analysis along with our suggestions for future research in the field.

5.1 Discussion of methods

The company had previously carried out several Kaizen projects on the assembly line but couldn’t achieve sustainable results. Thus to understand the problem from different perspectives, the company gave us “free hands” and didn’t specify the exact problem area. This gave us the freedom to study the assembly line and apply theories and methods used in our academic program. Thus it was a challenge to identify the root causes of their problems. Out of the literature used in this case study, the main framework, namely Porras and Robertson organizational framework is relevant to this study. Furthermore this framework involves the interaction of four categories namely; organizing arrangements, technology, physical setting and social factors. The interaction of these factors creates individuals perception about the workplace and thus influences his or her on the job behavior. Thus this framework helped us identify factors that can influence the workers on the job behavior in a more positive manner. The use of Porras and Robertson organization framework has definitely increased the validity of the thesis. We also believe that the extra sources used as a complement to the framework have been beneficial. As the company is working with lean production such literature also has been used in the study. Furthermore, the literature selected was established after our pre-study at the company as we got the opportunity to get familiar with the line in the sense of production and communication. As the thesis project progressed further, more time was spent on collecting data. Our main methods for this were observations and time measurements. Our observations, however, lacked the expected validity due to the problematic situation at the assembly line e.g. downtimes, shortage of labor and machinery problems which made it difficult to observe the production flow. Therefore to increase the validity, we collected various other quantitative data over a period of 17 weeks. Moreover, the measurement data has been very time consuming but has given us enough numbers to analyze the line. Using observations and Porras and Robertson’s organizational framework we were able to establish a picture of the current working conditions at the line and with the support from measurements we could justify our statement. The applied state was established with the Soft systems methodology (SSM) and we could develop recommendation in how the line should work. Even though the SSM is a methodology used in the IT world we wanted to find the exact nature of the problem and what were the underlying reasons for the company. We believed that with the use of this methodology we could find how they are currently working and what issues need adjustments and improvements.
In order to get a more overall view of the line we conducted interviews which gave valuable inputs when analyzing the line. The interviews were conducted with several different personnel that work with the specific assembly line. The challenges during the interview were to follow the planned structure of the questions as the interviewed persons had different inputs which made the interviews progress in other directions. Thus, we think that the structure was followed in most of the cases. Moreover the collected data were of primary type but with one exception: the shift records were of secondary type and displayed the difficulties e.g. breakdowns, machinery problem, and availability of labor force during each shift. From this data we calculated the different type of measurements such as OEE, production efficiency etc. We believe that the methodology chosen for this thesis project has met the requirements and answered our research questions. Furthermore this methodology helped us identify the current state for the production line and this was alsoconfirmed by the company to ensure that our project was going in the right direction. As we discovered that there are more factors causing problems at the line we believe our course of action has been the right one. If we should criticize e.g. what we could have done better, our literature study could had been more intense and wide but this project had a more practical approach so we feel confident with the chosen literature and methodology. Moreover the period during which quantitative data was measured could have been extended to increase the validity of the research. However since most of our data was gathered from shift records, the records for the previous year contained severe discrepancies and thus restricted us in analyzing data over a longer period of time. In this case detailed data from the shift records could have helped us with more accurate data.

The reliability of the research is dependent on the type of data that will be collected. The measurement will vary but the end results of the research would be moreover the same. For example the interviews could be formed in another way with answers neglecting our study. If the improvement suggested will be implemented and the study repeats it’s very likely that the findings will vary. However the core finding will be the same. By conducting this type of research with the use of SSM in a manufacturing industry, we believe that our research can be validated to some extent. As mentioned, the concern lies in the transformation of SSM to the manufacturing industry. The validity is also justified since we believe we have been able to answer the research questions formulated.

5.2 Discussion of findings

Before we start with the discussions of our findings we would like to remind the reader about the research questions:

Q1: Why is the current productivity output targets not met at EUCD 1?

Q2: Which process of improvement and methods should be followed to increase the consistency of the manufacturing processes?
Q3: How can the suggested methods be used and adapted for the development of similar/future production cells?

Our findings reflect the answer to all of these questions. The current productivity at the company has high variation due to machine breakdowns and low labor force availability at the line, the machinery problems has its roots to the poorly established maintenance system. Figure 4.15 with the long term recommendations explains the state in which the company should work in order to minimize the high variation. We believe that forming work groups, overlooking the maintenance system along with making sure that the planned labor is operating at the line would improve the consistency of the manufacturing process. The long term recommendations that we brought forward can be seen in Figure 4.15. As mentioned these will give the company a more stable process, where everyday problems will be brought up to the surface and where operators will have more inputs to solve them. We furthermore believe that the result we found need to be taken into consideration when forming/designing future production cells. As it is today, the company doesn’t work with root cause analysis, and this is creating short-term solutions for the symptoms which in the end lead to a low productivity.

5.3 Conclusions and recommendations

The purpose of this study was to identify the root causes behind the different problems causing a high variation and disruption in the production flow. As said, due to the complexity of the line we choose an approach using an organizational framework to identify communication, problem solving methodology etc. Along with the qualitative data we used different quantitative performance measurement data to strengthen our result. We are of the opinion that we have managed to identify the reasons for not meeting the production targets and what should be the steps taken to reach those. The main recommendations for the EUCD 1 assembly line are as follows:

- The current performance measurement parameters are not enough to get the real picture of EUCD1. The other parameter that should be included is OEE.
- The daily maintenance activities are inadequate and the company should initiate the implementation of TPM.
- The process of TPM implementation should be started by working on the frequently occurring as robot dropping the parts, robot not putting parts in conveyor. For the EOL rebooting of computer and crash should be an area to begin focusing on. Furthermore constant monitoring of the problems should be carried out by the maintenance department.
- The operators should be involved in the problem solving processes and should work with the maintenance department to identify root causes of the problems.
• Training with regards to identifying waste as well as maintenance procedures should be given a priority.

• In order to increase productivity the assembly line needs to increase its resources and invest in long terms solutions. As of today they everyday problems are solved with the use of countermeasures where the problems reappear. The company has to invest time and resources in creating improvement groups among operators to get to the root cause of problems.

• From the financial analysis, it can be seen that along with losses due to shortage of labor, there also exists losses due to machinery breakdown. Thus if these are eliminated by root cause problem solving the company will be able to make more profit in the long run.

• For being able to transition into a thorough lean manufacturing company, TPM is an important base.

5.4 Suggestion on further studies

The company strives hard to satisfy their customer needs but the EUCD 1 line faces problem in meeting the output of planned target. We can say that the company is an anorexic organization having a strategy of downsizing with permanent personnel reductions. There is a constant debate going on about the advantages of downsizing (Wilkinson, 2005). A further research study that could be carried out is how organizational effectiveness gets affected in “anorexic organizations” or how to strategically manage a downsizing process.

Finally, our delimitations included not considering the changeover activities but we believe that if they are focused upon it would further help in meeting production targets. Even though the main body shell of the shifter is the same for all shifters, the model varies which caused a delay and complications in the changeover. If the changeover process is standardized, it might lead to a more consistent production output with improved quality of products. The further research that can be carried out is how the changeover process standardizing influences the quality of products.
6 References


References


References


References


7 Appendices

7.1 Interview Questions

Here follows the questions asked during the interviews held’s with involved personal at the line. The questions are based on Porras and Robertson organizational changed based framework

7.1.1 Questions for line supervisor

1. How do you find work here? How did you start in Kongsberg?
2. What exactly are your tasks? What are your responsibilities?
3. What does she do during and after team meeting? Are you present during Patrick’s meeting with the workers? What exactly happens there?
4. What are the main problems you think in EUCD1?
5. What is the most challenging part of your job? Do you have any expectations or suggestions for it?
6. Who are the other supervisors for the lines?

Organizing Arrangements

1. Goals
   - Does the management set any improvement goals concerning the line’s performance? If yes what type?
   - Are the workers familiar with company’s goals and objectives? Are they given any information on that?

2. Formal Structure-
   - How do you co-ordinate work with Lagombud (Team organizer)? Do you or Lagombud are supposed to look after task allocation in case of absenteeism?

3. Administrative policies
   - How, when do you take data from shift records? What is the further action taken on this data? Do you do this task for all assembly lines? If no then how many?
   - Do you think this data is useful or can be used in any way?
   - What other policies are there for doing other work? Is there any formal policy for problem solving or maintenance?

4. Culture/Values –
   - Do you think the values of the organization are practiced by everyone on the line? E.g. Right from me, customer first?
   - Are they made aware of on-going customer issues e.g. quality, delivery, etc?
5. Management style

- Does the management involve you when they want to stop the line and talk to the operators? Like deciding the time or etc?
- What kind of information is given from management during stops?
- What are management’s expectations from workers and yourself? Is management willing to give more responsibility to the workers other than regular work?
- Do you think the daily meeting held in the Metal plant not useful for operators in the plastic division? Do you think it would be beneficial if it is moved in the plastic division?(BOARDS)
- Can all the mentioned improvement activities in different sections be discussed in the weekly meetings with Patrick? How can these be applied more practically without compensating on the daily work of the operators?

Social Factors

1. Interaction processes

- How you notice there is shortage of workers?
- How do you find the workers interact with each other, for e.g. decision making, general communication, problem-solving, conflict management, implementing improving procedures, other issues etc?
- Do you have regular communication with the workers?
- Is there dissatisfaction among the workers due to some issues? Are the workers issues recorded formally and considered?

2. Informal patterns and network?

- Are there common employees working at EUCD1 and 2.
- Are same people always together in the same group, or group structure is changed?
- Who decides which workers work for which line and which shift?
- Are there informal groups formed depending on the time the workers are present here? Till e.g. senior employees stay together?
- Is absenteeism data recorded and observed?
- What is the frequency of workers leaving the job?

3. Individual attributes

- How is the Lagombud elected?
- Is there any monitoring of workers suggestions, ideas, etc?
- Are they given additional training for improving their skills?
• Is workers’ performance evaluated in any way? If yes how?
• Reward systems- Do you know if groups are given rewards in any form for goal completion? Give e.g. when we observed this.

**Technology**

• Are the workers given any training for key maintenance issues and solving the everyday problems?
• Is there a formal maintenance manager?
• Do the workers find the job challenging? What is your point of view in making the work more creative?
• How motivated do you think the workers are? Do you think by giving them training in problem solving or improvement tasks, they would be motivated?
• Sometimes workers find better ways to do the work different from the standard working procedure? Is it formally applied?
• If there are improvement groups formed for this kind of activities and standard working procedure is revised, every time an improvement is maintained, do you think management will allow this?(Design and content has most influence on on-the-job behaviour)

**Physical setting**

• Do you find there is space restriction on the shop floor? Do you have any suggestion concerning layout?
• If given this task for freeing up more space to the workers this can be more beneficial?

### 7.1.2 Questions for production technicians

1. How do you find work here? How did you start in Kongsberg?
2. What exactly are your tasks? What are your responsibilities?
3. What are the main problems you think in EUCD1?
4. What is the most challenging part of your job? Do you have any expectations or suggestions for it?
5. What is your role in the meeting? Before and after
6. How do you work with improvements?
7. Do you work with performance measurements e.g. efficiency, analysis etc?
8. What does management expect from you?
9. Do you think the daily meeting held in the Metal plant not useful for operators in the plastic division? Do you think it would be beneficial if it is moved in the plastic division?(BOARDS)
10. Do you participate in shop floor meetings?
11. Do you have regular communication with the workers?
12. Is there any monitoring of workers suggestions, ideas, etc?
13. Do the workers find the job challenging? What is your point of view in making the work more creative?

14. How motivated do you think the workers are? Do you think by giving them training in problem solving or improvement tasks, they would be motivated

7.1.3 Questions for maintenance manager

1. When do you handle maintenance issues? And how is repeated problems dealt with?
2. Are the workers given any training for key maintenance issues and solving the everyday problems?
3. Is there a formal maintenance manager? If no, why? Do you think there should be a manager formally appointed in your team? If yes what would be the benefits and which areas should be focused more as a part of his responsibility?
4. Preventive maintenance? Do you think workers can take some additional relatively difficult maintenance activities if given more training? If yes what can be the hurdles in achieving this?

Additional questions

1) How is maintenance carried out? Process?
2) How is maintenance schedule prepared?
3) Which tools are used for maintenance?
4) How are the workers involved in maintenance process?
5) How is the data for machinery breakdown recorded? Is it made use of if future problems?