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The Productivity Potential Assessment at Ekornes in Sykkylven, Møre and Romsdal

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Preface

This thesis represents the end of my Master of Science degree in Product and System Design at NTNU Ålesund. The work related to this thesis has been challenging, but also interesting. The chosen research topic is based on my personal interest for lean manufacturing and production development.

First of all I would like to thank Kristin Aurdal and Bernt Inge Tandstad at Ekornes AS for providing me with valuable information throughout the study and inviting me to Ekornes' management development course.

Most importantly, I would like to express my gratitude to my supervisor, Ola Jon Mork and his assistant, Irina-Emily Hansen for helping me getting perspective on obstacles and keeping me motivated in my research.

Abstract

This thesis explains a PPA study conducted at Ekornes' shop floor bottle-neck in their factory in Sykkylven. As their goals towards the end of 2016 are to save 210 mill NOK and increase productivity by 4% in their sewing- and sconce departments the management was eager to get an objective view of their actual productivity potential and suggestions to improvement measures.

The PPA method is divided into four levels, where level 1 withstand of a work sampling study and an overall equipment efficiency calculation, level 2 withstands of common KPIs for the company and level 3 withstand of a summary of level of production engineering and an assessment of the work environment. Level 4 is not a formal part of the PPA method, but this level withstand of the most important results of this thesis; suggested improvement measures with calculations regarding their impact on productivity. And nevertheless, the reason why the PPA level 4 is not a formal part of the PPA is challenged with the implementation of the lean tool A3 report.

The main results from the conducted research are that Ekornes' productivity potential is presented and the productivity increase of three cases with implemented improvement measures have been calculated. Ekornes' productivity can actually be improved a lot by not so large measures;

- Implement a Kanban system
    - 21% calculated productivity increase
- Improve their existing sewing robot
    - 46% calculated productivity increase
- Combination of three improvement measures
    - 85% calculated productivity increase

Keywords

PPA, Lean Manufacturing, Production Development, Work Sampling, Manufacturing System, Root-Cause Analysis, A3 report, Norwegian Company.

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Abbreviations

TPS	Toyota Production System
PPA	Productivity Potential Assessment
OEE	Overall Equipment Effectiveness
MTM	Methods- Time Measurement
CCS	Ceiling Conveyor System
KPI	Key Performance Indicator

1 Introduction

"The productivity of a company is an important factor for its success in the fierce competition on the global market" (Almström & Kinnander, 2011, p. 758) and for its competitiveness on a corporate level (Almström, 2012). As more and more production is being outsourced abroad it is crucial that the actual productivity and the productivity potential at Norwegian factories are investigated and compared to keep improving manufacturing methods and to keep Norwegian companies competitive.

Ekornes is the largest furniture manufacturer in Norway and was founded by Jens E. Ekornes in 1934. Ekornes owns the brand names "Stressless", "Svane" and "IMG", where "Stressless" is one of the world's best known furniture brands and is sold on a global scale (Ekornes, 2015). As the management has chosen the lean philosophy to develop and streamline Ekornes, there are many lean initiatives implemented and Ekornes has come a long way in becoming a lean company.

1.1 Project background

The management at Ekornes' plant in Sykkylven, Møre and Romsdal, are working continuously with improvement work through the lean philosophy. Their goals towards the end of 2016 are to save 210 mill NOK and increase productivity by 4% in their sewing- and sconce departments. As they have met challenges in the reduction of lead times and error rates previous years and that the utilization of their sewing robot is not good enough they found the methods for this research appealing. Lean coordinator, Kristin Aurdal, and operations engineer, Bernt Inge Tandstad, wanted to see how the PPA method would present Ekornes' productivity potential and were interested to see how their productivity could be increased.

1.2 Research questions and objectives

The research questions addressed in this study are:

RQ1: Can Ekornes' productivity potential be presented through a PPA study?

RQ2: How can their actual productivity be increased?

In order to answer the research questions this study applies a productivity potential assessment (PPA) study that withstands of mainly quantitative methods, but also qualitative methods.

The research objectives addressed in this research are:

RO1: Locate Ekornes' shop floor bottle-neck

RO2: Execute a PPA study

RO3: Suggest measures and changes to improve productivity

1.3 Structure

This thesis consists of seven chapters. The introduction outlines the background for the study, the purpose of the study, the research questions and the research objectives addressed. Chapter 2 describes the theoretical framework used to answer the research questions and to conduct the research objectives. Chapter 3 describes the methods used in the study. In chapter 4 the results from the pre-study and the PPA study are presented and are followed by a discussion (chapter 5) and a conclusion (chapter 6). In chapter 7 suggestions to future work are presenter.

2 Theoretical framework

The following chapter introduces the theory used to form the theoretical foundation for this thesis. First the general aspects of lean manufacturing are explained. The the productivity model is explained followed by the explanation of the general aspects of the PPA method. In addition, the ethics taken into consideration in the research are explained.

2.1 Lean Manufacturing

According to Wilson (2015), Bellgran & Säfsten (2010) the TPS is where one can find the origin of lean manufacturing. "Lean production applies and develops the pioneering ideas from Toyota's Production System about reduction of waste and added value" (Bellgran & Säfsten, 2010).

Liker & Meier (2006) states that Toyota has identified seven types of non-value added activities in manufacturing processes which can be applied to several types of businesses. To their list of non-value added activities they have added an additional eighth waste;

1. **Overproduction:** to produce more, or earlier than the demand of the next process/ customer.
2. **Waiting (time on hand):** an operator cannot carry out his/her work tasks because he/she is waiting for parts, information, substrates or decisions.
3. **Transportation or conveyance:** unnecessary transportation of goods, materials, documents, etc.
4. **Overprocessing or incorrect processing:** to carry out more work than necessary with respect to specifications etc.
5. **Excess inventory:** more goods and information than necessary.
6. **Unnecessary movement:** because of factory layout etc.
7. **Defects:** not right the first time (wrecking, rework, decrease of productivity etc.)
8. **Unused employee creativity:** loss of good ideas and skills.

Lean manufacturing is all about eliminating waste and creating flow through continuous improvements as illustrated in Figure 1.

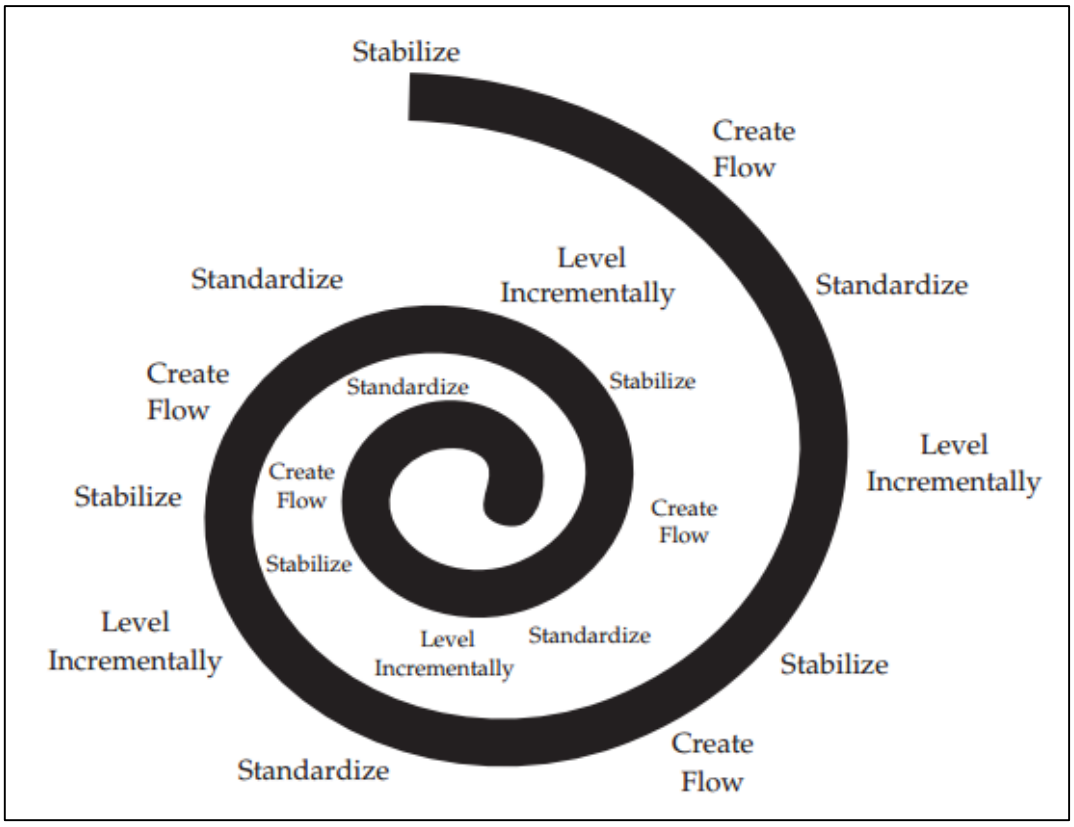

Figure 1. Continuous improvement spiral (Liker & Meier, 2006, p. 51)

What Liker & Meier (2006) illustrates with Figure 1 is that improvement work never ends. By improving for example a process by creating flow and standardizing the procedures a new potential for flow increase will reveal itself. The flow created may not give the same results as the first improvement, but nevertheless it is an improvement.

According to Niklas Modig (2016) lean is a journey where flow efficiency is prioritized before resource efficiency (see Figure 2). By placing a company, or a shop floor in the efficiency matrix one can see whether the management should focus on flow-, or resource efficiency to become more lean.

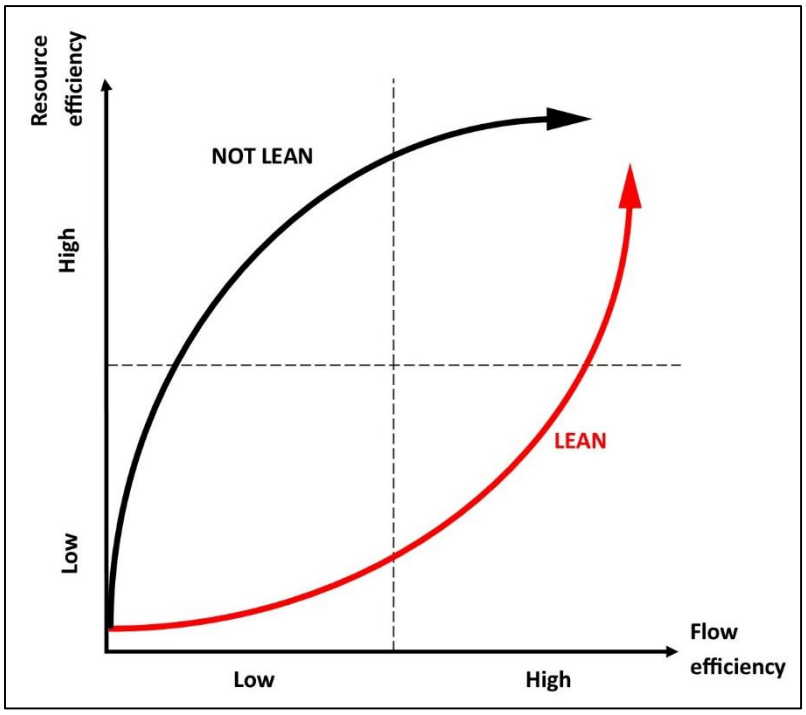

Figure 2. Efficiency matrix (Modig, 2016).

When a company, or a shop-floor is getting close to what is often referred to as "the perfect state", or "the impossible state" they have achieved a production method where value adding activities correspond to the resource utilization and surplus labor is eliminated (Modig, 2016) (see Figure 3).

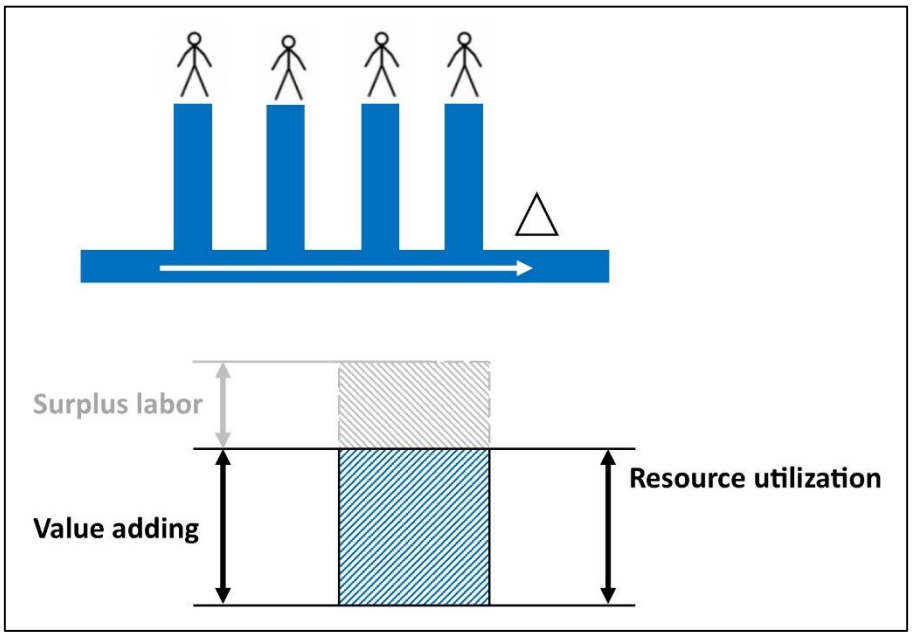

Figure 3. The perfect state: short lead times, high resource efficiency

2.2 Productivity

According to Tangen (2005) “productivity is usually defined as output over input, for example correctly produced products that fulfil their specifications over the value of all resources spent for producing these products during a specific time period” (as cited in Almström & Kinnander, 2011, p. 759). Initially, productivity can be increased by decreasing the input, or increasing the output. According to Almström (2012, p. 3) “productivity can be improved through better methods (M), increased performance (P), and increased utilization (U)”. Productivity can be calculated with the basis in these three factors by the use of Equation 1.

$$Productivity = M\ x\ P\ x\ U \tag{1}$$

“The method factor (M) is defined as the ideal or intended productivity rate. It is the inverse of the ideal cycle time for the specific work task. In order to determine the ideal cycle time for manual work tasks it is necessary to use a predetermined time system” (Almström, 2012, p. 4). According to Almström (2012) most of the available systems are based on MTM, but that a piecework salary system will provide data to determine the ideal cycle time.

“The performance factor (P) corresponds to the speed the work is carried out at in relation to the ideal cycle time. For manual work the performance factor can be both below and above 100%. The normal speed in MTM is set to be valid for a “normal” person working at this speed for 8 h a day and for the whole working life without getting exhausted or injured. The performance rate is lower for not fully trained workers and for people with disabilities. For machine work can performance by definition never go beyond the ideal cycle time, i.e. 100%” (Almström, 2012, p. 4).

“The utilization factor (U) represents the time that is spent on performing the intended work in relation the total planned time. Utilization can never go beyond 100%. The planned production time is usually defined as the paid work time minus planned stops, like weekly meeting or planned maintenance stops” (Almström, 2012, p. 4).

According to Almström & Kinnander (2011) the PPA method’s main focus, considering productivity, is the utilization rate, but both the method factor and the performance factor are considered as well.

2.3 Work sampling

"Work sampling was introduced in England by a statistician, L. H. C. Tippett. Its application was first applied to direct factory labor. Later is was employed to determine time utilization of office workers, teachers, management, as well as downtime and uptime of machines, material-handling equipment, and elevators" (Zandin, 2001).

Work sampling is a statistical, quantitative technique used for work studies where the researchers are studying object activities. A work sampling study is a structured observation study where the researchers are either studying fixed object sequences at random time intervals, or random objects at fixed time intervals. The latter work sampling technique is the one used in PPA, where the fixed time interval between observations is 30 seconds (Zandin, 2001) (Almström & Kinnander, 2011).

The accuracy and precision of a work sampling study has its roots in Equation 2 where the probability of the smallest activity's occurrence (p) and the accepted relative error (e) are the parameters for precision and the z-score (z) being the main parameter for accuracy. In order to calculate the number of observations needed (N) and determine the length of the work sampling study these parameters must be calculated, or set (Zandin, 2001).

$$N = \frac{z^2 p(1-p)}{(pe)^2} \tag{2}$$

2.4 Research Ethics

When conducting a research at a shop-floor it is important that the researcher considers ethical issues throughout the research. It is important to take the operators into account already in the planning of the research to avoid ethical challenges and dilemmas. There are some fundamental ethical challenges to this research considering the operators and the company;

- informed consent;
- anonymity; and
- confidentiality.

Informed consent involves providing the participating operators with clear information about what the research will involve and giving them the opportunity to decide whether or not they want to participate (Wiles, 2013).

Managing anonymity involves providing the participating operators about how anonymity will be managed and what the implications of participating in the research will be (Wiles, 2013).

Managing confidentiality involved both the operators and the company being studied. Regarding the participating operators the way confidentiality are handled is identical to the managing of anonymity. Regarding the company all confidentiality agreements must be respected, whether it is stated in a contract or just an oral agreement.

2.5 PPA

The productivity potential assessment (PPA) method is a Swedish method developed to counter the strong outsourcing trend in Swedish industry (Almström & Kinnander, 2011) and is a tool used to investigate and assess a company's productivity potential.

"The development of the PPA Method started in spring 2005, through an initiative from the Swedish Agency for Economic and Regional Growth (Nutek). The challenge from Nutek was to prove the thesis that there is a large potential for productivity improvement at the factory floor level" (Almström & Kinnander, 2011, p. 761).

The PPA Method is divided into parameters of different levels (Figure 4) where "level 1 is the core of the method, constituting two parameters for measuring utilization in manual work and machine work respectively. Level 2 parameters affect productivity at the corporate level, while 3 parameters indicate the company's ability to improve the production while maintaining a sound work environment" (Almström & Kinnander, 2011, p. 761).

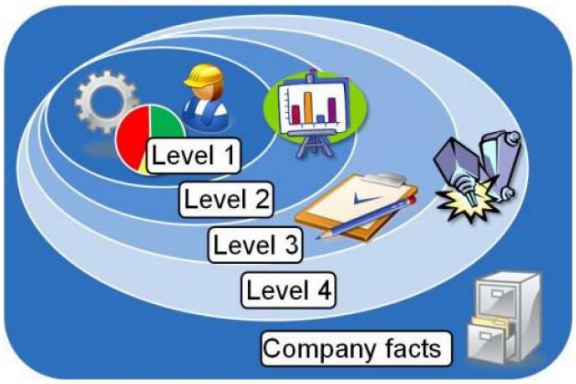

Figure 4. The levels in PPA (Almström & Kinnander, 2011)

3 Method

Ekornes has been working continuously with improvement measures and has come a long way in the implementation of lean tools. Their methods to retrieve data are solid, but the relatively new PPA method has never been applied at their shop-floor.

The method used in this study is the PPA Method, but two A3 analysis have also been made to support the choices of improvement measures.

3.1 Ethical approach

Through lean team manager, Elisabeth Nedreberg, the operators were informed in the morning, at her morning meeting, about the presence of a researcher.

Regarding informed consent, anonymity and confidentiality all participating operators were provided with clear information and the opportunity to decide whether or not they wanted to participate in the research.

The participating operators were never identified in the research, but the work stations were given numbers and were randomly observed in the work sampling studies.

Regarding confidentiality with respect to Ekornes a contract was never presented, nor signed. However, an oral confidentiality agreement was concluded and their sewing robot, "Aqua Lene" could not be photographed.

3.2 The PPA Method

3.2.1 Level 1

Manual work is a large part of the production at Ekornes' sewing department. The operators are divided into "Lean Teams" of up to 16 operators and the sewing department are operational over two, eight hour shifts daily. The measuring technique for manual work in PPA is work sampling where the analyst measures random objectives at fixed time intervals of 30 seconds (Almström & Kinnander, 2011). The general categories for the PPA work sampling are:

1) Value adding activities
2) Supporting activities
3) Not value adding activities

These general categories must be pre-defined heading into the real study. A pre-study is therefore preferable.

The observation method in the level 1 parameter of the PPA method is structured observations. Structured observations are quantitative and are used to investigate;

1) in what frequency the production team do what they do;
2) how much time goes to the PPA method's respective general categories; and
3) if there are any lean tools fit to eliminate waste

3.2.2 Level 2

"Level 2 consist of familiar result parameters that are used by a vast majority of manufacturing companies for their control of operations" (Almström & Kinnander, 2011, p. 763). These result parameters are all affecting productivity and the parameters are:

- Inventory turnover
- Delivery accuracy
- Scrap rate
- Customer reject rate

Inventory turnover is defined as the ratio of cost of goods sold to inventory, and indicates how many times inventory is created and sold during the investigated period (Drake & Fabozzi, 2012).

Delivery accuracy is an indirect measure of productivity. "It is very different what delivery accuracy means for different companies depending on their customers and the customers' requirements. For example, for a supplier of just-in-time products to a car assembly line, it is absolutely crucial to have 100 per cent accuracy, while for a supplier that delivers stock products in times of high demand, it is not a big problem" (Almström & Kinnander, 2011, p. 764). Delivery accuracy in PPA is focusing on the measurement of internal precision where a low delivery accuracy rate is an indicator of an inability to plan operations and the system's difficulty in handling variety (Almström & Kinnander, 2011).

Scrap rate and customer reject rate are both outputs of the manufacturing operation and will therefore affect productivity. Scrap rate can sometimes be hidden when scrapped material are recycled into raw-material and reused. In such a case the scrap rate affects productivity through the OEE calculation. The customer reject rate affects the customer relationship and future business. How the customer reject rate is defined varies from company to company from parts per million, number of rejected orders, value of rejected

products and so on. The customer reject rate does not affect the OEE (Almström & Kinnander, 2011).

3.2.3 Level 3

The parameters at level three are split into two main objectives; the level of production engineering and the assessment of the work environment.

The level of production engineering is defined as how many "yes" answers the researcher collect from a list of 40 pre-defined questions (Table 1). These 40 pre-defined questions are sorted into 11 topics:

1) strategy – goals;
2) work methods;
3) maintenance;
4) competence;
5) cleanliness and order;
6) material handling;
7) change over;
8) continuous improvement
9) calculations;
10) planning; and
11) quality. (Almström & Kinnander, 2011)

The 40 questions that a linked to the 11 topics are used to evaluate the level of the company's manufacturing unit's production engineering and how close it is to what is considered an ideal state of production engineering. "That ideal state is not based on any particular production philosophy, but rather on the author's experience of sound production practice and traditional industrial engineering principles." (Almström & Kinnander, 2011).

TOPIC		QUESTIONS
Strategy - goal	1	Can the management present a clear production strategy, based on qualifying and order winning criteria?
	2	Is the strategy converted into measurable goals for the production?
	3	Are the goals measured regularly and are these measures available to the shop-floor personnel?
	4	Is the fulfillment of the goals connected to any kind of reward?
Work method	5	Is a standardized work method used and is it documented?
	6	Is the standardized work method changed if the workers find a better method?
	7	Do operators serve several machines?
Maintenance	8	Is downtime measured and are causes for stoppages documented?
	9	Is down time measured by an automatic system?
	10	Are small stoppages monitored and actions taken to eliminate them?
	11	Is preventive maintenance used?
	12	Is condition based maintenance used?
Competence	13	Is there anyone responsible for and competent to measure manual work?
	14	Has the first line manager knowledge about the work to lead improvement actions?
	15	Is there a competence development plan?
Cleanliness and order	16	Have all material, tools etc. fixed positions and is everything in place when not used?
	17	Is there enough space around the workplace to move all materials as planned?
	18	Are the floor and other surfaces free from waste material, scrap products etc.?
Material handling	19	Are the load carriers (pallets etc.) adapted to the components?
	20	Does the batch size correspond to the delivery pace?
	21	Is the same load carrier used for a component as far as possible?
	22	Is material stored close to the point of use?
	23	Is the shop independent of trucks, cranes etc. to move the material?
Changeover	24	Are changeover times measured?
	25	Is there a continuous effort to reduce changeover time in the bottleneck?
	26	Are tools, fixture etc. stored close to where they are used?
Continuous improvements	27	Is the continuous improvement work carried out systematically, and is it documented and visualized?
	28	Are the workers engaged in the improvement work?
	29	Has the management a realistic idea about the productivity potential?
	30	Is knowledge from previous development projects used systematically?
Calculations	31	Are investment calculations revised?
	32	Are product calculations revised?
Planning	33	Is the ideal cycle time known and is it based on facts?
	34	Are real operation times reported to the planning system?
	35	Are the operation times in the planning system updated based on the real operation times?
	36	Is the production planned according to pull principle when possible?
	37	Are lead times measured in order to reduce them?
Quality	38	Is there a standardized quality system in use (e.g. ISO 9001)?
	39	Is the single operator responsible for the quality of his/her own work?
	40	Are the systematic methods used to eliminate the occurrence of errors?

Table 1. Questions to evaluate the level of production engineering (Almström & Kinnander, 2011).

The assessment of the work environment is divided into three different parameters that define the work environment; the workload ergonomics, the physical- and the psychosocial work environment. The researcher is to score these parameters on a scale from 1 to 5 through conversations with the operators and observations. The assessments from the work environment parameters are then compared to personnel turnover, short time absence and absence due to illness (Almström & Kinnander, 2011). According to Hackman and Oldman (1980) "the basic hypothesis is that a good work environment (i.e. a high score in the assessment) does not affect the productivity either positively or negatively. However, a low score may affect productivity negatively, through increased absence and personnel turnover and possibly performance drop due to lacking motivation and discontent (as cited in Almström & Kinnander, 2011, p. 765).

3.2.4 Level 4

"Level 4 i.e. productivity increase through method improvement, is not a formal part of the PPA method." (Almström & Kinnander, 2011). However, it is always discussed in a PPA study. There are several reasons why level 4 is not a formal part of the PPA method;

1) improvement potential cannot be fetched in one parameter,
2) variation in researcher's experience,
3) rough estimations as basis for the potential calculations
    - it is hard to find acceptable measures,
4) comprehensive analysis is required.

Productivity improvements can be achieved through the improvement of work methods, investments in new technology, introduction of lean tools etc.

3.3 A3 report

Documentation of complex problem solving processes has been targeted by Toyota and one of their clever results is something they call the "A3 report". The reason for the A3 format is that there was a lot of communication across various sites in Toyota and the A3 format was the largest paper size corresponding with a fax machine (Liker & Meier, 2006). According to Wig (2016) the problem solving A3 analysis is used to front improvement work regarding quality, cost, delivery, HSE, logistics, productivity etc. and as Liker & Meier (2006) argues, the A3 reports are not reports, but are used to tell a story with a beginning, middle and end. According to Liker & Meier (2006) there are three distinct stages in problem-solving A3 reports; *proposal* stage, *status reporting* stage and *final reporting* stage.

At the *proposal* stage the A3 reports are proposal stories where the goal is to gain acceptance and approval of the proposed countermeasures (Liker & Meier, 2006).

When there is a common understanding and approval of the investigated concepts the A3 reports changes format to the *status reporting* stage. The goal in this stage is to report and update others regarding the activity and the scheduled progress. The completeness of thinking is also being questioned in order to control the need of resources to stay on schedule (Liker & Meier, 2006).

When the countermeasures have eliminated the problem the A3 reports changes format to the *final reporting* stage. The purpose of this stage is to acknowledge the activity, the successful implementation and the team's or individual's success (Liker & Meier, 2006).

Ekornes uses the template shown in Figure 5 to tell a story through these stages;

1) situation now, background;
2) wanted situation;
3) analysis;
4) action; choices and measures;
5) what measures; and
6) evaluation, standardization and learning

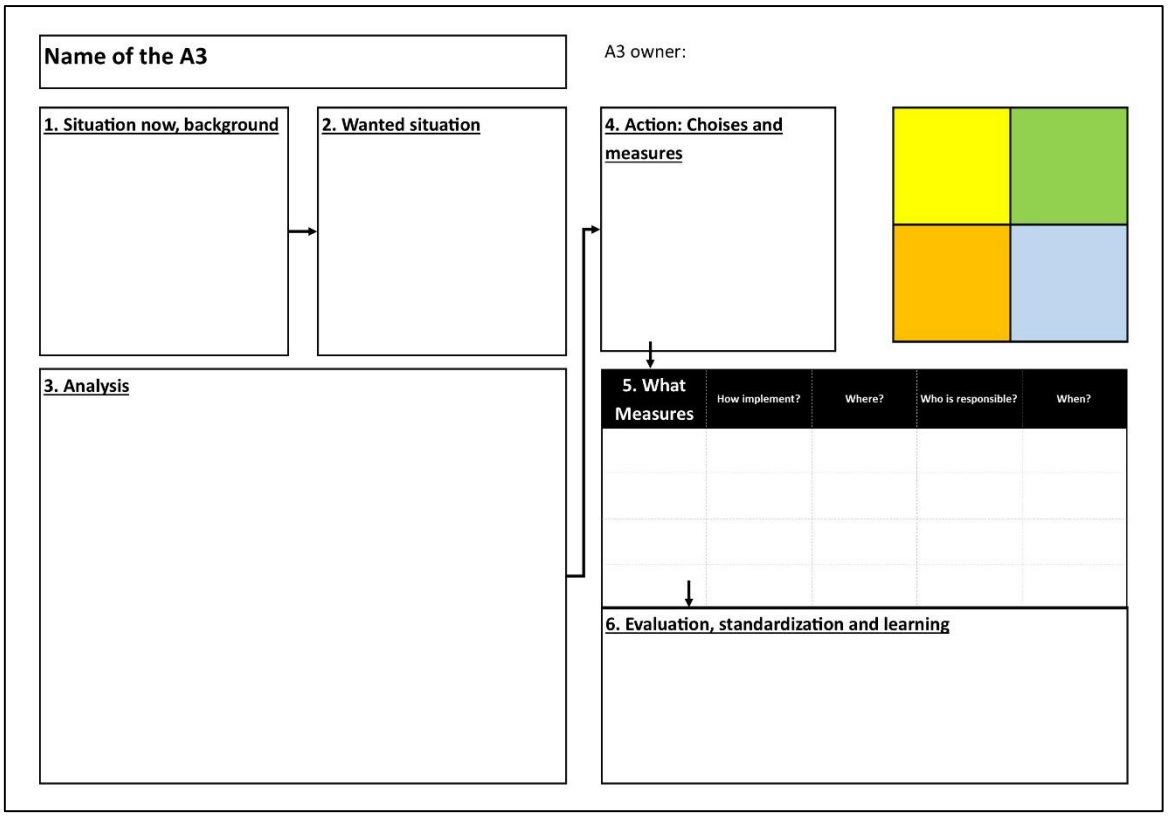

Figure 5. Proposal A3 report template

Figure 5 shows a *proposal* A3 template used at Ekornes, and this is the format used to locate root causes and countermeasures in this thesis.

4 Results

4.1 Pre-study

In order to conduct a PPA study with trustworthy results a pre-study must be conducted. The target with this type of pre-study is to get to know the companies value chain, shop-floor interfaces and activities and get an insight on possible ethical challenges.

The pre-study that was conducted heading into the PPA study of Ekornes withstood of three parts:

1) management development course at Ekornes, Sykkylven;
2) factory tour; and
3) work sampling.

4.1.1 Management development course at Ekornes Sykkylven

The management development course was a two day course held at Ekornes in Sykkylven where the main theme was "lean work for increased competitiveness" (see Appendix 2).

The first day the theme was lean work in Ekornes. For this research the most important was to get to know the lean coordinators, to get an overview of their value chain and to get proper A3 training. Operations engineer, Bernt Inge Tandstad was in charge for the A3 training and in addition he went through their value stream map to illustrate why A3 training is so important.

The second day was a lecture day where Niklas Modig held a seminar in lean business strategies and how to implement a lean business strategy.

Before the work sampling pre-study could be conducted the shop floor bottle-neck had to be located. From Ekornes' value stream map it was obvious that the sewing department was their shop floor bottle-neck and through earlier studies conducted by Ekornes, Figure 6 was developed.

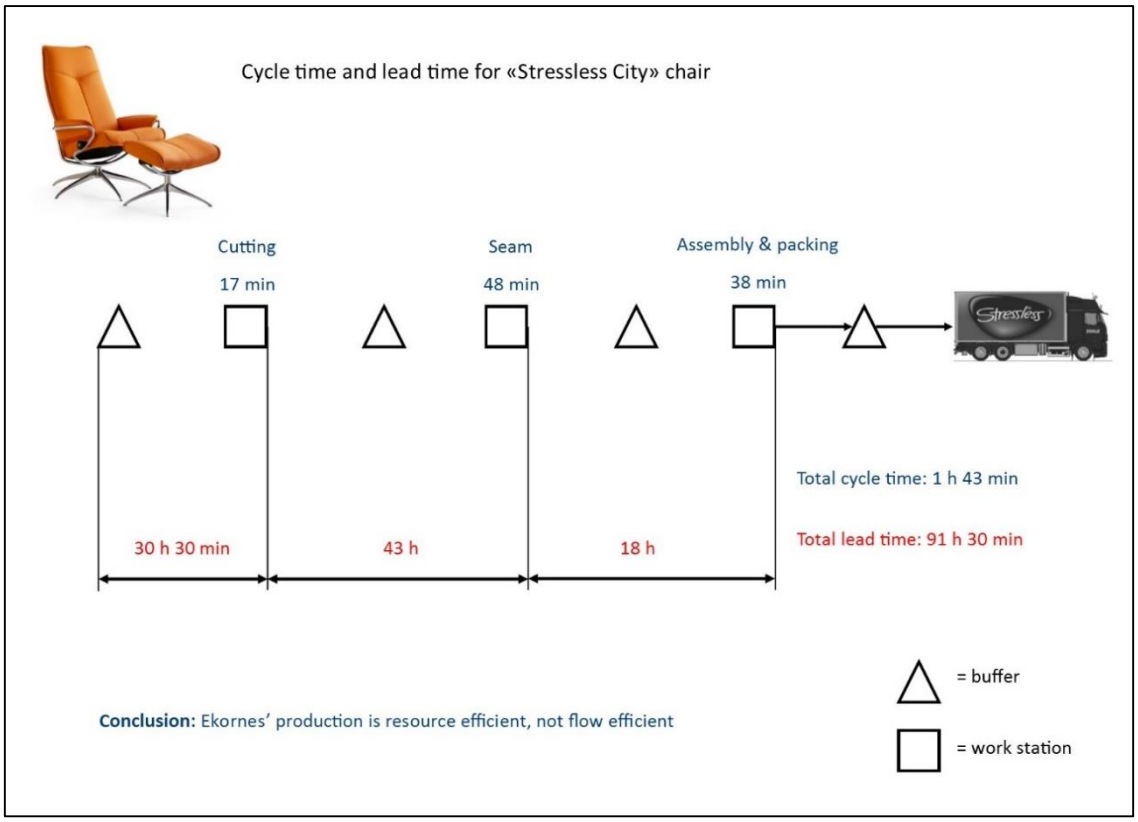

Figure 6. Lead time and cycle time for a "Stressless City" chair

According to both Ekornes' value stream map and Figure 6, the shop floor bottle-neck was located as the sewing department (seam) where 47 per cent of the lead time has been observed.

In addition, Figure 6 reveals that Ekornes has a resource efficient production, rather than a flow efficient one, where the value adding activities does not correspond to the resource utilization (see Figure 7).

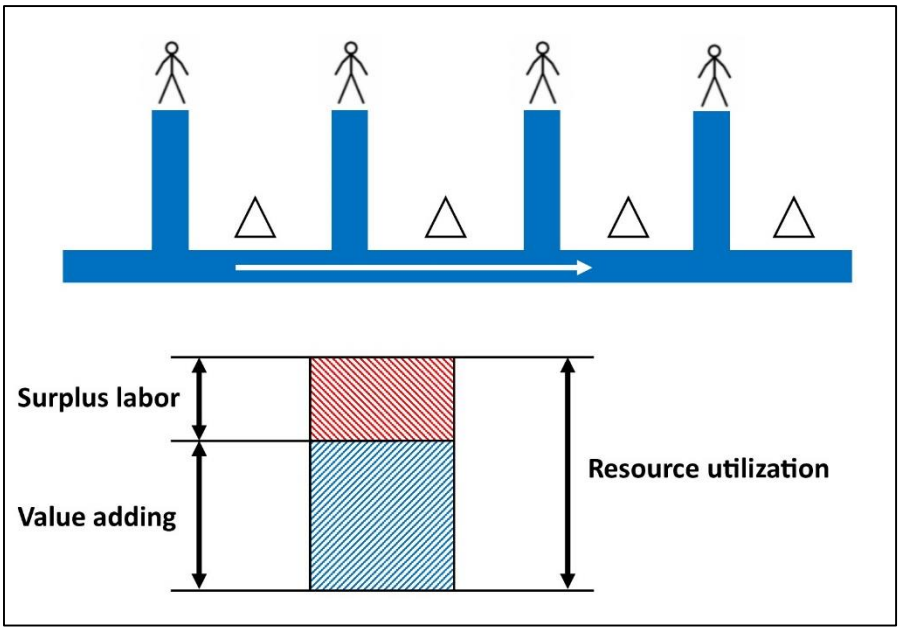

Figure 7. Situation now: long lead time, high resource efficiency

From Figure 7 one can see that a resource efficient manufacturing process does not necessarily mean that the production is lean. Compared to "the perfect state" (Figure 3) regarding lean it becomes clear that Ekornes has a lot of potential when it comes to their production method and productivity.

4.1.2 Factory tour

The factory tour was led by lean coordinator, Kristin Aurdal, and the whole value chain was presented. A sketch of the bottle-neck's layout (Figure 8) was made after the factory tour. Figure 8 illustrates the sewing department's shop floor and one of the main problems at the bottle-neck was identified.

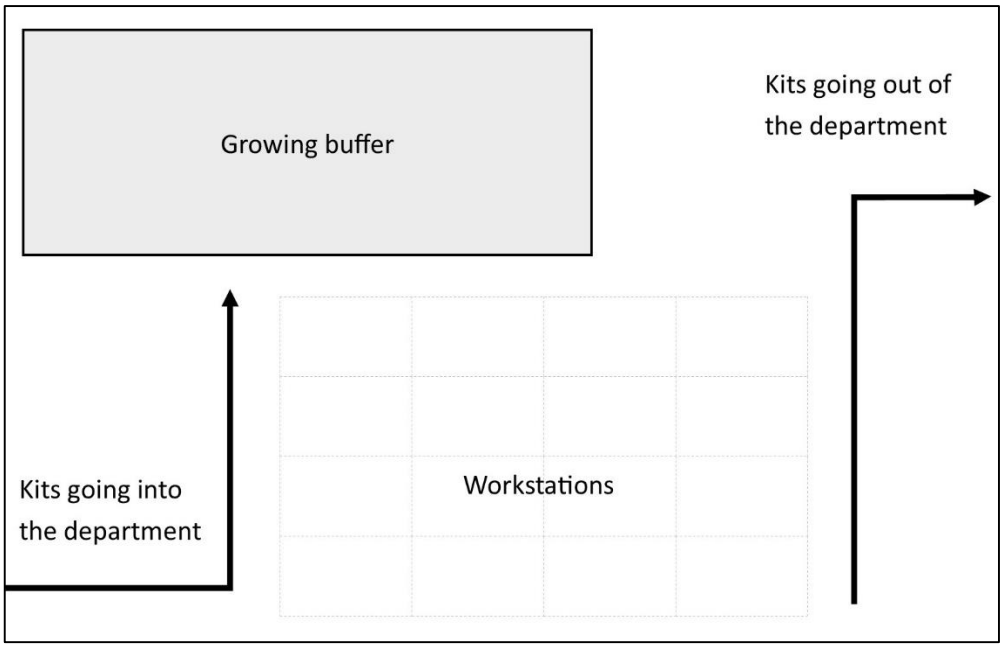

Figure 8. Situation now: sewing department layout

One of the main problems is that the kits are going into the sewing department on the CCS and the operators are taking the kits off of the CCS and placing them into the growing buffer. Because the operators cannot process the amount of kits being sent from the skin department the buffer keeps on growing and lead times are becoming longer.

In addition the sewing department has a sewing robot called "Aqua Lene" (see Figure 9) that unfortunately is still in a development phase.

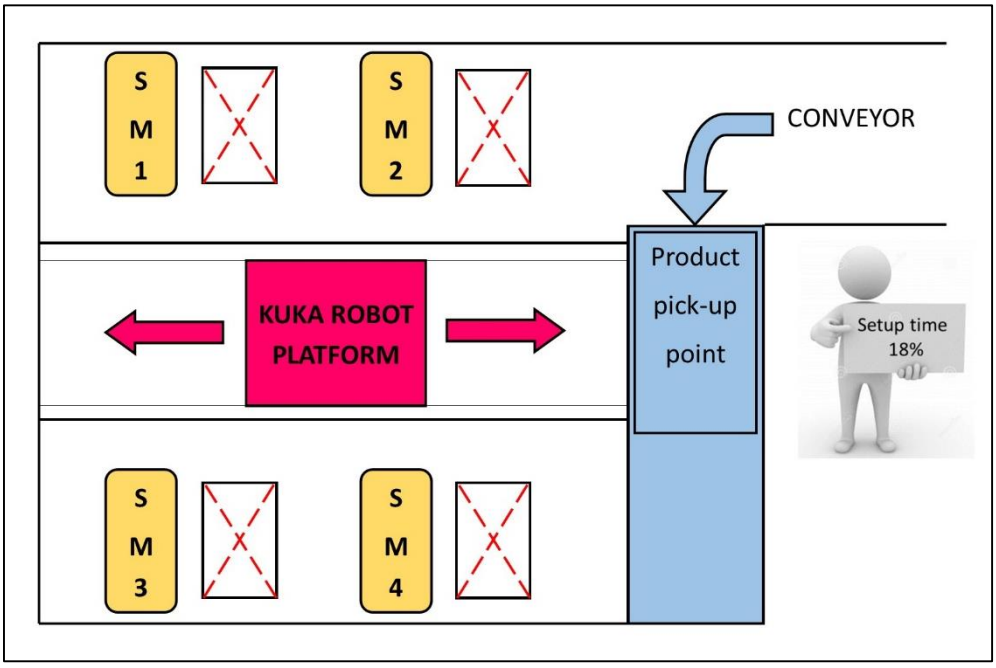

Figure 9. Ekornes' sewing robot, "Aqua Lene"

The situation now is that “Aqua Lene” can only sow one type of furniture parts that have 90 degree angles. She works according to these five sequences:

1. A piece of skin and a piece of fiber (from now on referred to as “part”) are set up manually by an operator and sent into “Aqua Lene” on a conveyor.
2. As the part reaches the “product pick-up point” the “kuka robot” skids over and picks the part onto its platform.
3. The “kuka robot” skids over to one of the four sewing machines and feeds it with the part until the sewing machine is finished with the part.
4. A collection hatch is opened and the part is now within reach of an operator.
5. The “kuka robot” skids back to the “product pick-up point” to repeat sequence 1-4, if there is a new part on the “product pick-up point”.

4.1.3 Work sampling

With a location on the shop floor bottle-neck the department activities were to be defined. Through observations and cooperation with both lean coordinator, Kristin Aurdal and lean team manager, Elisabeth Nedreberg Figure 10 was established.

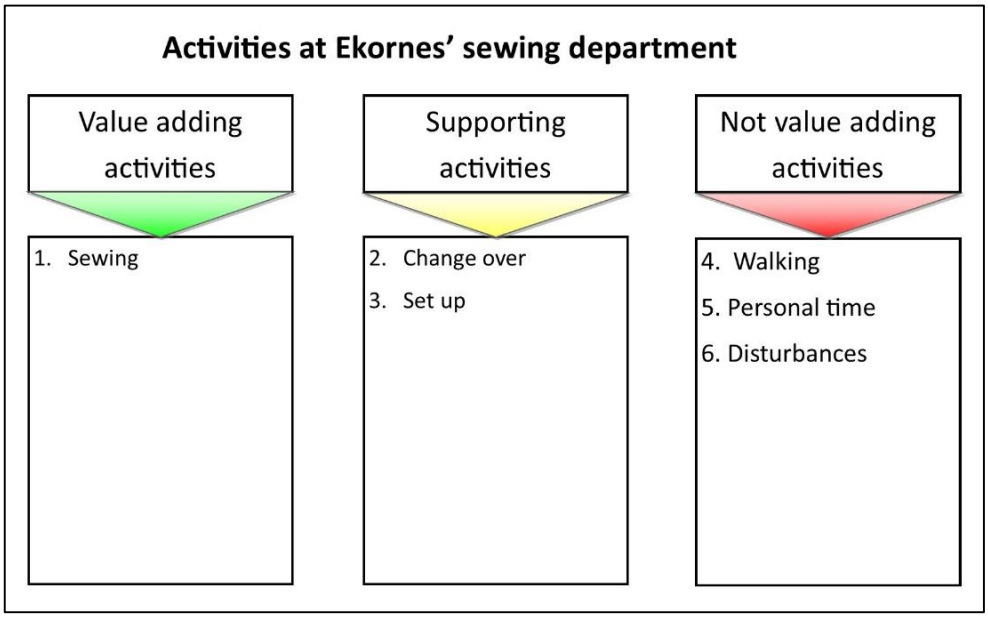

Figure 10. Activities at Ekornes’ sewing department

With the activities in Figure 10 the work sampling pre-study was started, but the study enlightened more and more activities that had to be defined before a study with reliable results could be conducted. After revising the activity list twice the final activities used for the work sampling pre-study are presented in Figure 11 and the work sampling pre-study results are shown in Figure 12 and Figure 13.

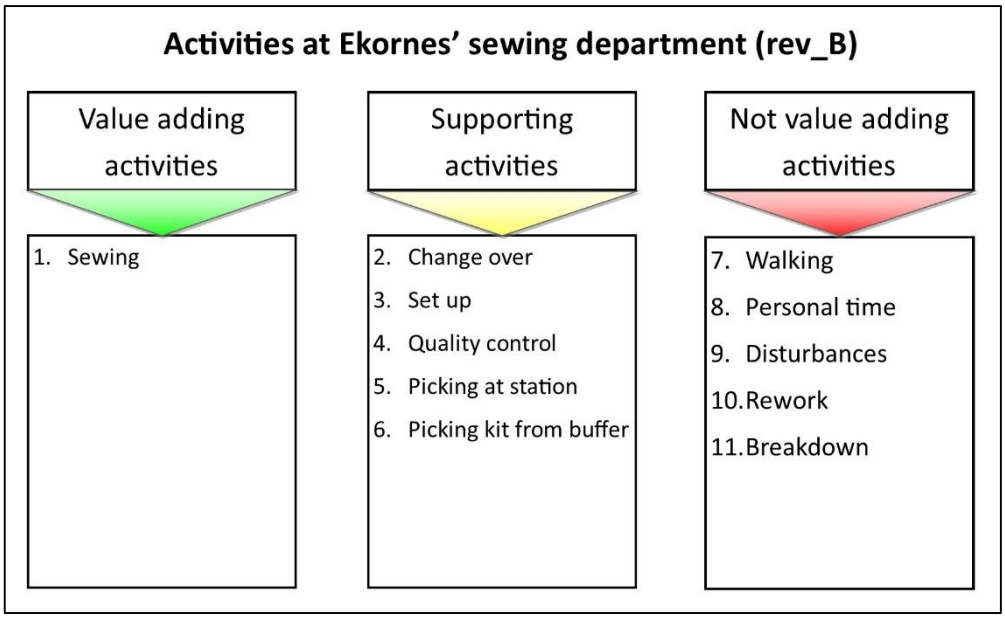

Figure 11. Activities at Ekornes' sewing department (rev_B)

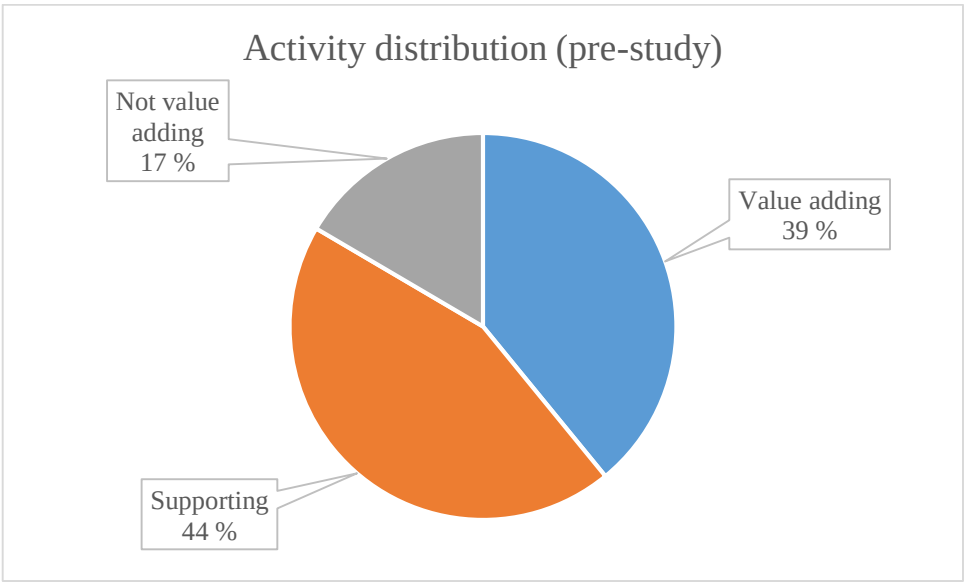

Figure 12. Activity distribution, N = 417 (pre-study)

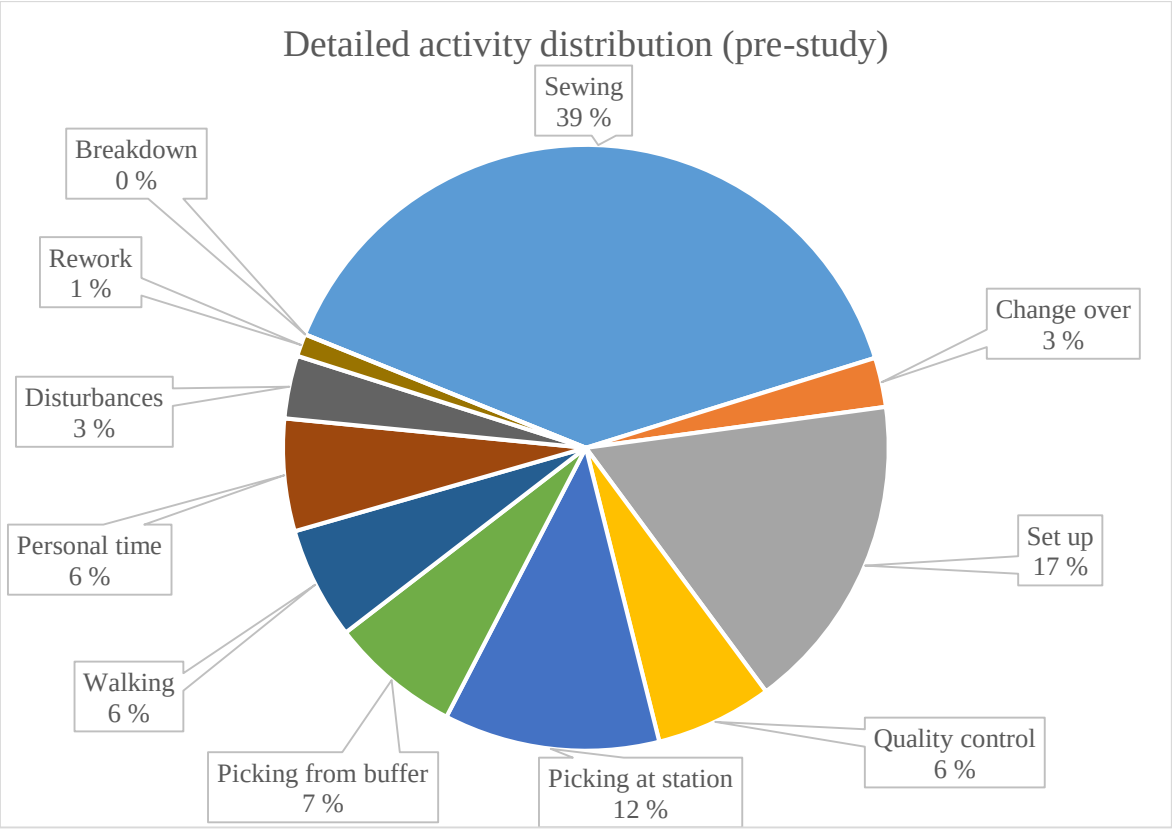

Figure 13. Detailed activity distribution, N = 417 (pre-study)

The results from the work sampling pre-study showed the distribution of the general activity categories in a PPA study (see Figure 12) and that the smallest activity was observed to be 1% of the whole work day. In cooperation with thesis supervisor, Ola Jon Mork, an agreement stating that all activities below 3% were to be neglected was concluded. From this the confidence and relative error was stated and the number of observations needed for the work sampling study was calculated through Equation 2 (Zandin, 2001).

In order to conduct a study with an 80% confidence (z-score), a probability of the smallest activity's occurrence (p) of 3% and an accepted relative error (e) of 10% the number of observations needed (N) are 5297.

4.2 The PPA study

4.2.1 Level 1

A work sampling study with an 80% confidence, a chance of the smallest activity's occurrence of 3% and an acceptable relative error of 10 % was conducted and the results are shown in Figure 14 and Figure 15.

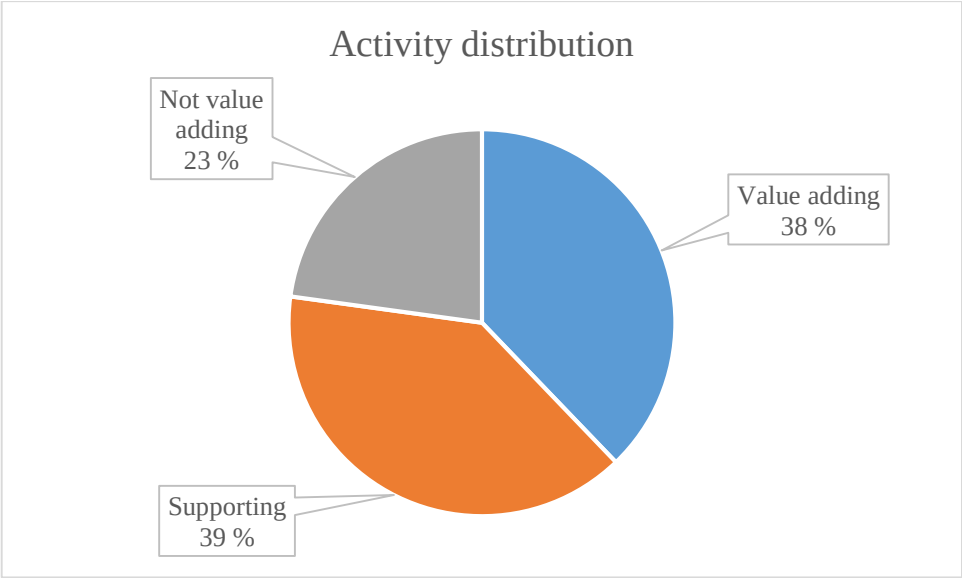

Figure 14. Activity distribution, N = 5481

From Figure 14 one can see the distribution of value adding-, supporting- and not value adding activities.

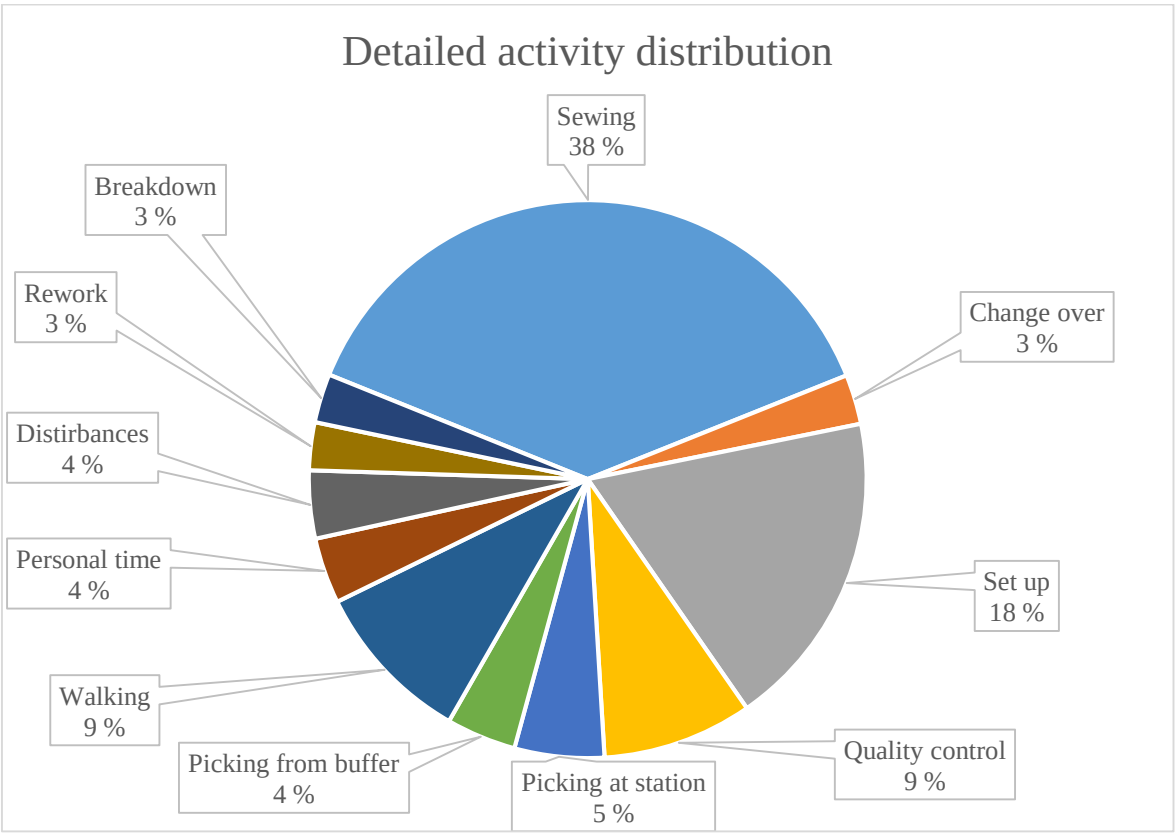

Figure 15. Detailed activity distribution, N = 5481

From Figure 15 one can see the distribution of all activities observed in the work sampling study.

The OEE for the sewing machines were 97%.

4.2.2 Level 2

Ekornes' inventory turnover over the five past years are shown in Table 2.

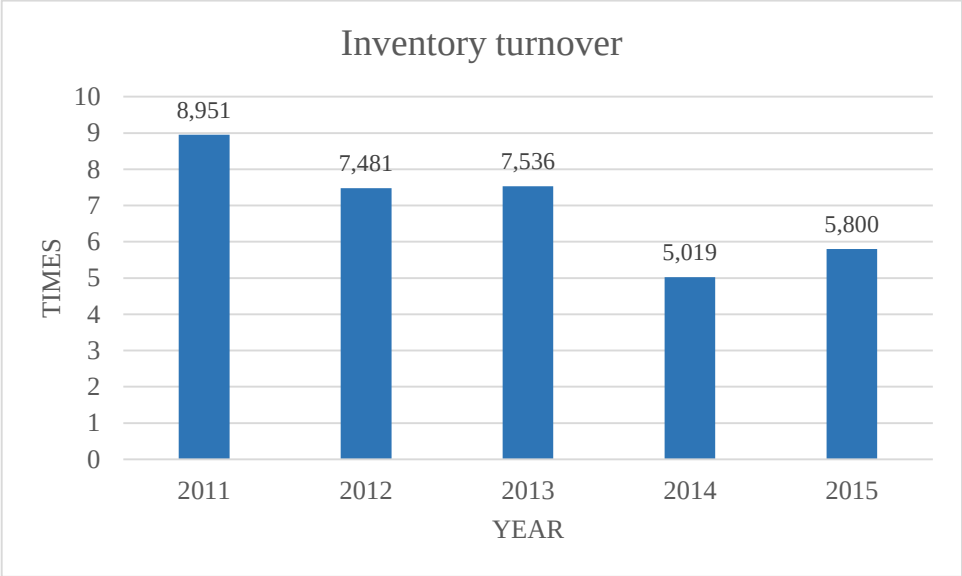

Table 2. Inventory turnover (2011-2015)

Ekornes' delivery performance in a year is presented in Table 3.

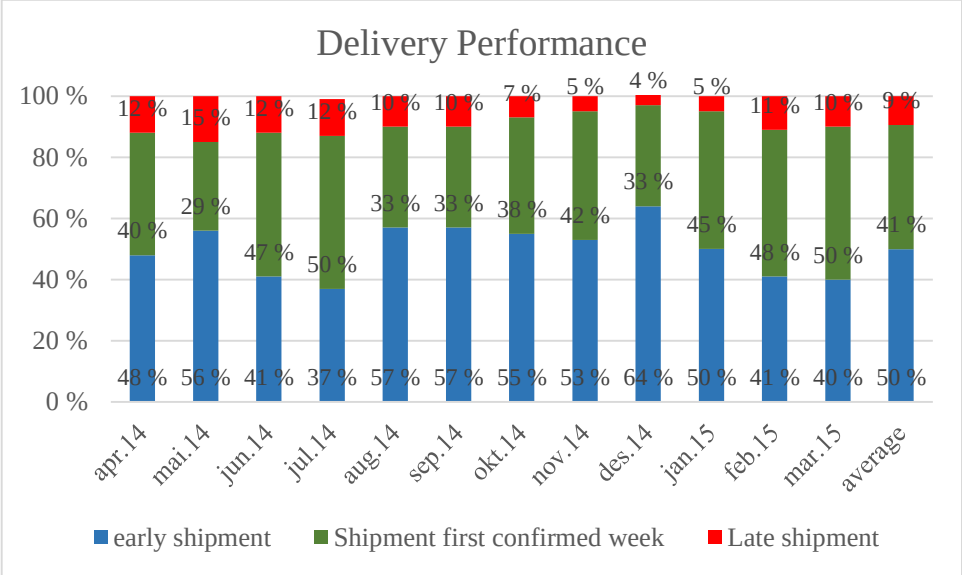

Table 3. Delivery accuracy (apr.2014-mar.2015)

As Ekornes' management could not present numbers for their scrap rate it could not be included in this study. However, as the number of seam-errors from their sewing department are between 40 and 45 daily, and the factory produce approximately 1100 seats daily, the rate of seam error from the shop floor bottle-neck is 4%.

Customer reject rate is presented by Ekornes' management to be 0,5%.

4.2.3 Level 3

Based on the answers to the 40 pre-defined question in Table 1 (see Appendix 1), the score matrix presented in Figure 16 was established followed by a statement describing the reason behind each topic's score.

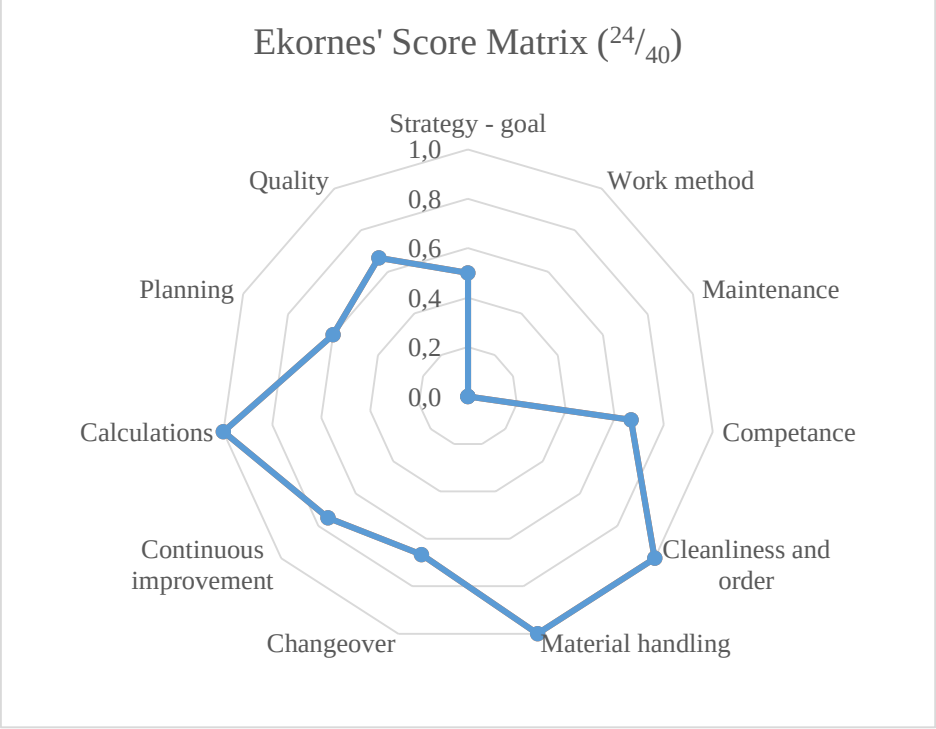

Figure 16. Level of production engineering score matrix

Strategy – goal: The management presents their production strategy to be resource efficient where a lean shop floor is the key to success. Production measurements are presented on screens in the factory and are available for the shop floor personnel at all times. However, their strategy and goals are not converted into measurable goals in the production and their incentive system consists only of a workpiece system. The level of production engineering considering "strategy – goal" is therefore 0,5 (50%).

Work method: Standardized work methods are not used in Ekornes' shop floor and their current methods are not challenged with improvement work. In addition, the operators does not operate several machines. The level of production engineering considering "work method" is therefore zero.

Maintenance: Downtime in production due to breakdowns and stoppages are not measured, or documented. This way the management cannot present any strategic

approach to eliminating stoppages. On the shop floor there is no sign of preventive- or condition based maintenance, but a run-to-failure maintenance philosophy has been observed. The level of production engineering considering "maintenance" is therefore zero.

Competence: At Ekornes the first line manager is responsible for the measuring of manual work and he/she also have competence in the work leading to improvement. However, the management cannot present a competence development plan. The level of production engineering considering "competence" is therefore 0,67 (67%).

Cleanliness and order: All materials, tools etc. have fixed positions and are in place when not used. The floor and other surfaces are free from waste material, scrap products etc. and there is enough space to move all materials as planned. The level of production engineering considering "cleanliness and order" is therefore 1,0 (100%).

Material handling: The kits and pallets are adapted to the components used in production and the same load carrier is used as far as possible for a product. All materials are stored close to the point of use, the shop floor is independent of trucks and cranes and the batch sizes correspond to the delivery pace. The level of production engineering considering "material handling" is therefore 1,0 (100%).

Change over: The management can present a continuous effort to reduce the changeover in the bottle-neck. All tools are stored close to the point of use, but the changeover times are not measured. The level of production engineering considering "changeover" is therefore 0,67 (67%).

Continuous improvement: The management has a realistic idea about the productivity potential. The continuous improvement work is being carried out systematically and it is being documented and visualized for all employees. Knowledge from previous development projects are used systematically in their improvement work, but the operators are not engaged in the improvement work. The level of production engineering considering "continuous improvement" is therefore 0,75 (75%).

Calculations: All investment calculations and product calculations are being revised. The level of production engineering considering "calculations" is therefore 1,0 (100%).

Planning: The ideal cycle time is known to the management, but real operation times are not being reported to a planning system. However, the operation times in the planning

system are updated based on real operation times that are being calculated through work method studies. Lead times are measured and presented in their value stream map in order to reduce them, but their production is not planned according to pull principles. The level of production engineering considering "planning" is therefore 0,6 (60%).

Quality: At Ekornes they have strict policies regarding quality and there is a standardized quality system used. All operators are held responsible for his/her work, but they do not have to do the rework themselves and there is no systematic methods used to eliminate the occurrence of errors. The level of production engineering considering "quality" is therefore 0,67 (67%).

The work environment score was $^{10}/_{15}$ where the physical and psychosocial work environments are the reason for the imperfect score (see Table 4). The problems observed regarding the physical and psychosocial work environment can all be traced back to Ekornes' incentive system, the piecework system.

Work environment assessment	Score				
	1	2	3	4	5
Physical work environment		■			
Workload ergonomics					■
Psychosocial work environment			■		

Table 4. Work environment assessment

Physical work environment: The piecework system opens up the opportunity to earn a lot of money and many operators are tempted towards a large paycheck. This has a negative effect on the operators because they are taking on a too large workload. Even though the workload ergonomics are very adapted to the operators the high workload wear out the operators' joints, where the elbow- and shoulder joints are the most exposed. Sick leave can be traced back to the bad physical work environment and a relatively high personnel turnover can also be explained through that.

Workload ergonomics: Ekornes' shop floor has a lot of smart solutions regarding the workload ergonomics. The CCS that transport kits in between the different departments, the adjustable sewing benches and the fact that each operator get specialized and tailored

solutions at their workstations are enough to say that the workload ergonomics are good enough as they are.

Psychosocial work environment: The operators are tempted towards a large paycheck through the piecework system, but there is another way to achieve that. The kits that are transported from the skin department by the CCS contains different types of Stressless chairs and sofas. Each chair or sofa has a rate in the piecework system and some have a larger rate than others. This system together with a date system that tells the operators which kits to take next is the core in an up building frustration between the operators and to their management. The frustration builds up because many operators cheat on the date system to get the kits they can earn more money from. In addition the individual is separated from the team because of the piecework system where the lack of teamwork makes each day a lonely and stressful one.

In order to develop and improve the work environment the incentive system must be changed from being a piecework system to being a team based bonus system (see Appendix 4 and 5 for A3 reports). The incentive system based on team bonuses will both trigger teamwork within the lean teams and the departments, and Ekornes' KPIs will be common for all and something everyone will strive to accomplish. This type of incentive system must be based on measurable KPIs where the KPIs are distributed in percentages:

KPI	Percentage of the total bonus
Productivity	45%
Quality	45%
Cleanliness and order	10%

Table 5. Incentive system: team bonus system

4.1.4 Level 4

In order to increase productivity the method needs to be known and measured. According to Figure 6 the cycle time for a Stressless City is 1 hour and 43 minutes and the sewing department stands for 48 minutes of the total cycle time. According to Figure 14 the supporting activities in the sewing department are 39% of the total work day and personal time without lunch break is 3% (10% with lunch break). By the use of Equation 3 (Almström, 2012) the utilization rate was calculated to be 51% and backed up by observations the performance is set to be 100%. By the use of Equation 1 (Almström, 2012) the actual productivity at the sewing department was calculated to be 20 $^{seats}/_{day}$.

All calculations regarding productivity are for one line of operators throughout the sewing department as illustrated in Figure 17. As an example, the actual productivity 20 $^{seats}/_{day}$ is for one line of operators throughout the sewing department, not the whole department.

$$Utilization = 100\% - (supporting\ activities + personal\ time) \quad (3)$$

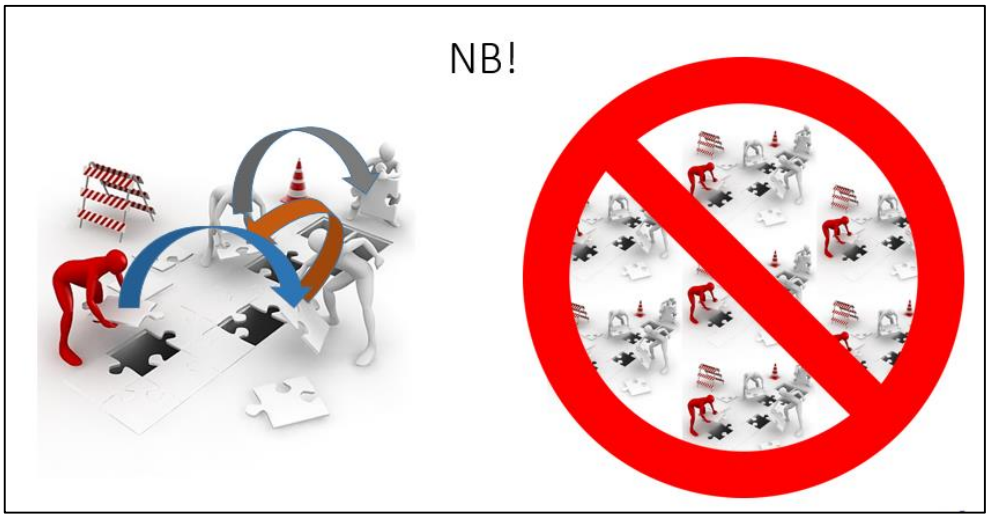

Figure 17. Illustration

Factor	Productivity
Actual productivity	20 $^{seats}/_{day}$
Utilization	20 $^{seats}/_{day}$
Performance	20/0,51 = 39,2 $^{seats}/_{day}$
Method	39,2/1,0 = 39,2 $^{seats}/_{day}$

Table 6. Actual productivity at Ekornes' sewing department

From Table 6 the method, without losses from the method-, performance- and utilization rates, can be converted into (16/39,2)*60 = 24,5 minutes.

In order to identify improvement actions to increase productivity two A3 reports were created (see Appendix 4 and 5). In the first A3 report (Appendix 4) the problem to be solved was the growing buffer in the sewing department, which is the source for the long lead times, extra walk distances and extra kit-processing for the operators. The hypothesis from the first A3 report is stated as following; "The fact that the operators in the sewing department are working fast and good as they can makes it unreasonable to do something

about their performance. The fact that the operators in the dewing department does not succeed in processing the large and growing buffer can be solved by introducing a Kanban system, by increasing their manpower and by improving "Aqua Lene's" productivity and boundaries. The fact that the skin department are over-producing kits and the buffers are growing because of that can be solved by decreasing their manpower."

The suggested improvement measures were then put into a score matrix (see Figure 18) where the x-axis shows how easy the improvement measure is to implement and the y-axis shows how effective the improvement measure will be as a problem solver. As an example one can say that the Kanban system is fairly easy to implement and is highly effective as a problem solver.

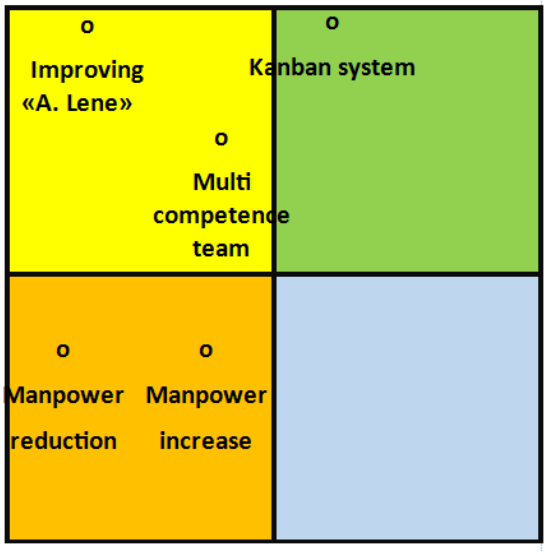

Figure 18. 1st A3: improvement actions' score matrix

As one can see from Figure 18 the Kanban system has the highest score of the improvement measures and the ones taken further into level 4 of the PPA method are presented in Table 7.

In the second A3 report (Appendix 5) the problem to be solved was the lack of teamwork in the sewing department. The hypothesis from the second A3 report is stated as following; "The fact that the operators in the sewing department are already put together in teams gives us a good foundation to form teams with teamwork as a key component. The fact that the piecework system singles out the individual, rather than contributing to teamwork and that is tempts the operators to cheat on the date system can be solved by changing the incentive system, or by forming team kits (2-3 operators working together on one kit)".

The suggested improvement measures were then put into a score matrix (see Figure 19).

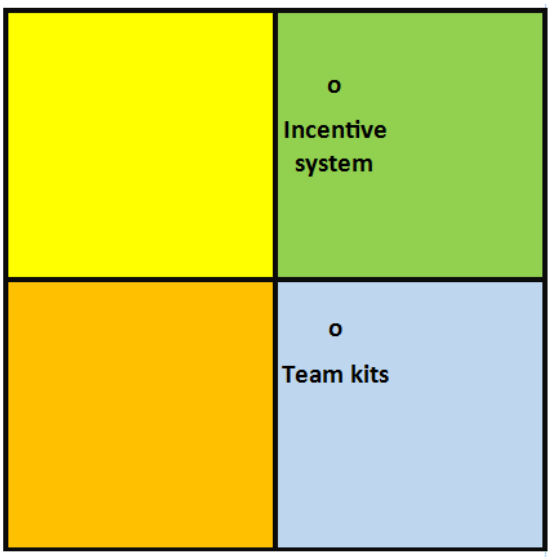

Figure 19. 2nd A3: improvement actions' score matrix

As one can see from Figure 19 to change the incentive system had the best score of the two suggested improvement measures in the second A3 report. The improvement measure taken further in level 4 of the PPA method is presented in Table 7.

Problem to be solved	Improvement action(s)
The growing buffer	1. Kanban system 2. Improve "Aqua Lene" ~~3. Train a multi competence team~~ ~~4. Manpower increase in sewing dept.~~ 5. ~~Manpower reduction in skin dept~~.
The lack of teamwork	1. Change incentive system ~~2. Generate team kits~~

Table 7. Improvement actions from the A3 reports

The problems are obvious when comparing Figure 15 to Figure 8, where the activities that are linked to the growing buffer is "walking" and "picking from buffer".

A Kanban system will eliminate the growing buffer and have a positive effect on both productivity and flow. The Kanban system, where the already existing CCS will be acting as the Kanban, will change the shop floor (see Figure 20).

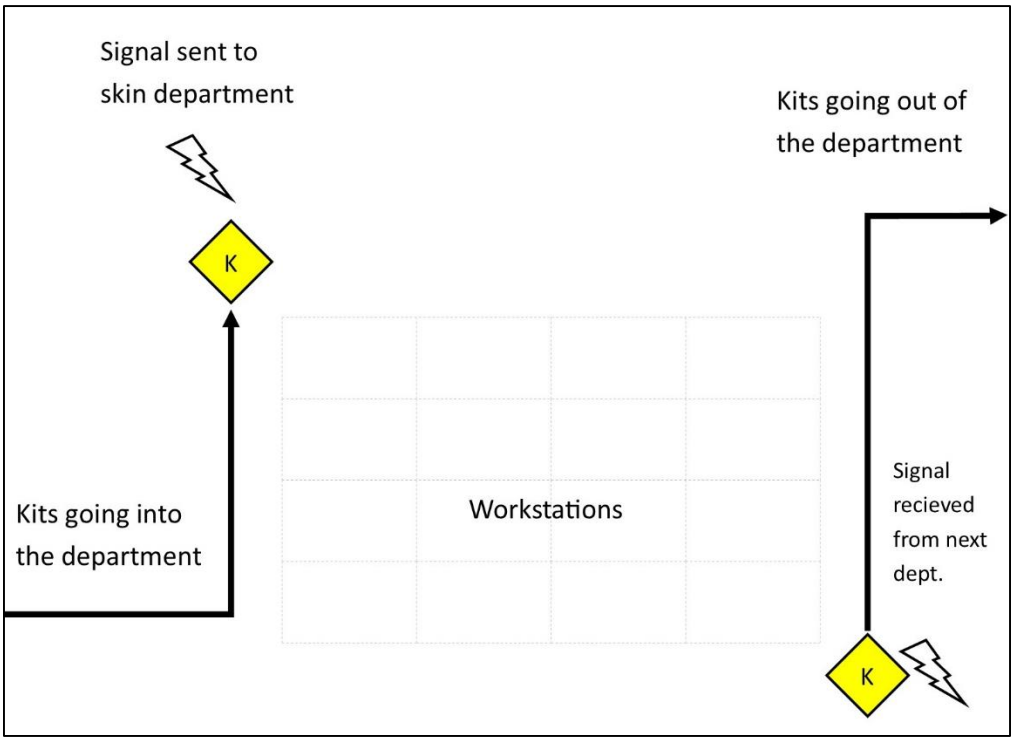

Figure 20. Future situation: sewing department interface

The Kanban system can improve the method by 4% by eliminating the buffer and thereby reducing "walking". The cycle time decreases to 24,5 min – 4% = 23,5 min. The performance shall remain at 100%. The utilization can be increased to 59%, assuming that supporting activities are reduced to 32% and personal time and breaks are reduced to 9% "which is a normal agreed level" (Almström, 2012). The supporting activities are reduced by eliminating the "picking from buffer" activity and reducing setup by 3% by implementing a standardized setup method. The resulting productivity increase can be calculated step by step assuming a 16 hour operative shop floor (see Table 8).

Factor	Productivity before	Productivity after
Method improvement	39,2 $^{seats}/_{day}$	16/(23,5/60) = 40,8 $^{seats}/_{day}$
Performance improvement	39,2 $^{seats}/_{day}$	40,8*1,0 = 40,8 $^{seats}/_{day}$
Utilization improvement	20 $^{seats}/_{day}$	40,8*0,59 = 24,1 $^{seats}/_{day}$
Actual productivity	20 $^{seats}/_{day}$	24,1 $^{seats}/_{day}$
		Total improvement = (24,1 – 20)/20 = 21%

Table 8. Calculation of productivity increase step by step for 1 work day = 16 h

As one can see from Table 8 the productivity can be increased by 21% by introducing a Kanban system.

The improvement of "Aqua Lene" can improve 20% of the method by 50%. The reason that "Aqua Lene" can only improve 20% of the method is because she is located on the "pre-seam" part of the sewing department that is responsible for 20% of the sewing department's productivity. The cycle time decreases to 24,5 min – (24,5*0,2*0,5) = 22 min. The utilization can be increased to 67%, assuming that supporting are reduced to 24% and personal time and breaks are reduced to 9%. The supporting activities are reduced by reducing "changeover" by 2%, "set up" by 4%, "quality control" by 7% and "picking at station" by 3%. The resulting productivity increase can be calculated step by step assuming a 16 hour operative shop floor (see Table 9).

Factor	Productivity before	Productivity after
Method improvement	39,2 $^{seats}/_{day}$	16/(22/60) = 43,6 $^{seats}/_{day}$
Performance improvement	39,2 $^{seats}/_{day}$	43,6*1,0 = 43,6 $^{seats}/_{day}$
Utilization improvement	20 $^{seats}/_{day}$	43,6*0,67 = 29,2 $^{seats}/_{day}$
Actual productivity	20 $^{seats}/_{day}$	29,2 $^{seats}/_{day}$
		Total improvement = (29,2 – 20)/20 = 46%

Table 9. Calculation of productivity increase step by step for 1 work day = 16 h

As one can see from Table 9 the productivity can be increased by 46% by improving "Aqua Lene".

Combining the Kanban system with the improvement of "Aqua Lene" and in addition investing in a prefabricating machine to reduce the setup time of 18% the productivity can be increased further. The cycle time decreases to 24,5 min – 4% - (24,5*0,2*0,5) = 21 min. The performance remains at 100%. The utilization can be increased to 81%, assuming that the supporting activities are reduced to 10 % and personal time and breaks are reduced to 9%. The supporting activities are reduced by reducing "changeover" by 2%, "setup" by 12%, "quality control" by 7%, "picking at station" by 3% and eliminating "picking from buffer". The resulting productivity increase can be calculated step by step assuming a 16 hour operative shop floor (see Table 10).

Factor	Productivity before	Productivity after
Method improvement	39,2 $^{seats}/_{day}$	16/(21/60) = 45,6 $^{seats}/_{day}$
Performance improvement	39,2 $^{seats}/_{day}$	45,6*1,0 = 45,6 $^{seats}/_{day}$
Utilization improvement	20 $^{seats}/_{day}$	45,6*0,81 = 36,9 $^{seats}/_{day}$
Actual productivity	20 $^{seats}/_{day}$	36,9 $^{seats}/_{day}$
		Total improvement = (36,9 – 20)/20 = 85%

Table 10. Calculation of productivity increase step by step for 1 work day = 16 h

As one can see from Table 10 the productivity can be increased by 85% if the management decide to implement a Kanban system, improve "Aqua Lene" and invest in a prefabrication machine.

The actual productivity increases from the three cases are summarized in Table 11.

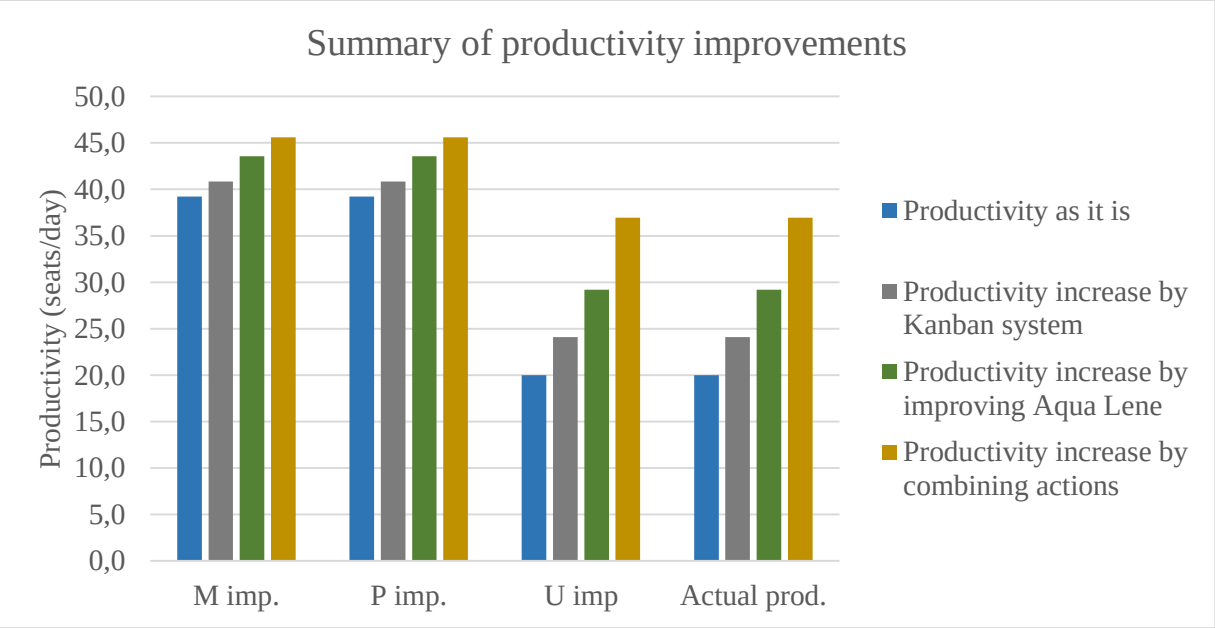

Table 11. Summary of productivity improvements

5 Discussion

The PPA method is a tool used to assess and measure a company's productivity potential through the interpretation of parameters at four different levels. The method has been used in the Swedish manufacturing industry and works as a trigger for continuous improvement work.

In this thesis the PPA study states that Ekornes has come a long way in becoming a lean company and that they have achieved a high level of productivity. However, the management has not been able to utilize their manufacturing productivity potential.

The results from the level 1 parameters of the PPA study was easily interpreted. The work sampling study generates clear models where you have a statistical calculation saying how trustworthy the data is according to reality. The standardized work sampling method for PPA is that objects are to be observed randomly at fixed time intervals and the study shall withstanding of 480 observations. Because it was preferable for both Ekornes and NTNU Ålesund to have a more detailed study, the work sampling study in this thesis withstand of 5297 observations. One can therefore say that with 80% confidence you can trust that the results from this work sampling study reflects the real distribution of the selected activities at the shop floor bottle-neck where the smallest activity measured is 3% of the whole distribution, with an acceptable relative error of 10%. The results showed that Ekornes' sewing department was value adding 38% of the time. However, the common KPIs, error rate of 4% and customer reject rate of 0,5% will have a negative drag to the 38% value adding activities at the department and what we can state with 80% confidence is that the real value adding activities will stand for approximately 36% and not 38%. In addition the OEE of the sewing machines were taken into account, and with an OEE of 97% one can argue the necessity of a better maintenance philosophy than their current run-to-failure maintenance philosophy.

The results from the level 2 parameters of the PPA study was somewhat harder to interpret because how good, or bad one can say that the common KPIs are will vary from business to business and from market to market. However, the trends in inventory turnover and delivery accuracy were interesting to investigate and together with the error rate and the customer reject rate one will get a clear statement regarding how much of the underlying potential has been utilized. In addition, additional errors that are hidden from the work sampling study are reviled and taken into account. The inventory turnover has dropped

the last five years, but can be explained by the fact that Ekornes has more designs available for customers and their inventory does not turn over as fast as earlier. The delivery accuracy is somewhat stabile, but an average accuracy of 91% opens up for some improvement. Regarding the error rate in the sewing department of 4% this must be eliminated and that will also contribute to lower the customer reject rate of 0,5%.

The results from the level 3 parameters of the PPA study constitutes the company's ability to improve the production while maintaining a sound and healthy work environment. As Ekornes scored 24 out of 40 possible on the level of production engineering, where the clear weaknesses were found in maintenance and work method. However, these weaknesses were not taken into account when heading into the level 4 part of the PPA study. The reason is that other observed deficiencies such as no pull principles used in production, no measurable goals for the production used in the incentive system and unengaged operators were preferred going into the search for improvement measures. The work environment scored 10 out of 15 possible where the reason for the imperfect score could be traced back to the piecework system. A lean environment must have teamwork, and if Ekornes continues to use the piecework system they will not become as lean as they could have been. By eliminating the piecework system the management must provide the operators with clear information regarding what changes the new salary system will come with. As an introduction I would recommend the management to implement it in a small scale on one lean team to illustrate that the new incentive system will gain everybody positively.

The results from level 4, which is not a formal part of the PPA method, were the most satisfying to achieve. These results are the main results of this thesis, but they can only be presented by conducting a PPA study and then include all the results and knowledge achieved by studying the three previous levels. The main reason that the fourth level is not a formal part of the PPA method is that comprehensive analysis and studies are needed to get accepted data and the fact that the researcher's knowledge and experience can contaminate the results. For this study, A3 reports were a very helpful and effective tool to use in the search of improvement measures. A3 reports can be stated as comprehensive studies, but well written A3 reports can be red and interpreted quickly and feedback from experts, management or operators can come to the surface quickly. The results are clear and by different measures Ekornes can increase the productivity in the sewing department between 21% and 85%.

As there are many positive aspects to the PPA method, some limitations regarding the method and the conduction must be pointed out.

A PPA study is normally carried out by two certified analysts that split the workload in two and then align the results at the end of the study. In the study conducted in this thesis there was only one researcher with limited experience and due to the PPA being a relatively new method, few others could be involved in the study. These factors may be a source of bias.

The standardized PPA work sampling method withstands of only 480 observations, and the detailed activities cannot be identified by trustworthy distributions. The limitation to that is that the many small activities (breakdown, setup, walking etc.) are not identified, but just a part of the larger groups (value adding-, supporting- and not value adding activities). The purposed improvement measures in level 4 will therefore have limitations regarding their credibility and reflection of reality.

As “Aqua Lene” still is in a development phase some predictions regarding her productivity potential can cause some of the calculations to differ from reality.

6 Conclusion

The PPA study conducted at Ekornes in Sykkylven was successful and the Ekornes' productivity potential was brought to light.

By interoperating the results from level 1, 2 and 3 the suggested improvement measures in level 4 was presented.

By implementing a Kanban system the cycle time could be decreased to 23,5 min. The performance remained at 100%. The utilization could be increased to 59%, assuming that supporting activities were reduced to 32% and personal time and breaks were reduced to 9%. This resulted in a calculated productivity increase of 21%. In addition it will kick start the lean journey as explained by Modig (2016) in the efficiency matrix (Figure 2) where Ekornes' shop floor will move towards being more flow efficient.

By improving "Aqua Lene" the cycle time could be decreased to 22 min. The utilization could be increased to 67%, assuming that supporting were reduced to 24% and personal time and breaks were reduced to 9%. This resulted in a calculated productivity increase of 46%. In addition a more automated production will have a positive effect on the typical wear injury that operators that does repetitive manual work can get.

By implementing a Kanban system together with the improvement of "Aqua Lene" and an investment in a prefabrication machine that reduces the setup time needed to feed "Aqua Lene" drastically, the cycle time could be decreased to 21 min. The performance remained at 100%. The utilization caould be increased to 81%, assuming that the supporting activities were reduced to 10 % and personal time and breaks were reduced to 9%. This resulted in a calculated productivity increase of 85%.

Ekornes can improve their productivity between 21% and 85% by implementing a Kanban system, improve "Aqua Lene" or to combine those improvement measures together with a new prefabrication machine.

7 Future research

Future work is to conduct more PPA studies to cover the whole factory so that Ekornes has more data collected from the whole value chain. The lack of standardized work methods and maintenance philosophy should be investigated so that a best practice can be formulated for the operators and breakdowns will be rarer. I would recommend Ekornes to implement the improvement measures presented in this thesis in a small scale and then measure productivity results and trends in order to gain confidence prior to a full scale implementation. In addition an investment calculation regarding the prefabrication machine that eliminates manual setup in the sewing department should be conducted to assure that Ekornes can earn more money from an investment in that machine.

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Appendix

Appendix 1: 40 Questions to evaluate the level of production engineering

TOPIC		QUESTIONS	
Strategy - goal	1	Can the management present a clear production strategy, based on qualifying and order winning criteria?	Yes
	2	Is the strategy converted into measurable goals for the production?	No
	3	Are the goals measured regularly and are these measures available to the shop-floor personnel?	Yes
	4	Is the fulfillment of the goals connected to any kind of reward?	No
Work method	5	Is a standardized work method used and is it documented?	No
	6	Is the standardized work method changed if the workers find a better method?	No
	7	Do operators serve several machines?	No
Maintenance	8	Is downtime measured and are causes for stoppages documented?	No
	9	Is down time measured by an automatic system?	No
	10	Are small stoppages monitored and actions taken to eliminate them?	No
	11	Is preventive maintenance used?	No
	12	Is condition based maintenance used?	No
Competence	13	Is there anyone responsible for and competent to measure manual work?	Yes
	14	Has the first line manager knowledge about the work to lead improvement actions?	Yes
	15	Is there a competence development plan?	No
Cleanliness and order	16	Have all material, tools etc. fixed positions and is everything in place when not used?	Yes
	17	Is there enough space around the workplace to move all materials as planned?	Yes
	18	Are the floor and other surfaces free from waste material, scrap products etc.?	Yes
Material handling	19	Are the load carriers (pallets etc.) adapted to the components?	Yes
	20	Does the batch size correspond to the delivery pace?	Yes
	21	Is the same load carrier used for a component as far as possible?	Yes
	22	Is material stored close to the point of use?	Yes
	23	Is the shop independent of trucks, cranes etc. to move the material?	Yes
Changeover	24	Are changeover times measured?	No
	25	Is there a continuous effort to reduce changeover time in the bottleneck?	Yes
	26	Are tools, fixture etc. stored close to where they are used?	Yes
Continuous improvements	27	Is the continuous improvement work carried out systematically, and is it documented and visualized?	Yes
	28	Are the workers engaged in the improvement work?	No
	29	Has the management a realistic idea about the productivity potential?	Yes
	30	Is knowledge from previous development projects used systematically?	Yes
Calculations	31	Are investment calculations revised?	Yes
	32	Are product calculations revised?	Yes
Planning	33	Is the ideal cycle time known and is it based on facts?	Yes
	34	Are real operation times reported to the planning system?	No
	35	Are the operation times in the planning system updated based on the real operation times?	Yes
	36	Is the production planned according to pull principle when possible?	No
	37	Are lead times measured in order to reduce them?	Yes
Quality	38	Is there a standardized quality system in use (e.g. ISO 9001)?	Yes
	39	Is the single operator responsible for the quality of his/her own work?	Yes

40	Are the systematic methods used to eliminate the occurrence of errors?	No

Appendix 2: Management development course

	THURSDAY 21. JANUARY
Kl. 08.30	**Welcome speech and introduction** with CEO Olav Holst-Dyrnes Ekornes 2020 and Lean
Kl. 08.45	**Status for Lean work** at departments that have started with managers and lean coordinators
Kl. 10.00	Breakfast
Kl. 10.20	Presentation of status for Lean work continues
Kl. 11.20	**Information flow in Lean** with operations engineer Arne Christian Jensen
Kl. 11.50	Break
Kl. 12.00	**Strategic A3 for the improvement network** with operations engineer Bernt Inge Tandstad
Kl. 12.30	Lunch
Kl. 13.15	**A3-training in groups** with Bernt ing and the lean coordinators
	FRIDAY 22. JANUARY
Kl. 08.30	**From words to action** with Niklas Modig **To understand a Lean business strategy** • How to develop a common strategy • How to understand a lean business strategy • Why is the lean impetus behind increased competitiveness, productivity and profitability? • What entail a lean business strategy? • Why create flow through the whole value chain? **To implement a Lean business strategy** • How to develop a business strategy- situation now, wanted situation, critical changes and flow of implementation • How can we realize a scheduling of the business strategy, routines, progress control, escalations and continuous follow up? • The managers role and lean leadership • How to develop a lean culture
Kl. 15.45	Summary with CEO Olav Holst-Dyrnes
Kl. 16.00	Course ending

Appendix 3: Research paper

Linking level 1 and 4 of the PPA Method with Lean Tools

Abstract

The research paper aims to investigate and analyze the opportunity to link level 1 and 4 in the PPA method with an A3 report instead of the PPA method's level 2 and 3.

Keywords

PPA, A3 reports, Lean Manufacturing, Root cause analysis, productivity improvement

Introduction

"The productivity of a company is an important factor for its success in the fierce competition on the global market" (Almström & Kinnander, 2011, p. 758) and for its competitiveness on a corporate level (Almström, 2012). As more and more production is being outsourced abroad it is crucial that the actual productivity and the productivity potential at Norwegian factories are investigated and compared to keep improving manufacturing methods and to keep Norwegian companies competitive.

1 PPA

The productivity potential assessment (PPA) method is a Swedish method developed to counter the strong outsourcing trend in Swedish industry (Almström & Kinnander, 2011) and is a tool used to investigate and assess a company's productivity potential.

"The development of the PPA Method started in spring 2005, through an initiative from the Swedish Agency for Economic and Regional Growth (Nutek). The challenge from Nutek was to prove the thesis that there is a large potential for productivity improvement at the factory floor level" (Almström & Kinnander, 2011, p. 761).

The PPA Method is divided into parameters of different levels where "level 1 is the core of the method, constituting two parameters for measuring utilization in manual work and machine work respectively. Level 2 parameters affect productivity at the corporate level, while 3 parameters indicate the company's ability to improve the production while maintaining a sound work environment" (Almström & Kinnander, 2011, p. 761).

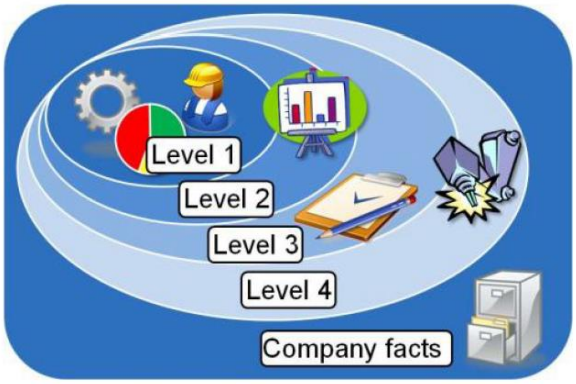

Figure 1. The levels in PPA (Almström & Kinnander, 2011)

1.1 PPA level 1

The measuring technique for manual work in PPA is work sampling where the analyst measures random objectives at fixed time intervals of 30 seconds (Almström & Kinnander, 2011). The general categories for the PPA work sampling are:

1) Value adding activities
2) Supporting activities
3) Not value adding activities

These general categories must be pre-defined heading into the real study. A pre-study is therefore preferable.

The observation method in the level 1 parameter of the PPA method is structured observations. Structured observations are quantitative and are used to investigate;

1) in what frequency the production team do what they do;
2) how much time goes to the PPA method's respective general categories; and
3) if there are any lean tools fit to eliminate waste

1.2 PPA level 4

"Level 4 i.e. productivity increase through method improvement, is not a formal part of the PPA method." (Almström & Kinnander, 2011). However, it is always discussed in a PPA study. There are several reasons why level 4 is not a formal part of the PPA method;

1) improvement potential cannot be fetched in one parameter,
2) variation in researcher's experience,
3) rough estimations as basis for the potential calculations
   - it is hard to find acceptable measures,
4) comprehensive analysis is required.

Productivity improvements can be achieved through the improvement of work methods, investments in new technology, introduction of lean tools etc.

2 A3 report

Documentation of complex problem solving processes has been targeted by Toyota and one of their clever results is something they call the "A3 report". The reason for the A3 format is that there was a lot of communication across various sites in Toyota and the A3 format was the largest paper size corresponding with a fax machine (Liker & Meier, 2006). According to Wig (2016) the problem solving A3 analysis is used to front improvement work regarding quality, cost, delivery, HSE, logistics, productivity etc. and as Liker & Meier (2006) argues, the A3 reports are not reports, but are used to tell a story with a beginning, middle and end. According to Liker & Meier (2006) there are three distinct stages in problem-solving A3 reports; *proposal* stage, *status reporting* stage and *final reporting* stage.

At the *proposal* stage the A3 reports are proposal stories where the goal is to gain acceptance and approval of the proposed countermeasures (Liker & Meier, 2006).

When there is a common understanding and approval of the investigated concepts the A3 reports changes format to the *status reporting* stage. The goal in this stage is to report and update others regarding the activity and the scheduled progress. The completeness of thinking is also being questioned in order to control the need of resources to stay on schedule (Liker & Meier, 2006).

When the countermeasures have eliminated the problem the A3 reports changes format to the *final reporting* stage. The purpose of this stage is to acknowledge the activity, the successful implementation and the team's or individual's success (Liker & Meier, 2006).

A typical A3 tells a story through these stages;

1) situation now, background;
2) wanted situation;
3) analysis;
4) action; choices and measures;
5) what measures; and
6) evaluation, standardization and learning

3 Root cause analysis

According to Wilson (2015), Bellgran & Säfsten (2010) the TPS is where one can find the origin of lean manufacturing. “Lean production applies and develops the pioneering ideas from Toyota’s Production System about reduction of waste and added value” (Bellgran & Säfsten, 2010). The TPS’s approach toward root cause analysis are the 5 whys, which is a great tool to be used as a part in an A3 report.

3.1 5 whys

The 5 whys is a root cause analysis where the researcher questions the addressed problem five times in order to anwer the why-questions “because…”. This has shown itself to be a severely effective root cause analysis where one can get to the root cause in a matter of minutes.

4 A3 reports as link between level 1 and 4 in PPA

As the PPA method is today, the 4th level of the method is not a formal part of the study because comprehensive studies are needed for improvement work and the fact that the researcher’s level of experience can contaminate the resulting improvement measures.

The link between level 1 and 4 in PPA are level 2 and 3. Level 2 and 3 mainly withstand of the company’s common KPIs and its level of production engineering together with an assessment of its work environment. The question is, can this link be substituted by an A3 report as in Figure 2?

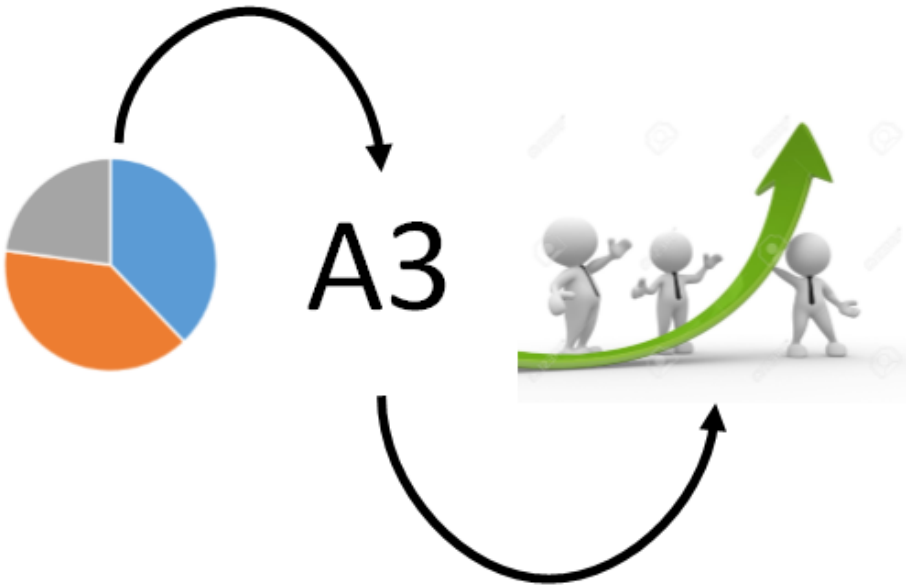

Figure 2. A3 as link between work sampling and method improvement

Identify the problem and through an A3 report some improvement measures will reveal themselves.

According to Vartdal (2016) the results from a work sampling study executed at Ekornes, a Norwegian furniture manufacturing company, their sewing department's activity distribution were shown as in Figure 3.

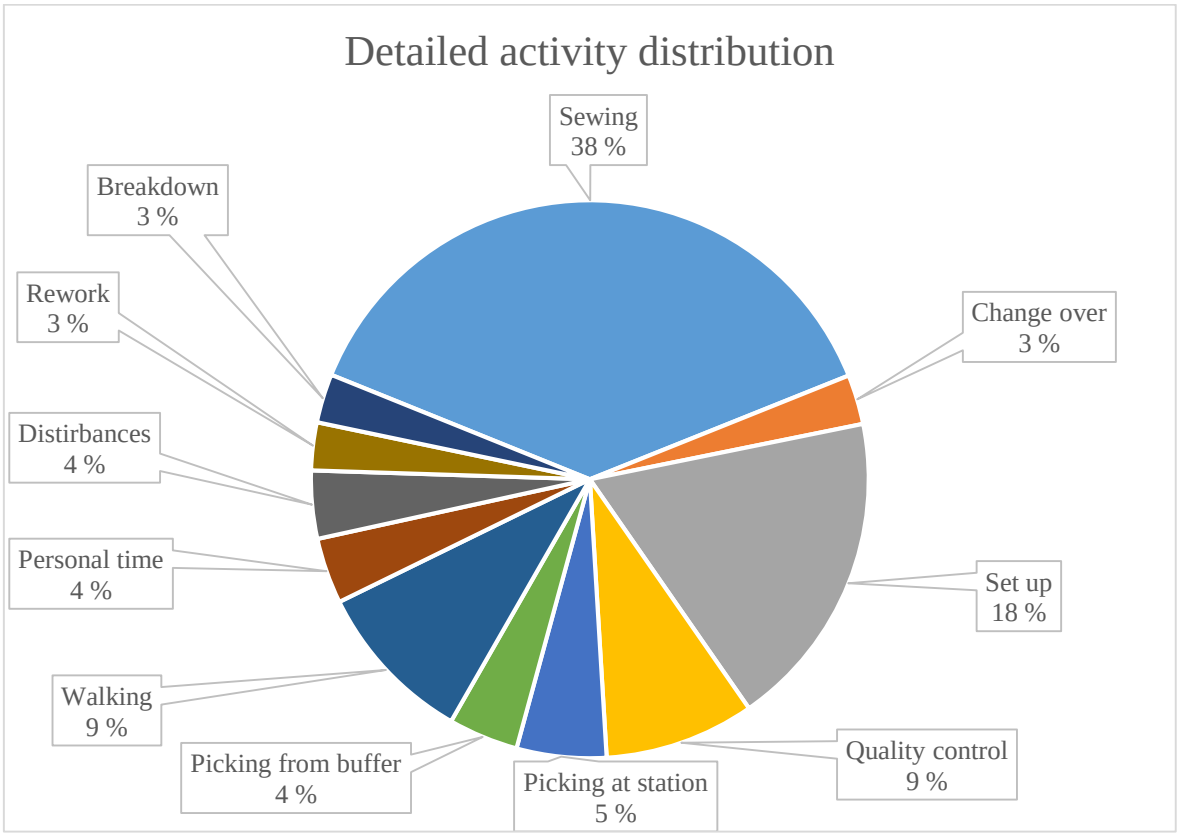

Figure 3. Work sampling study at Ekornes' sewing department (Vartdal, 2016)

An A3 report generated from only the work sampling study (Figure 3) could have the title: "Breakdowns in the sewing department". The researcher would know the problems related to the breakdowns because of his/her observations during the work sampling study, and would be able to form an analysis part and state a hypothesis to test. With a stated hypothesis a list of improvement measures must be generated and scored in a matrix where the x-axis shows how easy the improvement measure is to implement and the y-axis shows how effective the improvement measure will be as a problem solver (Vartdal, 2016). When the improvement measure(s) with the highest score are located the PPA level 4 can be initiated in order to improve productivity.

5 Conclusion

In order to be an objective researcher and link level 1 and level 4 of the PPA with only A3 reports one can end up with improvement measures leading to increased productivity. As the work sampling study is conducted through observations the researcher will know the layout and interfaces at the department being observed. In addition, a work sampling study is a source withstanding of activity distributions triggered by something one can improve. By identifying an activity that should be investigated, the researcher have enough data to proceed with improvement work. However, the PPA level 3 withstands of statements regarding the company's level of production engineering which is a great source to allocate production engineering shortcomings.

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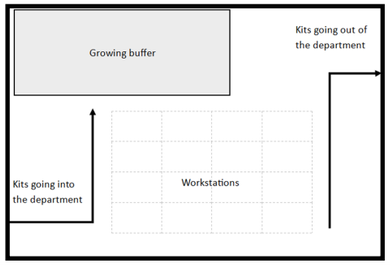
Appendix 4: A3 report: Buffers in production

A3 owner: Andreas Vartdal

Date: 20.03.2016

1. Situation now, background

The buffers in the sewing department are growing faster than they are beeing processed. The large buffers are a problem that have been going on for years. There is a lot of frustration in the sewing department regarding the large buffers and wether or not the operators are doing their best.



2. Wanted situation

Smaller buffers and higher level of buffer control

More flow in parts and products.

Replace the fustration and mistrust with a pleasant work environment where everyone contributes to the common good for the company.

Reduce number of kits in buffers to withstand of minimum 1 kit and maximum 10 kits.

3. Analysis

Analysis:

The operators are doing their best to process the kits in the buffer, but the system makes it almoust impossible to succeed.
The skin department are producing too many kits to the skidding system. This binds capital to products that are staying unfinished in stocks.

Hypothesis:

The fact that the operators in the sewing department are working as fast and good as they can makes it unreasonable to do something about their performance.
The fact that the operators in the sewing department does not succeed in processing the large and growing buffer can be solved by introducing a KANBAN SYSTEM, by increasing their manpower or by improving «Aqua Lene»'s productivity and boundaries.
The fact that the skin department are over-producing kits and the buffers are growing because of that, this can be solved by reducing the manpower in the skin department.
To implement a multi competence team can contribute to improve productivity in departments where it is needed on demand. By training operators from the skin department into the multi competence team instead of terminating their operators, this will contribute to the shrinking of the buffers.

4. Action: Choises and measures

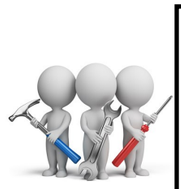
Manpower reduction in skin department

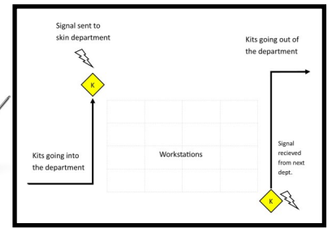
Manpower increase in sewing department

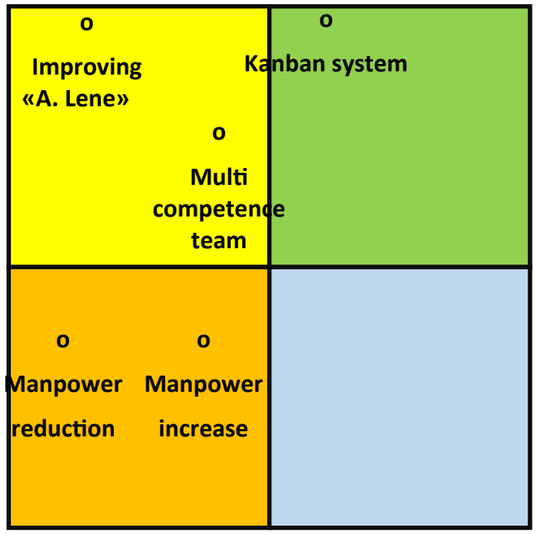
Implement a multi competence team

Improving «Aqua Lene»

Implement a KANBAN SYSTEM







5. What Measures	How implement?	Where?	Who is responsible?	When?
Redefine kits	Mark pallets to fit the KANBAN system	Skin-, sewing– and assembly dept.	A.V	ASAP
Train operators	IT department Management	Skin-, sewing– and assembly dept.	A.V	ASAP
Implement KANBAN	IT department	Sewing department	A.V	01.08.2016
Measure trends	Gather data	Skin-, sewing– and assembly dept.	A.V	01.09.2016

6. Evaluation, standardization and learning

Appendix 5: A3 report: Teamwork in sewing department

A3 owner: Andreas Vartdal

Date: 01.04.2016

1. Situation now, background

Operators are working in «lean teams» of up to 20 operators, including a table manager.
The operators are working for themselves, and are cheating on the date system in the buffer.
There is no teamwork observed

2. Wanted situation

Increased teamwork.

A more lean department.

Replace the fustration and mistrust with a pleasant work environment where everyone contributes to the common good for the company.

3. Analysis

Analysis:

The payroll system (piecework system) kills the teamwork philosophy by separating the individual from the team. This makes it impossible to develop a teamwork environment between the «lean team» members.

The piecework system tempts the workers to cheat on the date system and grab the kits that gives them more money per seat produced. This kicks up the fustration between «lean-team» members and to their managers.

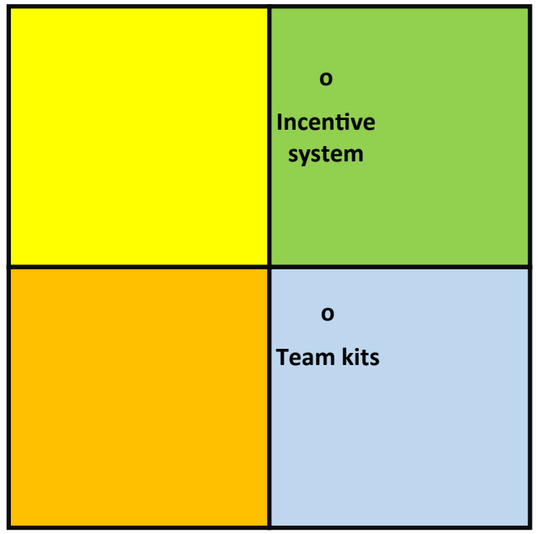
Hypothesis:

The fact that the operators in the sewing department are already put together in teams gives us a good fundation to form teams with teamwork as a key component.
The fact that the piecework system singles out the individ, rather than contributing to teamwork and that it tempts the operators to cheat on the date system can be solved by changing an INCENTIVE SYSTEM, or TEAM KITS (2-3 persons working together on one kit).

4. Action: Choises and measures

Implement an INCENTIVE SYSTEM

Implement TEAM KITS



5. What Measures	How implement?	Where?	Who is responsible?	When?
Define KPI's	Management	Ekornes	A.V	ASAP
Inform operators	Management	Skin-, sewing– and assembly dept.	A.V	ASAP
Implement insentive system	IT department Management	Skin-, sewing– and assembly dept.	A.V	01.06.2016
Measure trends	Gather data	Skin-, sewing– and assembly dept.	A.V	01.07.2016

6. Evaluation, standardization and learning