SAVONIA

OPINNÄYTETYÖ - **AMMATTIKORKEAKOULUTUTKINTO**
TEKNIIKAN JA LIIKENTEEN ALA

STANDARD OPERATING PROCEDURES, PREVENTIVE MAINTENANCE AND LAYERED PROCESS AUDITS

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SAVONIA-AMMATTIKORKEAKOULU

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Tiivistelmä

Tämän opinnäytetyön toimeksiantaja on ovia päätuotteena valmistava JELD-WEN Suomi Oy Kuopion yksikkö. Työ liittyy yrityksen kehityssuunnitelmaan ja sen tavoitteena oli saada yksinkertainen toiminta- (SOP) ja ennakkohuolto-ohjedokumentti jokaiselle valmistusprosessin työpisteelle sekä suunnitella systemaattinen tuotannon LPA-auditointijärjestelmä.

Opinnäytetyön tuloksena luotujen dokumenttien tarkoituksena on osaltaan parantaa tuotteiden laatua, työpisteiden turvallisuutta ja valmistusprosessien tuottavuutta. Suunniteltujen ohjeiden ja dokumenttien kehitystyössä hyödynnettiin LEAN-filosofian periaatteita sekä menetelmiä ja niiden mallina käytettiin JELD-WEN Vääksyn tehtaan käytössä olevaa prosessikuvausmallia.

Työ toteutettiin luomalla SOP- ja ennakkohuoltopohja Vääksyn tehtaalta saadusta prosessikuvausmallista. SOP-ohjeet luotiin jokaiselle työpisteelle (44kpl) haastattelemalla työntekijöitä, havainnoimmalla tärkeimmät työvaiheet ja tekijät sekä ottamalla valokuvia työvaiheista. Ennakkohuolto-ohjeen pohja luotiin samasta prosessikuvausmallista kuin SOP ja käyttämällä aikaisempaa tietoa, jonka JELD-WEN Kuopio oli jo kerännyt.

Valmiit SOP - ja ennakkohuolto-ohjeet kiinnitettiin työpisteiden info-tauluille ja tallennettiin yrityksen omaan tietokantaan. Dokumentit ovat helposti muokattavissa yrityksen tietokannasta käsin.

JELD-WEN Kuopio oli tyytyväinen lopputulokseen. Nämä parannukset ovat lisänneet tuottavuutta, työntekijöiden osaamista ja tietotaitoa sekä vähentäneet koneiden rikkoontumista. Ohjeet ovat myös parantaneet yrityksen imagoa.

Avainsanat
Standard Operating Procedure (SOP), Layered Process Audits (LPA), Preventive Maintenance (PM)

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

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Abstract

This final thesis subject came from JELD-WEN Kuopio which was going through improvements inside the company. Their need was to have a simple SOP and PM sheets for every workstation and LPA auditing system for their factory. These would help the employees how to operate and maintain different processes and machines.

The objective was to develop SOP, PM and LPA systems by exploiting the principles and procedures of LEAN philosophy.

The task was executed by creating a new template for SOP and PM from the process description model which came from JELD-WEN factory in Vääksy. From those templates a simple SOP sheet was created for every workstation (altogether 44 ones) by interviewing the employees who worked in those workstations, writing down the unit operations and taking photos of every operation within those workstations. A PM sheet was also created from the same process description model and by using the previous information that JELD-WEN already had on certain workstations and machines.

The finished SOP and PM sheets were put available on the information board of each workstation and on the company's own database. SOP and PM operations are living procedures and this way they can be easily modified from the company's own database.

JELD-WEN Kuopio was satisfied with the results. These improvements have increased their productivity, know-how and capability of operators and decreased machine breakdowns. The sheets that can be viewed on information boards have also upgraded their factory image.

Keywords
Standard Operating Procedure (SOP), Layered Process Audits (LPA), Preventive Maintenance (PM)

PREWORDS

We would like to thank the whole JELD-WEN Kuopio for this opportunity to do our thesis for them, without forgetting the manager, Esko Ovaskainen (Factory Manager) and all the employees for such a warm welcome to their facility and introducing their work stations to us with such a positive attitude. We would also like to thank our instructing teachers, Jarmo Pyysalo (Principal Lecturer) and Kai Kärkkäinen (RDI Adviser) in Savonia University of Applied Sciences for their guidance and insight during this engineer work.

This project started in November 2016 when we inquired about possible project that JELD-WEN Kuopio might have for us. The project proceeded with meetings with company managers where we decided and defined the actual engineer work topic and timetable. Project officially started on the 2nd of January 2017.

Kuopio 20.5.2017

Petri Valtanen & Pete Perälä

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ABBREVIATIONS AND DEFINITIONS

SOP = Standard Operating Procedure

LPA = Layered Process Audits

PM = Preventive Maintenance

TPM = Total Productive Maintenance

LEAN = Operation Strategy

5S = Method used with lean (Sort, Set in order, Shine, Standardize, Sustain)

JIT = Just-In-Time

TPS = Toyota Production System

Bottleneck = Phenomenon where system or machine is over capacitated and has too much workload to work properly

SQDCI = Safety, Quality, Delivery, Cost, Inventory

JEM = JELD-WEN EXCELLENCE MODEL

OEE = Overall Equipment Efficiency

TQC = Total Quality Control

TQM = Total Quality Management

1 INTRODUCTION

This final thesis subject came from JELD-WEN Kuopio and it is current because the company is going through developments to pursue better quality management system and lean manufacturing. Main purpose of this development project is to create unified visual operating procedures to every workstation.

The second goal is to improve their existing Preventive Maintenance program and research Layered Process Audit and Preventive Maintenance impact to 5S applying lean principles and especially 5S.

To understand how our research and development work is connected to increasing productivity and LEAN 5S, it's important to know the principle of LEAN in its simplicity. What every manufacturing facility drives to in their operations is increasing productivity and reducing no-value adding and time consuming functions from the operations. This is the fundamental idea which LEAN quality management principle pursues in its theory.

The main phases of this project were enquiring and interviewing the employees in different work stations and creating simple but formal standard work and preventive maintenance sheets.

The work in the company was done as pair work and the research and theory work was divided in the following way. Petri Valtanen researched SOP (Standard Operating Procedure) and its connections to 5S factors and productivity. Pete Perälä researched the impacts of LPA (Layered Process Audits) and Preventive Maintenance on the same 5S factors.

These topics are connected to LEAN principles and it is the foundation during our research work.

2 LEAN PRINCIPLES

Lean method is a management and operation strategy used mostly in industrial fields, but nowadays many other organizations from different fields are also adjusting their strategy to lean. Lean was created from Toyota Production System, which is Toyota's own production philosophy and it concentrated on transparency within the company and Just-In-Time method by keeping their storages empty and manufacturing only when customer makes an order. It's important to realize that even though LEAN and TPS (Toyota Production System) have many similarities, they are not the same concept. (Modig & Åhlström, 2013.)

The concept LEAN production was introduced to the world first time in 1988 in John Krafcikis article "Triumph of Lean production systems", which was published in Sloan Management Review paper. The article compared different car manufacturers productive levels and two production system; sturdy and fragile. (Modig & Åhlström, 2013, 78-79.)

Krafcik crushed the myth which said that productivity can only be achieved by scale advantages and hi-tech solutions (sturdy production system). Instead he pointed out that Toyota factories that have small inventories and small buffers and simple technique (fragile production system), could guarantee good productivity and excellent quality. He thought that the word fragile had a negative tone, therefore he decided to give this effective production system the name "lean". (Modig & Åhlström, 2013, 78-79.)

The main reason for using LEAN method is to increase flow efficiency, preferably so that resource efficiency does not suffer. Lean method is an improvement tool where the goal is to control and reduce variation within the company or operations and therefore reduce throughput time.

Important is to reach for the star and proceed towards the star by moving right and up on the efficiency matrix like the following figure below shows (FIGURE 1.)

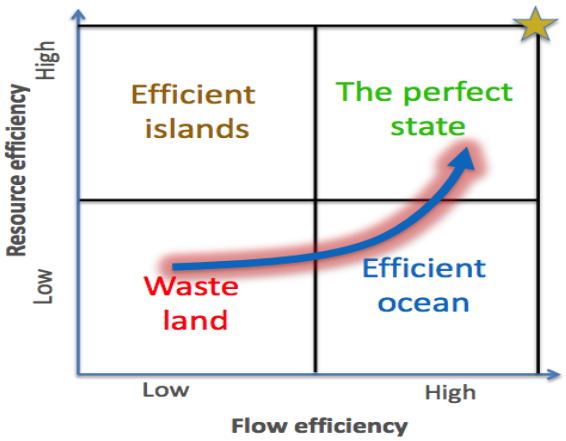


FIGURE 1. Resource- and Flow efficiency matrix (Lean Sanomat)

Concentrating on flow efficiency, organization can reduce extra labor and free unnecessary loss. When extra labor and loss is reduced, resource efficiency may grow, which lifts the organization upwards in the matrix. Lean operation strategy always highlights the flow efficiency instead of resource efficiency (Modig & Åhlström, 2013, pp. 123-125).

Standardizing every operation within the company helps reduce unnecessary actions within different operations. It also helps reduce waste and reduce throughput time and therefore lower costs when every work station has clear and simple instructions on how to operate in certain work station. When company has made standardizations for operations, it is easy to aim for continuous improvements if variations still happen alarmingly. Standardization also helps company to be more transparent. If a problem occurs, the reason can be found rather fast and be fixed. The questions that are necessary when problem occurs are such as: did the employee follow the standardized instructions, did he /she wear the necessary safety gear or are there some steps that are not working well in the operation.

2.1 JUST-IN-TIME (JIT)

Just-in-time is a system for companies that want to achieve the best quality, cost and delivery of products. This is done by eliminating unnecessary waste inside company's processes and by delivering the products just-in-time to the customers so that the products fill the desired requirements. (Imai, 1997, 145.)

Jidhoka, which is an essential part in JIT, comes from the Japanese word "autonomation". Idea of Jidhoka is that every machine would have a device that stops its functions if defected product is produced. (Imai, 1997, 145.)

JIT method is also known as Toyota Production System, Lean production and Kanban System. (Imai, 1997, 145.)

JIT consist three systems that the company needs for the JIT to work. They are TQC/TQM, TPM and just-in time production. (Imai, 1997, 145.)

1. **Total Quality Control (TQC) / Total Quality Management (TQM)**

   TQS aims to involve employees and managers in every level for continuous improvements on quality. The improvements and efforts to advance quality are assumed to lead more satisfying customers and success of business. (Imai, 1997, 145.)

2. **Total Productive Maintenance (TPM)**

   TPM focuses on maximizing the effectiveness of equipment and increasing their life-cycle. TPM aims for zero breakdowns and decreasing accidents. (Imai, 1997, 145.)

3. **Just-In-Time production**

   While TQC focuses on overall quality and TPM to the quality of equipment, JIT focuses on cost and delivery. It needs to be taken into account that JIT system requires TPM and TQC systems before introducing JIT system. (Imai, 1997.)

   JIT system is a ground-breaking method to reduce costs and to meet the customer's delivery needs. (Imai, 1997, 145.)

2.1.1 5S

"Another method often used to connect to LEAN is 5S (Sort, Set in Order, Shine, Standardize and Sustain). 5S in simple terms means that the right thing needs to be in its rightful place. Many organizations start using 5S method to create well organized and functional workplace. Well organized workplaces reduce variation, which arises easily if necessary things to operate needs finding longer than it's supposed to. (Modig & Åhlström, 2013, 144.)"

"5S method was developed in Japan it aims for workplace standardization. A well-organized workplace motivates people, improves safety, work efficiency, improves productivity and establishes a sense of ownership." (Plant Maintenance)

"Impact of 5S implementation reduce inventory, efficient on workplace usage, reduce time for searching spare part, reduce waste, reduce unstabilization, preventive of machine function, cleaning & checking machine condition, improve working condition, reduce work accident, increase discipline, follow procedure, and better relationship among employee." (Plant Maintenance)

Mahalik describes each 5S in a following way:
With Sorting, all the unnecessary goods will be removed. This releases space and removes broken or unnecessary tools which are stored just in case that someone would sometime need them. (Mahalik.)

Set in Order attempts to find good storing methods such as defining workplace areas, making clear and empty hallways and adding trashcans. (Mahalik)

Shine aims for cleaning of every work station on daily basis. (Mahalik)

Standardize aims to standardize the best methods of the workplace with employees. Deciding which tools are essential for certain workplace and how the cleaning of the work place will be carried out. (Mahalik.)

Sustain makes sure that appointed methods will be followed when all the unnecessary goods and tools have been removed and their repository has been decided. (Mahalik)

2.1.2 Total Productive Maintenance (TPM)

TPM focuses on maximizing the effectiveness of the equipment through its lifespan. TPM requires every department and employees on every level for it to work properly. (Imai, 1997.)

TPM also aims for motivating people for plant maintenance by using small groups, developing maintenance system, making introductions for keeping the workplaces clean, and problem-solving skills. (Imai, 1997.)

The ultimate goal of TPM is to have zero breakdowns and decrease accidents in workplaces. (Imai, 1997.)

Scheduled maintenances for the equipment are a crucial element in TPM and the maintenances should be done by employees. (Imai, 1997.)

5S is considered to be an entry step for TPM system. (Imai, 1997.)

2.1.3 Standardized Work

Standardized work is the best combination of employees, machines and materials. Standardized work contains three elements that are 1) the theoretical time to produce the product that is ordered by the customer, 2) work sequence and 3) standard work-in-progress. (Imai, 1997.)

Standardized work is one part of 5S method which defines what tools are the best for operating and completing different tasks and how to perform the cleaning of the workplace. (Imai, 1997.)

2.1.4 Six big losses

Six big losses is a part of TPM and OEE (Overall Equipment Efficiency) and one of their main targets is to reduce the six big losses within company.

The six big losses are generally defined as follows:

1. **Equipment/machine failure**
   Equipment or machine failure is defined for great period of time in which the machine is scheduled to be in use but due the failure it is not running. Equipment or machine failure is also generally mentioned as "down time" or "unplanned stop". (Vorne Industries Inc, 2002-2016.)

   The most common equipment failures are referred as tooling failure, breakdowns and unplanned maintenances. (Vorne Industries Inc, 2002-2016.)

2. **Setup and Adjustments**
   Setup and adjustments as a big loss mean that the equipment or machine is supposed to be in production but is "down" because of the changeover or possible equipment adjustments. (Vorne Industries Inc, 2002-2016.)

   Most common reasons for setup and adjustments are changeovers and major adjustments that need to be done to the machine or equipment. Those adjustments require cleaning, warmup time, planned maintenance and quality inspections that take time before the machine is ready to be operated. That time always reduce the products being produced. (Vorne Industries Inc, 2002-2016.)

3. **Idling and minor stops**
   Idling and minor stops mean that the machinery or equipment is unusable for a short period of time. A short period of time is considered to be few minutes. (Vorne Industries Inc, 2002-2016.)

The most common idling stops are usually caused by misfeeds, material jams, obstructed product flow, incorrect settings, blocked sensors, equipment desing issues and periodic quick cleaning. (Vorne Industries Inc, 2002-2016.)

Idling and minor stops does not usually require maintenance personnel to solve this problem. (Vorne Industries Inc, 2002-2016.)

4. Reduced Speed

Reduced speed means that the machine or equipment is running slower than "normal". (Vorne Industries Inc, 2002-2016.)

Reduced speed is a performance loss and is also known as slow cycles. (Vorne Industries Inc, 2002-2016.)

The common reasons for machine or equipment to run slower than usually are dirty or worn out equipment, poor lubrication, substandard materials, bad environmental conditions, users lack of experience, startup and shutdown times. (Vorne Industries Inc, 2002-2016.)

5. Process Defects

Process defects refer that there are defected parts being produced during normal production. Reasons for this are scrapped parts and parts that need to be reworked. (Vorne Industries Inc, 2002-2016.)

Main reasons for causing defects are incorrect settings and users handling errors. (Vorne Industries Inc, 2002-2016.)

6. Reduced Yield

Reduced yields mean that machine has produced defected parts between startup and normal production speed. Reduced yields also happen because of scrapped parts or products that need to be reworked. Loss can occur after equipment startup, but it's mostly detected after changeovers. (Vorne Industries Inc, 2002-2016)

Reasons for reduced yields abnormal changeover, incorrect settings when parts are run, too short warmup times or due waste that is produced after startup. (Vorne Industries Inc, 2002-2016.)

2.2 Connections to SOP, LPA and PM

As mentioned in the earlier chapters, LEAN is a tool of continuous improvement which concentrates on increasing flow-efficiency without reducing resource efficiency by controlling and reducing variation in the production and reducing throughput time.

5S aims for well-organized workplaces, safety and productivity by reducing inventory, waste, and accidents and by increasing workplace efficiency and work conditions. By keeping the workplaces and machines clean and free from debris ensures machines to function correctly.

SOP, LPA and PM are linked in to all previously mentioned LEAN methods in various ways. Here are few examples, how they are connected.

- **SOP**
  SOP reduces variation occurred in processes by standardizing workplace operations so that every employee performs their tasks the same way correctly and with safety. This way SOP also reduces throughput time of product in production lines and increases flow-efficiency.

  SOP makes the workplace more organized which supports the 5S method which aims for advancing work conditions.

  It reduces waste in materials and increases workplace efficiency when the operations are done correctly the first time, there is no need for extra labor and therefore no additional material is used.

- **LPA**
  LPA is a management tool, which helps to monitor and ensure workplaces, machines and processes are operated correctly. The aim is to prevent variations in processes.

  LPA is an important tool for ensuring the continuance of 5S sectors and is closely tied to the fifth S – Sustain, which prevents the company's LEAN improvement from sliding back to the old methods.

  LPA is part of continuous improvement and is based on PDCA function (plan-do-check-act).

- **PM**

  Preventive Maintenance is a part sector in TPM and has influence in variation and throughput time, by preventing the malfunctions of machinery.

  Therefore PM also increases workplace efficiency and decreases accidents, when ensuring that machines are maintained and check regularly.

  By creating preventive maintenance program and schedule, the actions become standardized and are therefore supporting the 5S method.

3 STANDARD OPERATING PROCEDURE

3.1 Overview

Standard operating procedure is a tool for controlling company's operations to reach the desired outcome of products and services. SOPs are in its simplicity written documents from which employees can check step-by-step what is the next task in his/her workstation. (bizmanualz, 2017.)

SOP's main objective is to help employees to perform their job with routine and certainty and they also ease to achieve better and required quality of products and end-results. (EPA, 2007, 6.)

A well-written SOP can be used to satisfy compliance requirements and are recommended for all procedures that pose a potential risk to the health and safety of personnel. (SOP.)

Standard operating procedures allows company to operationalize documents such as plans, regulation, compliance and policies. (SOP.)

SOP's should be made into format that they can be used by staff members in their work environment. SOP's should be the basis of everyday training Programme of every employee. Standard operating procedures should be often updated or checked to ensure the realization of conditions and the working practice. (SOP.)

3.2 Purpose of Standard Operating Procedure

Creating and implementing as accurate SOP's as possible has many benefits in company's operations, turnout and making every employee working habits more routine. When employees follow the accurate and acceptable steps in SOP, it has impacts on costs, inventory, delivery, safety and quality. Following SOP's in everyday work also reduces expenses, variation and throughput time that therefore increases productivity for every work station and facility. (EPA, Environmental Protection Agency, 2007, 6.)

Poorly written SOP's offer only limited amount of value in operations and even the best created SOPs will fail if the employees do not follow the proper step-by-step functions mentioned in SOP. Therefore, it is important to review the SOPs with the management and supervisors before implementing them. (EPA, Environmental Protection Agency, 2007, 6.)

The idea of having SOPs is to make better company's efficiency. SOPs may have been created for regulatory reasons as part of compliance. Having SOPs also protects the employees when those instructions about safety are followed through in every action. Procedures and instructions protect the customers as well, when SOPs are being followed. SOPs ensure that every product is done accord-

ing the same principle, which diminishes variation such as defects, improves quality and improves throughput time. Therefore, the customer gets the right product and on-time. (bizmanualz, 2017.)

3.3 Benefits of Standard Operating Procedure

Use of SOP within organization is a continuing progress for developing end-results of products. Developing and implementing SOPs in operations minimizes variation and advances quality even if the personnel changes are temporary or permanent. Therefore, SOPs can also be used as a part of personnel training in addition that they are in continuing use in work stations, since well-written SOPs provides accurate steps on how to perform certain tasks. Following the SOP reduces miscommunication. Employees know what to do all the time and therefore there is not so much time used in consulting a foreman if an error occurs. Employees can prevent or fix the problem on their own. This increases employee's own time of work and can be as productive as possible in his/her own workstation. (EPA, Environmental Protection Agency, 2007, 6-7.)

SOPs also reduce work effort, extra work, costs and has significant positive impacts on delivery, safety issues and throughput time. (EPA, Environmental Protection Agency, 2007, 6-7.)

3.3.1 Costs

Following the steps mentioned in SOP reduces costs in a following ways. Employees know what to do all the time and therefore there is not so much time used in consulting a foreman if an error occurs. Employees can prevent or fix the problem on their own. This increases employee's own time of work and can be as productive as possible in his/her own workstation. Following SOP's initial start-up and the working steps ensures that every machine or tool is set-up and checked properly before starting manufacturing. These simple methods reduce machinery failures and can foretell if certain machinery needs maintenance in a near future. Ensuring that the workstation is workable prevents possible defects in the manufactured product and therefore reduces variation in operations. Defects in a product increases costs, because it often requires extra labor from the employee to fix the defect, increases machine usage time and increases throughput time. It's important to root out the possibility of defects as much as possible, because massive number of defects creates massive costs for the company and may create bottlenecks in the operation system.

3.3.2 Delivery

The SOP impacts on delivery are also related to variations and defects. If proper working methods are not followed it might cause defects or somehow delay in manufacturing the product in its rightful time. Therefore, if product is delayed due defect, which might occur on machinery error, wrong working method etc. The product needs a new load date when to send to customer. This is also extra labor for production planning department to schedule new load date and to production workers to fix the defected product or, in the worst case, make a whole new product that effects the throughput time and causes extra pressure to the production. The most crucial factor in following SOP for the delivery factor is that due to variation the customer might have to wait for its product a

lot longer than expected. This has effects on company reputation, image and customer satisfaction. The customer receives the product late and is not therefore as satisfied as possible.

3.3.3 Safety

Every SOP needs to contain safety factor that indicates what kind of safety gear must be used in operating machines and work stations, also what hazards certain work station might hold. Including safety hazards and proper safety gear to wear in Standard operating procedures reduces costs and prevents accidents from happening. When the possible hazards of work station are brought forth, the employees can notify those hazards and focus on preventing them from happening.

Every workstation might have some factors that might cause accidents. If the proper instructions are neglected or they don't exist, it might cause accidents to employees. Those accidents cause costs to the company when they need to finance the employee's recovery which are possible doctor visitations or even medical operations and paying the employee's sick leave.

While the regular worker is on sick leave, the company needs to have someone else do his/her job, and this might require hiring new employee, hiring new employee requires introduction and training for this workstation. There is also the case that the new employee is not yet familiar with procedures and might not be as productive as the regular worker is and it effects the productivity. These causes extra costs to the company which could have been easily been avoided by following or having proper safety requirements in Standard operating procedure.

Humans, of course, make mistakes and accidents happen all the time but following the instructions diminishes those accidents and costs to minimum and saves money for the company.

Also, things that needs to be pointed out are storing and waste control. Those areas may contain huge safety issues. When storing products or material the correct steps needs to be followed to ensure that no employee suffers from poorly storage goods. Storing hazards are such as the pile of material falling on someone when the pile is not set correctly to its rightful place.

Many industrial fields also produce waste because of the material they use to create products. Important is to set a rightful way to manage that waste. Where to collect the waste, who should be the one doing that and which way the waste will be taken care of in a safe way. The waste may be harmful to skin, eyes or even for lungs if employee is exposed to the waste for too long without proper safety gear.

Storing and waste control should also have their own SOPs on how to storage the material in a safe and reasonable way to reduce hazardous situations. As well as waste control should need instructions on determining who oversees waste control and how the waste is being taken care of. These actions increase clarity and transparency inside the company and secures employees well-being.

3.4 Preparation of SOP

Procedures (for example, workstations) that require SOPs should be determined by management of certain company and what information the SOPs should contain at least. To get as high-quality SOPs as possible, the individuals that are creating SOPs should have good knowledge about those processes and the whole organizations structure. This would be the most ideal way to get SOPs done. (EPA, Environmental Protection Agency, 2007, 8.)

If the individuals working with SOPs are not so experienced about the processes (for example students), the accomplishments should be monitored regularly by supervisors, management and employees. This also highlights the importance of reviewing and approving of finished SOPs, to guarantee the right steps and high-quality end-result. (EPA, Environmental Protection Agency, 2007, 8.)

SOPs are recommended to be created with small group to ease the work load of working individuals. Finished SOPs should contain limited amount of information about processes within workstation, but that information needs to be as accurate and clear as possible so that even employees with small experience and expertise should be able to understand and perform the steps in SOP. (EPA, Environmental Protection Agency, 2007, 8.)

3.5 SOP Review and Approval

Standard operating procedures should be checked and gone through with personnel that are involved with that SOP for example workstation. These people could be the employees that work in the workstation and the management and supervisors that oversee that area. Getting approval from those people guarantees that every step and fact are correct. (EPA, Environmental Protection Agency, 2007, 8.)

Finalized SOPs should also contain a slot where the approver of those SOPs can write his/her signature. Nowadays SOPs are created with computer so all the information of SOP is in electronical format, therefore also initials of the approver are also valid. Writing initials or signatures in SOP proves that those SOPs are reviewed and approved and supervisors have seen this method being high-quality. (EPA, Environmental Protection Agency, 2007, 8.)

3.6 Controlling the documents

Organizations that are implementing or about to start implementing SOPs into their procedures should have a system how to number and name SOPs. Organizations could divide their operations in for example 5S areas where each area contains certain amount of operations and should be named and numbered so that they are easily recognized. In addition, the SOPs should have dates of SOPs being created and approved, as well as name of the operation and page numbers. (EPA, Environmental Protection Agency, 2007, 9.)

These SOP factors should be installed to the very top of the sheet where they are seen first when starting to read the SOP sheet.

Name of the operation / process	
	Date of SOP: Approval date: Page number: SOP name: Creator name(s): Approver's name:

These factors help to understand which operation is which as well as when the SOP has been made and approved and by whom. If the organization uses synchronized names or ID initials of different operations, it's easy to find the wanted operations (SOP) location from database and inside the factory. The date of SOP tells when the procedures have been updated. The page number also helps the employee to check if he/she has completed all the steps in SOP.

3.7 Guidelines for Technical SOP Text

Technical Standard Operating Procedures can be written to very different means, but mostly they are written to describe an operation or procedure, like JELD-WENs case. Technical SOPs should contain all the important and essential information that is required to operate in certain workstation. Document control information is essential in archiving, locating and understanding what a certain SOP is about. It depends on the procedure and the technical field what kind of information is essential to which SOP. When writing the SOPs, the writer should only use short, understandable and effective sentences when describing a step or safety/quality/cost factor for example. This saves space of SOP and it is much easier and faster for the reader to get the idea.

For industrial companies, such as JELD-WEN Kuopio, the logic and guidelines for essential functions of Standard Operating Procedure comes from JELD-WENs top management and experts. These guidelines were created from JELD-WENs own "JELD-WEN EXCELLENCE MODEL", which is their model for making improvements throughout the company. This model contains topics like Daily Visual Management, Hour-By-Hour Boards, SQDCI Boards, Gemba Walks, Standard Work, Layered Process Audits, Basic Problem Solving, 5S Workplace Organization, Model Area and Helpful Links.

Like the definition of Standard Operating Procedure says, JELD-WEN also aims with their standard work to increase efficiency in a way that ensures safety of the employees and to provide the best quality possible while to maintain on-time-delivery and decrease costs.

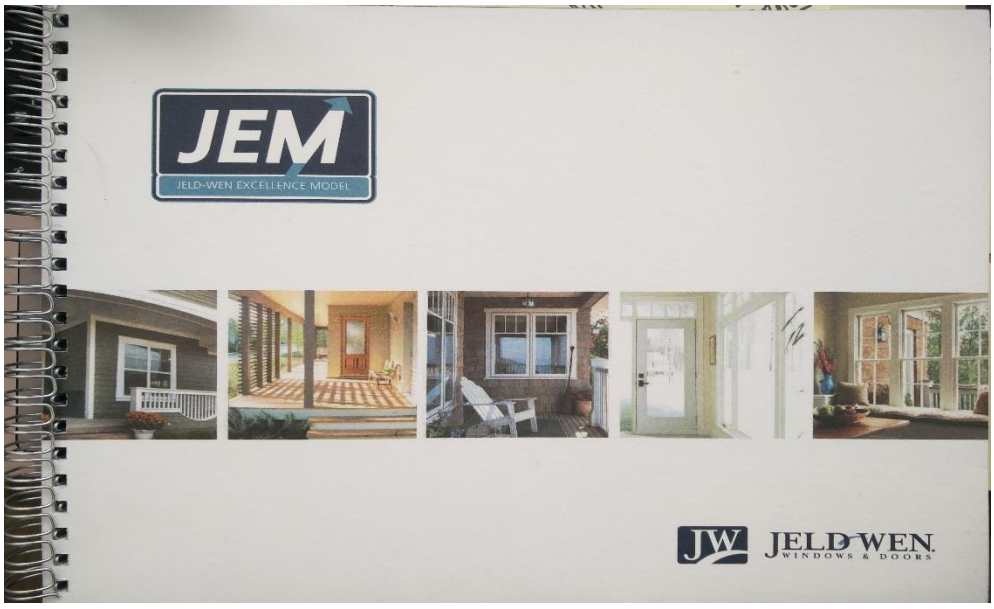


IMAGE 1. JEM, JELD-WEN Excellence Model

The functions and notable information that the SOPs require in JELD-WENs case were put together using this JELD-WEN Excellence Model (IMAGE 1.) and with the co-operation of Vääksy factory's raw model and information that they relayed concerning Standard Operating Procedures. With these information, it was possible put together the most essential functions that the SOPs in their case would need.

A proper standard operating procedure for industrial fields should contain steps like:

- **Initial start-up**
  What needs to be done before the actual work can start with safety and properly, such as starting the machines and checking machine and material condition.

- **Normal operations/procedures**
  What regular steps the work station contains that the work is done properly and with safety. Also it tells in which order those steps are to be performed.

- **Emergency shutdown / operations**
  How to react when machines fail or accidents happen.

- **Normal shutdown**
  How to perform safe and right shutdown for machines after the shift.

- **Start-up following turnaround**
  How long does it take to perform certain start-up procedures in work station?

- **Pictures**
  Take pictures of every step to SOP so even not so experienced employee can check what each step mean and is connected to

- **Possible procedure times**
  Possible times of certain steps and whole procedure. This can provide crucial information about throughput time.

- **Consequences of deviation**
  What to do when deviations occur, where to report and what the actions are to correct deviations.

- **Possible hazards of the procedure**
  Point out the possible hazards that might cause accidents and how to prevent them from happening, for example safety gear.

- **Quality factors**
  Steps that might have impact on quality of product should be pointed out. Employees can focus on that step more effectively and make sure no deviations occur or gets past that point.

- **Cost factors**
  Steps that might have impact on costs inside organization should be pointed out. Such as broken materials, machine malfunctions, massive deviations in multiple products.

- **Safety factors**
  Steps that need extra attention from the employees to prevent accidents. Point out what is so hazardous about certain step and how to prevent it.

- **Reporting**
  Possible step in SOP where the employee makes reporting, for example, of quality variations or material loss. (This step can also be done during other steps, for example hourly basis)

- **Clean-up**
  Cleaning up the workstation regularly ensures better and safer work environment. Workstation dirtiness may expedite accidents and machinery malfunctions.

3.8 Summary

By following the accurate and simple visual standard operating procedure, the company increases its productivity, diminishes costs, reduces safety hazards and keeps the customer happy. All these factors that standard operating procedures affect, end's up to costs, productivity and better work environment.

Creating and implementing standard operating procedures in manufacturing facility creates solid picture of the facility and its actions and provides a safer environment for every employee to work. Having standard operation procedures also increases trust among customers and co-operation partners. They know that company has put effort in making their facilities and actions more solid and it gives the image to outsiders that the company knows what it is doing all the time.

While 5S aims for organizing workstations, materials and equipment so that they are safely organized and placed to right locations makes employees work more effectively and with safety. Well organized workstations ensure better end-result and more fluent product movement between workstations. Well-written SOPs instruct the employees to fill these requirements and it has enormous impact on work environment, productivity of the employees, routines and employees spirit to work.

LEAN as an entity aims for increasing flow efficiency so that resource efficiency does not suffer, and therefore it controls and reduces variation, costs and throughput time. SOPs, when properly written and followed, ensure that variations stay minimum and therefore diminishes costs when there are no variations that need to be focused on. The organization saves money when "broken" products do not need any extra effort when it is sent to the customer. There is no need to pay for extra labor and for extra material to get the product done. The most important thing is that the customer gets the right product on time.

4 LAYERED PROCESS AUDITS

4.1 Definitions

Layered = Comes from the word layer: "A sheet, quantity, or thickness of material, typically one of several, covering a surface or body (Oxford Living Dictionaries, 2017)." So, layered means something that consists of various different layers. In this context, it means a group of people composed from various different levels and positions inside a company or an organization.

Process =" Sequence of interdependent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts, etc.) into outputs (BD Dictionary)."

Audit =" The on-site verification activity, such as inspection or examination of a process or quality system to ensure compliance to requirements. An audit can apply to an entire organization or might be specific to a function, process or production step. (American Society for Quality, 2017.)"

Process audit =" A verification that processes are working within established limits. It evaluates an operation or method against predetermined instructions or standards to measure conformance to these standards and the effectiveness of the instructions. (American Society for Quality, 2013.)"

4.2 Overview

Layered Process Audit is a quality tool developed especially for manufacturing management and it is meant for auditing processes and working conditions inside organizations and companies. LPA improves quality and also reduces scrap and customer rejections. The audit is normally carried out by several levels or layers of supervision from a worker to the top management. (Quality System Enhancement, 2017.) It is a continuous system of process examinations based on variance and risk evaluations. It verifies that proper methods, tools and operations are used in a process. (SmartLPA, 2010.) It also helps to recognize gaps and areas of improvement inside organizations in their processes (CEBOS, 2017).

Purpose of LPA is to control and minize possible variation occurred in processes.

This table below (TABLE 1.) gives a good view what Layered Process Audit is and what it isn't.

TABLE 1. What is LPA (Viilanen, 2013)

LPA is	***LPA is not***
Confirmation that processes are followed according plans and instructions.	An Audit of part or product characteristics.
Owned by the group or part of the organization where the audit is performed. For example, Coating or Painting department.	Owned by quality manager.
Auditing performed by multiple different levels of supervision in a certain area.	Performed only by an inspector.
Quick and clear audit consisted of questions that require yes/no answers.	Auditing what requires measuring or testing of products.
A short listing of most important and critical processes, steps and procedures.	A long to-do list of items that have no straight connection to customer satisfaction.
Performed regularly and pre-scheduled.	An audit what is done whenever there is spare time.
Performed on site.	Performed in auditor's office.
An audit which results are revied regurarly in management review.	An audit which results is stored without reviewing.
An audit where any nonconformance is addressed immediately.	An audit where nonconformance is noted and addressed with delay.
Designed especially for processes and procedures.	Designed for machines or equipment.
A method to improve communication between workers and top management	A method that points out the worst workers.
A method which emphasize the connection between procecces and procedures.	A method to show personnel that there is somebody watching them.
An audit of selected processes and work phases.	An audit which replaces ISO 9001 audits.
A method to define and develop corrective actions.	A method to determine which corrective actions can be used.

4.3 Benefits of LPA

Properly implemented layered auditing system is the best way to ensure that processes coherently follow approved standards, reduces waste and rework, improve quality and drive cultural change throughout an organization (Ease Inc., 2017).

There are numerous different kinds of benefits what layered process audits can provide to organizations, such as (CEBOS, 2017; Quality Systems Enhancement, 2017):

- Improvement to communication
- Better efficiency in processes
- Reduction in waste of time and resources
- Prevention of erros and mistakes in operations and processes
- Continuos improvements on every level and across all departments
- Improved stability
- Reduction in variation of production
- Improvement to discipline
- Improvement to overall quality
- Increases employee participation
- Reduction in scrap and waste
- Helps identificate problems

"The benefit of LPA comes from all levels of management constantly emphasizing the importance of quality and variation reduction in every department, every shift, every day. Each audit layer is expressing interest in the work being done, and verifying that the most critical elements are completed correctly. (Sittsamer, The Luminous Group LLC, 2005, 3.)"

4.4 Implementation of a Layered Process Audit system

When developing an LPA system, it is essential to use enough time on planning the implementation. Well planned and thoroughly executed implementation with committed management doing coherent follow-through will make the effectiveness of LPA possible. An LPA created poorly and in rush will be a waste of time.

There are various different ways to do the implementation of LPA and it's hard to say which one is the best option. Here is presented a quite simple 14-step model.

TABLE 2. 14-step model (Sittsamer & Leslie, The Luminous Group LLC, 2005)

Step	***Mission (to-do)***	***Important question***
1.	Create a LPA team	Who to involve?
2.	Make gap analysis	What is different?
3.	Plan and choose where to begin	What is right/best place to start making audits?
4.	Recognize items of high risk	What causes risks in processes?
5.	Create audit checksheets	Elements that should be verified?
6.	Decide who will perform the audits	Who will perform the audits?
7.	Decide audit frequency	When will audits be performed?
8.	Connect to management review system	How does management monitor effectiveness?
9.	Documentation of LPA process	How will the LPA system been established inside organization?
10.	Educate auditing persons	What do auditing persons need to know?
11.	Communicate with personnel/staf	What do employees need to know?
12.	Initiate audits	What does the audit consist of?
13.	Supervise and modify LPA's	Does the audit work as planned?
14.	Expand the LPA system to other areas within the plant or manufacturing facility	How can we get even more benefit out of LPA?

There is a brief explanation of each 14 steps below.

Create a team

The team should consist of three to six persons chosen by the top management of the plant. These persons should be from different areas of the plant or facility so that there will be a lot of perspective on things and not just one point of view. One of the team members has to be a teamleader or a team supervisor and this person has to be someone who is trusted and respected by the top managent. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Make Gap Analysis

If necessary, perform a gap analysis to define what is the current situation like and what should be done to improve and achieve objectives in the future (Sittsamer & Leslie, The Luminous Group LLC, 2005).

Choose where to begin

Before expanding the LPA system across the plant or facility it should be focused in one certain area. There are plenty of ways to choose where to begin, for example a company might have one section or department that is keen to try new things or one department which is left behind in the development and needs improvements the most. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

The point is that regardless of wherever you choose to begin, the crucial thing is to find the most fluctuating process and create a checksheet that ensures those elements which are most vulnerable to variation (Sittsamer & Leslie, The Luminous Group LLC, 2005).

Recognize items of high risk

Recognizing the items of high risk may be a challenge and that is why the team must do some investigation work. Team should be focused on issues like top quality, throughput, customer complaints, scrap and rework in the chosen area. Interviewing the operators and foremans of the specific area will provide very important information and knowledge from processes. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Create audit check sheets

The main point of check sheets is that questions must be specific and meaningful. These kinds of imprecise terms like appropriately, correctly, accurately and properly should not be used because those cannot be used to verify a process. For example, rather than asking imprecise question like "Is the air pressure set correctly?" The question should be, "Is the air pressure set to 3,75 bars?" A good help for thinking and creating questions to LPA check sheets comes from standard operating procedures, assuming that those are already implemented to companys processes. The SOPs include all proper work methods, specified machine settings etc. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Purpose is to include important process elements to the check sheets instead of very general elements. These kinds of questions like "Is the worker guided", or "Is the working environment clean from dirt", might seem important but in reality, those don't add value of any kind in process checksheets. Such questions should be created that they go straight to the point into the process. For example, rather than asking "Is a worker guided?" a question shoul be made that verifies that the workman is assembling a product as required. It is also important to remember not to include questions which check things that don't change or differ from shift to shift or day to day, because this kind of questions waste time, makes auditors frustrated and might confuse the operators. Questions should be formed so that a bad or unfavorable finding from the process is always answered with a no. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Check sheets should also give some information for the auditor which helps him/her to understand the reason why a specific item or process needs to be verified, or what to do as a first response if the item or process is found to be nonconforming. Because the audit can be performed by almost anyone in the manufacturing facility, it is wise to provide a short explanation to clarify why the question is being asked. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Because the purpose of LPA is to authenticate and fix, the auditor's job is not only to make check and mark cross to a box of "yes or no". If nonconformity appears in item or process which is being observed, the auditor should prompt the operator or foreman to fix the situation. It is very important that LPA's do not just make a listing of nonconformances which are processed later in the future. While findings are documented and analyzed for corrective actions, the primary response to nonconformance process item is to bring it back into conformance. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Good way to ensure that cheksheet questions are valid is to perform a test audit on the plant floor. Feedback from other auditors, maybe one or two, is important and it can be used to adjust and modify the writing form and it will make the questions more effective in finding process nonconformances. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Decide who will perform the audits

Responsibility of performing audits is shared among multiple layers of management as the term "layered" implies. Audits will be conducted by all levels of personnel ranging from worker to personnel at the highest level of the organization. Operators, foremans, department managers and even the president of the company can conduct the audit. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Decide the frequency when the audits are performed

Audits are performed at some decided frequency and it is usually determined by the level of the auditor inside the organization. If the auditor is close to the level of area which is being audited, the more often that auditor will perform the audit. For example, a production line operator and foreman

may perform the audit every day, whereas a plant manager performs the audit only once in month. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

A management review

Essential task of manangement is to check that all the assigned audits are performed on schedule. This is easily done when they are performing their own audits and by performing their own audits on time they show good example and remind to all that completing audits is very important. Like any other corrective or preventive action systems, there's a responsibility for the top management to make sure that solutions to issues are effective. This can be measured by a decrease in appearence. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

All the nonconformances must be recorded on the check sheets, even those that could be corrected immediately. One part of implementation process is that the LPA team has to create instructions that define how nonconformances will be handled, for example flow diagrams that define how the issues will be tracked and analyzed. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Very important phase in LPA implementation is to link this new system to existing review systems. It is not difficult; the job is to decide what questions in the checkseet might be so important or even crucial that they require immediate notification to higher level management if a noncormity appears. Another important job is to set alarms to make sure that issues repeating and problems related to those found in different processes are reported to management. If a same problem or issue appears two times within two weeks or three times within a month that's a clear sign which points out there is a problem in that process. These kinds of severe issues appearing with high frequency must be reviewed and handled by top management in Management Review meetings. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

The LPA system might be worthless without the important connection between LPA and the commitment to continuous improvement. To get information about is the LPA effective or not; the job is to collect both the number of items checked per week and the quality metrics on the same timeline. Approximately after four months there should be enough data to determine if the LPA is providing benefit or not. If there is a correlation between the number of items checked and quality improvement, the LPA has had a positive effect. If there is no correlation, then it's top management's responsibility to define where the problem is. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Documentation of LPA

Like any other standard operating process in a company with good quality management system, the well planned and defined LPA process should be documented in a simply understandable LPA operating model. The operating model tells how the LPA sytems is beign integrated to quality management systems which already exist within the facility. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Train and educate auditors

Auditors need to be guided and oriented to the philosopfy of Layered Process Audit and also to their new responsibilities as an auditor but they don't need any special or broad training. Orientation can be done with a couple of hour review of LPA and the draft version checksheets, followed by test audit. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Communicate with personnel

The personnel should be informed about the ongoing LPA implementation process. They also need to know what LPA is and how it is going to affect on everyday life. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Initiate audits

When the auditors are satisfied with the checksheets and they have been oriented and operators and personnel are informed about the new method, then it is time when audits can begin (Sittsamer & Leslie, The Luminous Group LLC, 2005).

Supervise and modify

Modifying will be current when routines are found and audit methods focused. If the audits are not providing any help, the problem might be that they are not performed frequently enough. The questions might be worded wrong or not specific enough. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

Expand the LPA system across the plant

Once the top management is satisfied with the effort and benefits gained from LPA in that one specific area, it can be presented to other areas inside the facility as well. Usually LPA has been focused only on manufacturing areas but there is no reason why it cannot be applied for example to support activities. (Sittsamer & Leslie, The Luminous Group LLC, 2005.)

4.5 Summary

LPA is a powerful quality tool which helps companies to prevent providing faulty products to customer. It makes manufacturing of a product cost less by guiding the manufacturing process so that the process is done correctly at the first time. It reduces variation in processes which means that operations run smoother.

An LPA system should not be created just for pleasing customer requirements; it should be created for own benefit, to improve overall quality, working methods, processes and the quality management system in organization. It is especially for those organizations that are going through changes to be an organization where number one priority is quality and conformance of product and process requirements. By investing on LPA a company improves not only the customer quality, which can save a lot of money for example in corrective actions but at the same time improvements will be seen in decreased need of repair and rework, increased productivity and decreased amount of work related injuries.

To succeed, implementation requires open minded committed persons, careful planning and follow-through. Implementing process takes usually two to four weeks but with fully committed persons and with right resources it can be done in a week.

If there are no visible results to be seen after four months of auditing, then the task is to review the checksheets and possibly modify the questions and look into how the questions are asked and make sure that there is clearly defined instructions how to deal with nonconformances.

5 PREVENTIVE MAINTENANCE

5.1 Overview

Preventive maintenance system is based on an idea that failures and problems with machines and equipment are prevented before those might even occur. This system ensures the reliable and efficient performance of machines and equipment inside an organization. (Lean Manufacturing Tools, 2017.)

A good example of preventive maintenance is a car service or maintenance. To make sure that car is reliable and safe to use it is being serviced regularly, for example the oils have to be changed after every 10000 kilometers to prevent the failure of an engine. Of course, there might still occur a failure at the engine even though it has been serviced preventively, but the point is that by doing service and maintenance regularly on critical elements you might prevent the problems occurring, but most importantly keep the system running longer without major breakdowns which may be time consuming and cost a lot of money to repair. Just like cars need maintenance, machines require that as well within factories. (Lean Manufacturing Tools, 2017.)

The goal of preventive maintenance is to keep the machines and equipment in optimal operating condition and to prevent unessarry downtime which is caused by breakdowns. Trying to prevent breakdowns by maintaining equipment is important because problems often tend to occur when the manufacturing is most intense and the machinery is under lot of pressure, for example, when there is an important customer order what need to be fulfilled and all production lines and machines are running continuously. Preventive maintenance tasks usually consist of measuring, checking or replacing some various components of equipment or machine. (Lean Manufacturing Tools, 2017.)

Everything wears at some point and that's why replacing some part of machine before it breaks is wise, because it costs less than the repair what you have to do when the machine breaksdown when you haven't maintained it properly and replaced the wearing part. Neglecting the maintenance and replacement of critical parts at the right time might have serious consequences which at the worst case can lead up to stop of entire production at some period of time. (Lean Manufacturing Tools, 2017.)

Maintenance functions are usually seen as an expense and because of that it's very often the first department of organization where the cuttings are made whenever there's a difficult time. Reality is that the money invested in preventing problems from occurring is almost always a lot less than the money spent to fix problems and failures which occures at some point. (Lean Manufacturing Tools, 2017.)

5.2 Important knowledge

TABLE 3. Conceptions about Preventive Maintenance. (Levitt, 2011, 67-68)

Misconception	**The right conception**
PM is just a method of trying to determine what will wear out or break and when, so that it can be replaced before it does.	It's more than that. It's an approach to permanent corrections of problem areas. It reduces excessive use of recources.
All the PM systems are the same.	PM systems are always designed for the specific equipment or machine based on many variable factors, such as; age of the machine, type of service, hours of operation.
It is extra work and it costs more money.	There are multiple ways how PM saves resources of an organization, e.g. it will increase uptime, reduce un-planned events and reduce usage of energy. The only extra load to existing workload comes when the PM system is started and put into place.
Even unskilled people can do PM tasks if the forms and descriptions are good.	Some of that is true, for example easy TLC activities such as tightening bolts, lubrication or cleaning can easily be done by trained employee. Idea is however that skilled people do the maintenance tasks.
It will eliminate the possibility of breakdown	Breakdowns will appear regardless of how advanced the PM system is. Breakdown can happen from abuse, accident or misapplication. PM system can't eliminate breakdowns but it certainly can prevent and reduce them.

Two main types of preventive maintenance are mandatory and discretionary maintenance.

Mandatory

It is an activity required by contract, regulation, law, code or licence. For example, if a law demands to inspect and maintain some machine, then it has to be inspected and maintained. That is mandatory. Usually organizations which can demand mandatory PM's are insurance companies and sometimes even the big customers. (Levitt, 2011, 55)

Discretionary

It is an activity which is driven by profit and loss. It's performed to reduce breakdowns and financial consequences caused by those breakdowns. It is performed by the own will of an organization. (Levitt, 2011, 55)

5.3 Four dimensions of preventive maintenance

The four dimensions of preventive maintenance system are Economic, Engineering, Psychological and Management. To fully understand possible benefits gained from PM system, it's important to consider impacts and connections of these four dimensions. (Levitt, 2011, 65.)

Economic

The preventive maintenance system must be designed to be economically reasonable. For example, there's no sense to include tasks where the economic consequences of the failure of machine are a lot less than the actual costs of preventive maintenance activity for that machine, because that is waste of resources. (Levitt, 2011, 65.)

Engineering

Essential part of doing preventive maintenance is to really understand the failures and what causes them, because without that understanding the PM tasks might not be worth the effort.

Engineering provides right tasks to the right part with right tools and with the right frequency. With these it's easy to detect a failure or even avoid it. It helps to make PM tasks easier, safer and quicker to complete. (Levitt, 2011, 65-66.)

Psychological

Because there's a different kind of people and everybody has their own persona it's a challenge to create that kind of preventive maintenance system that everybody understands exactly what to do and what are the impacts what a procedure would make when it's done in the right way. Some worker might think that, for example, when the task is to lubricate a small moving component of a machine, that this is very important and he/she does it always according to instructions. Another worker instead, might think that this task is unnecessarry and neglects the instructions by not doing the lubrication because of own opionin on the task importance. These two workers can be equally talented mechanics, but only another of them does the work as guided. Reason to this is that they have different personalities. (Levitt, 2011, 66/249.)

Even the best possible preventive maintenance system will fail without committed people doing the tasks right and at the right time. That is why a part of preventive maintenance struggle is to make sure that all persons involved actually understand what, why, how and when to do. (Levitt, 2011, 66/249.)

Management

The management's job is to preserve and recreate this improved state what the company has achieved by preventive maintenance system. This could be done with management structures which keep procedures in place over time. (Levitt, 2011, 66-67.)

5.4 Impacts on costs, safety and quality

Costs

When performing maintenance tasks regularly on critical items with correct tools and correct ways, it's possible to postpone or prevent any major breaks of equipment or machines. This means that operations run smooth without problems and therefore the manufacturing is productive and keeps money coming in.

Of course, the preventive maintenance system itself consist of various different costs. These can be

- On time costs such as:
  - Costs of modernizating the equipment to match PM demands
  - Cost for training people
  - Indirect support systems costs
  - Labor costs of training inspectors
- On-going costs such as:
  - Labor of short repairs
  - Part costs
  - Additional investment in predictive maintenance technology
  - On-going training

Eventhough these costs might seem a lot, they are just a small part of the total costs caused by a minor shutdown. (Levitt, 2011, 36-37.)

Safety

Preventive maintenance system will improve the safety of processes by keeping the machines and equipment in good operational condition. When the machines are in good condition there is smaller risk of injuries caused by machine. Maybe the most common task of PM is to clean and keep the work stations and equipment tidy and free from dirt. This task is usually pointed out to be done in every work station at the end of or/and at the beginning of shift. This is the simpliest task to do and it's very effective to make working much safer. If the work station is not cleaned there's a possibility for example to trip to something or slip when there's saw dust on the floor. Another possibility is that, for example, if there's fine dust on top of some machine or part of it which heats up, it can catch on fire if it is not cleaned regularly.

Quality

Preventive maintenance improves products quality by assuring that the tools and equipment used to manufacture it are in good condition. For example, if there's a production line of wooden doors and the machinery is not regularly maintenanced there might be a bad blade on CNC machine which causes bad quality products and that causes extra costs.

Product quality is not the only thing what is important; the improvement in organizations own quality management system is what preventive maintenance provides.

5.5 Summary

Preventive maintenance is a system which trys to prevent problems and failures of machines and equipment before they even occur. It is an effective method to ensure the reliability of machines and equipment.

It has great impacts on reducing costs of rework and by preventing breakdowns; the company avoids costs of those as well. It will increase the uptime of processes. It also improves the safety and overall quality of manufacturing facility.

Preventive maintenance is linked to total productive maintenance implementation as a crucial part of lean initiative. Use of total productive maintenance and 5S gives a base for future improvement activities inside organization. It's a requirement of lean manufacturing that processes are stable and reliable. A well planned preventive maintenance system is reasonable investment to pursue lean manufacturing. (Lean Manufacturing Tools, 2017.)

6 PRESENTING THE PRACTICAL IMPLEMENTATION AND RESULTS

6.1 Implementation of SOP

JELD-WEN Kuopio is going through improvements inside the whole corporation to have similar transparent vision in every facility. Their next acute step was to create and implement simple and clear standard operating procedure for every workstation in Kuopio facility.

This thesis project was pointed to us because of its urgency. We had one month time to create and implement simple and approved pictorial SOPs to all 44 workstations inside Kuopio facility. The work started with meetings where we decided with the factory manager what kind of schedule we should have for this job and how the job should be executed that it would benefit everyone.

We made schedule for every working day and week what needed to be accomplished in what time. First, we created a base sheet for Standard Operating Procedure from Vääksy factory's raw version that only contained the upper part of a SOP sheet. The upper part consisted on indicating the work station name, dates, makers, acceptors, name of SOP and the compulsory work gear to ensure employee safety. To this upper part, we added multiple sections that were: Picture of operation, operation name, duration of procedure and complete duration, quality factors, expense factor and safety factor. Quality, expense and safety factors contained few new sections such as the reason and possible action to prevent any safety, quality or expense issues.

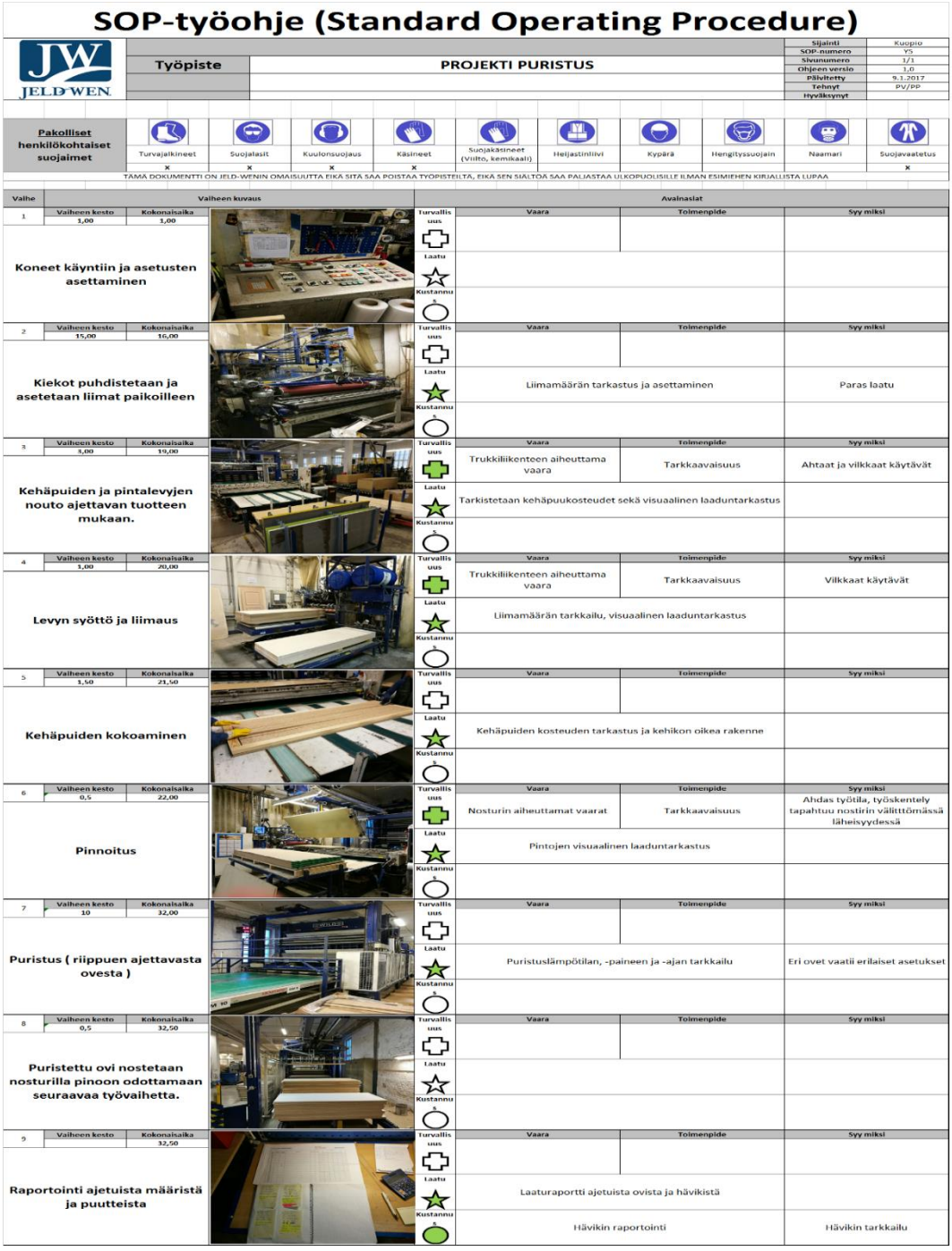
Our work continued by interviewing the employees that operated in different workstations. We wrote down the essential information concerning each workstation, took photos of every step and took time for some operations in the work station. From these information, we could create standard operating procedure for each workstation with Excel. Our first complete SOP was created and approved by several managers and from that basis we created all the remaining SOPs for every workstation.

All the approved and finished SOPs were printed out as A3 size, laminated and installed near to workstations. All finished SOPs went through the employees as well, so that they also would approve our accomplishments and check that SOPs are as accurate as possible and do not contain any errors or misleading information.

All the finished standard operating procedures and photos were also added to JELD-WEN's own database. There everyone with access can inspect SOP documents and make possible changes to those documents if any errors occur, that needs to be fixed or if more productive method is found to replace an operation in some workstation.

Almost every SOP created contained steps like "making report" and "cleaning the workplace" (depended on a workstation) as a last step before completing a workshift. These actions back-up the theory of 5S and LEAN and more importantly put them into action. Reporting in these SOPs meant

to make quality markings in separate quality report on an hourly basis and make notifications about possible loss of material or defects.



SOP-työohje (Standard Operating Procedure)

JELD-WEN	Työpiste	PROJEKTI PURISTUS							Sijainti	Kuopio
									SOP-numero	Y5
									Sivunumero	1/1
									Ohjeen versio	1,0
									Päivitetty	9.1.2017
									Tehnyt	PV/PP
									Hyväksynyt	

Pakolliset henkilökohtaiset suojaimet	Turvajalkineet	Suojalasit	Kuulonsuojaus	Käsineet	Suojakäsineet (Viilto, kemikaali)	Heijastinliivi	Kypärä	Hengityssuojain	Naamari	Suojavaatetus
	x	x	x	x						x

TÄMÄ DOKUMENTTI ON JELD-WENIN OMAISUUTTA EIKÄ SITÄ SAA POISTAA TYÖPISTEILTÄ, EIKÄ SEN SISÄLTÖÄ SAA PALJASTAA ULKOPUOLISILLE ILMAN ESIMIEHEN KIRJALLISTA LUPAA

Vaihe	Vaiheen kuvaus			Avainasiat			
	Vaiheen kesto	Kokonaisaika			Vaara	Toimenpide	Syy miksi
1	1,00	1,00	Koneet käyntiin ja asetusten asettaminen	Turvallisuus			
				Laatu			
				Kustannus			
2	15,00	16,00	Kiekot puhdistetaan ja asetetaan liimat paikoilleen	Turvallisuus			
				Laatu	Liimamäärän tarkastus ja asettaminen		Paras laatu
				Kustannus			
3	1,00	19,00	Kehäpuiden ja pintalevyjen nouto ajettavan tuotteen mukaan.	Turvallisuus	Trukkiliikenteen aiheuttama vaara	Tarkkaavaisuus	Ahtaat ja vilkkaat käytävät
				Laatu	Tarkistetaan kehäpuukosteudet sekä visuaalinen laaduntarkastus		
				Kustannus			
4	1,00	20,00	Levyn syöttö ja liimaus	Turvallisuus	Trukkiliikenteen aiheuttama vaara	Tarkkaavaisuus	Vilkkaat käytävät
				Laatu	Liimamäärän tarkkailu, visuaalinen laaduntarkastus		
				Kustannus			
5	1,50	21,50	Kehäpuiden kokoaminen	Turvallisuus			
				Laatu	Kehäpuiden kosteuden tarkastus ja kehikon oikea rakenne		
				Kustannus			
6	0,5	22,00	Pinnoitus	Turvallisuus	Nosturin aiheuttamat vaarat	Tarkkaavaisuus	Ahdas työtila, työskentely tapahtuu nostirin välitttömässä läheisyydessä
				Laatu	Pintojen visuaalinen laaduntarkastus		
				Kustannus			
7	10	32,00	Puristus (riippuen ajettavasta ovesta)	Turvallisuus			
				Laatu	Puristuslämpötilan, -paineen ja -ajan tarkkailu		Eri ovet vaatii erilaiset asetukset
				Kustannus			
8	0,5	32,50	Puristettu ovi nostetaan nosturilla pinoon odottamaan seuraavaa työvaihetta.	Turvallisuus			
				Laatu			
				Kustannus			
9		32,50	Raportointi ajetuista määristä ja puutteista	Turvallisuus			
				Laatu	Laaturaportti ajetuista ovista ja hävikistä		
				Kustannus	Hävikin raportointi		Hävikin tarkkailu

IMAGE 2. The first finished Standard Operating Procedure

Comparing the factors from earlier chapter "Guidelines for technical SOP" with the accomplishments in JELD-WEN's case for creating SOPs, there are numerous similarities to be detected. The finished SOP that was created for JELD-WEN contains factors like:

- **Workstation definition**
  Upper part indicates the name, date, creators, approvers, workstation area and page numbers.

- **Safety gear for personnel**
  Upper part also contains mandatory safety gear what the personnel needs to use to operate on certain workstation.

- **Normal operations**
  SOP contains all the necessary steps in order from start to finish that the personnel needs to operate the workstation.

- **Start-up following turnaround**
  The first step always indicates the start-up procedures before the actual work can start and the estimate on how long does it take.

- **Pictures**
  Every step contains an overview picture of the steps to clarify personnel what machines or tools he/she needs for operating in certain step.

- **Possible procedure time**
  Every step contains duration box for the step and overall time of the procedure.

- **Consequences of deviation / reporting**
  In all the workstations where deviation might occur, the SOPs contains reporting step, where the personnel reports on an hourly basis about possible deviations.

- **Possible hazards of the procedure**
  Every step contains safety factor, which indicates the possible hazard, how to prevent it and reason why the hazard might occur.

- **Quality factors**
  Every step has a quality factor box, where it can be written if the steps have significant impact on quality. It also contains "procedure" and "reason, why" boxes so that the personnel can take these factors into account.

- **Cost factors**
  Every step has a cost factor box, where it can be written if the steps have significant impact on cost, such as possible material loss. It also contains "procedure" and "reason, why" boxes so that the personnel can take these factors into account.

- **Clean-up**
  SOPs contain a "Clean-up" step. In the end of the shift or during the shift the employee's clean-up their workstations and put tools back into their rightful place. This supports the 5S principle.

6.1.1 Results of SOP

When announcing the results that JELD-WEN Kuopio has achieved since the Standard operating procedure project started, it is important to review and tell what the objectives of that project were, and what kind of an opinion the factory manager has for the finished SOPs. Criticism about the project, what kind of needs or improvement plans they have for SOPs and how will they exploit the SOPs in the industry even further are also important to review.

JELD-WEN Kuopio had an objective to have inclusive, functional and visual Standard Operating Procedure for every workstation in the factory within one month (January 2017), which was achieved completely.

As the factory manager said about the finished SOPs: "In my opinion, the SOPs are just the way they need to be. The SOPs are better than I assumed. They are easy to read and there were able to include job safety, quality, costs and required personal safety gear factors".

The only criticism that was told regarding this project was from their end. They thought that the foremen should have been more involved with this project, ensuring that the SOPs for every production line is the only wanted operation model.

JELD-WEN Kuopio is now starting to create the LPA system internally for their factory which is based on Standard Operating Procedure. They aim to audit at least in a monthly cycle that the SOPs instructions are up-to-date and that everyone is following the instructions in SOPs in every workstation. This process will be improved all the time and they intend to figure out if they want to make the SOPs even more specific and detailed than they already are.

The general opinion of JELD-WEN Kuopio is that SOPs are one of the hundreds LEAN tools. They see it as an essential tool for continuance improvements and if the processes are not defined, they cannot be improved in the future.

In a more general level the factory result has improved positively when the improvement projects have started, SOPs are one thing among them. JELD-WEN has determined the "VITAL 5" for every factory, which have the same topics as in JEM (JELD-WEN Excellence Model): Visual management which includes hour-by-hour management and SQDCI (Safety, Quality, Delivery, Cost, Inventory) boards; Standard work, which is much related to Standard Operating Procedures; Layered Process Audits, Basic problem solving and root cause analysis and 5S.

SOPs are one of the essential factors that those VITAL5 objectives can be started. (Ovaskainen, 2017.)

6.2 Implementation and results of LPA

JELDWEN Kuopio's plan is to start implementating an LPA system at the beginning of May 2017. Their purpose is to design it, so that it can be connected to their existing PCI/5S auditing system. It might also have influences from the LPA system used in JELDWEN Vääksy's factory.

Because there's nothing concrete created yet in Kuopio's factory, we had to base our results on information from Vääksy's factory.

LPA has been effective system which has clearly reduced variation in processes and brought certain type of posture and assurance to operations. Even the operators recognize the importance of auditing and think it is useful. (Siikanen, 2017.)

The vision what Kuopio's factory has about LPA is that it will bring discipline and systematicality to process operations and also discipline to performing audits in generally. When implemented it will be an important improvement to company's operations and quality management system. The LPA system along with SOPs and PM will make a great impact on company's effort to have better functioning operations and working environment. (Ovaskainen, 2017.)

6.3 Implementation of PM

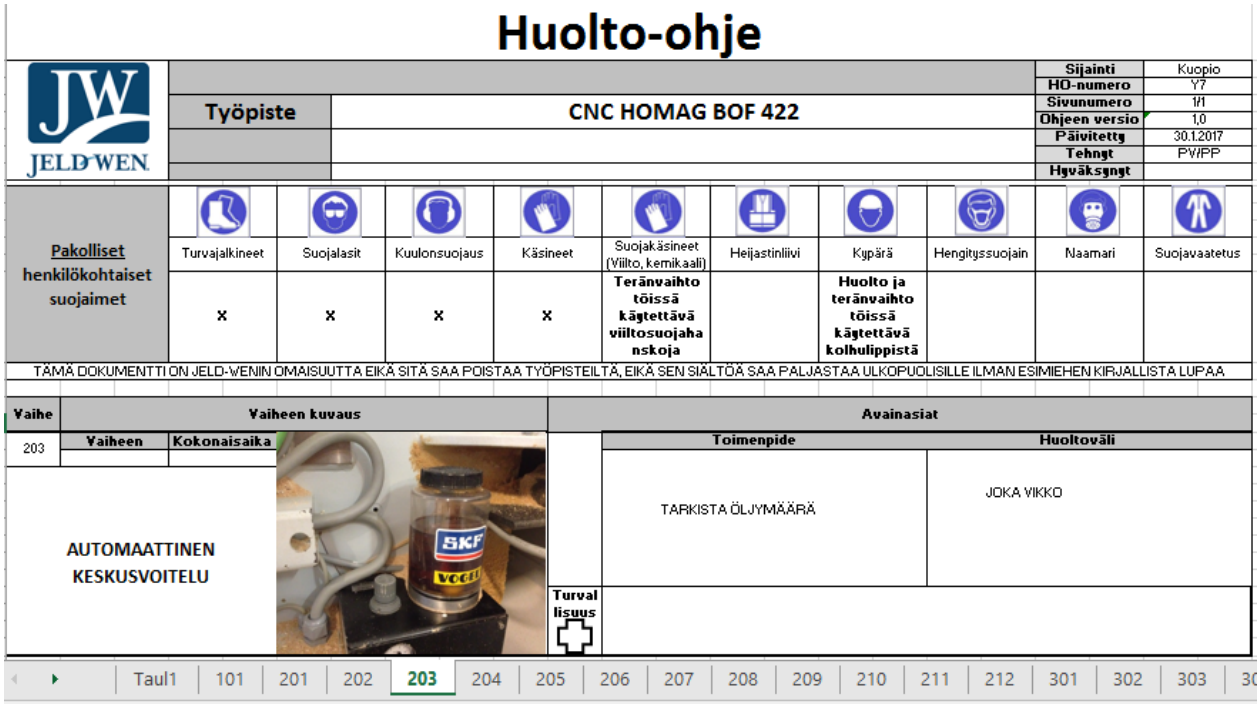
The second task besides creating SOPs to JELD-WEN Kuopio was to develop their preventive maintenance manuals further. JELD-WEN Kuopio had already done some research for their preventive maintenance program, from which we continued to develop them to the desired format.

The first idea was to create preventive maintenance sheets that looked just like the finished SOPs. From the previous information that JELD-WEN already had about maintenances, we created preventive maintenance manuals that indicated all the necessary maintenances that certain workstation or machine needs. Those maintenances were put in time order, starting from the maintenance that needs to be done most often and finishing to the maintenance which has the biggest maintenance gap.

Like the SOPs, preventive maintenance sheets contained pictures, definitions of maintenance, safety factor/safety gear and the maintenance gap time. It also contained the same upper part than the SOPs, which shows the target of maintenance.

Some missing information about maintenances were found in maintenance sheets located in workstations and consulting the personnel of maintenance.

The idea was to attach those maintenance sheets near workstations like the SOPs, so the personnel of maintenance can easily follow the required maintenances and how to perform them. But the preventive maintenance sheets became so extensive so the idea of the format changed a little.



Huolto-ohje

Työpiste	CNC HOMAG BOF 422	Sijainti	Kuopio
		HO-numero	Y7
		Sivunumero	1/1
		Ohjeen versio	1,0
		Päivitetty	30.1.2017
		Tehnyt	PV/PP
		Hyväksynyt	

Pakolliset henkilökohtaiset suojaimet	Turvajalkineet	Suojalasit	Kuulonsuojaus	Käsineet	Suojakäsineet (Viilto, kemikaali)	Heijastinliivi	Kypärä	Hengityssuojain	Naamari	Suojavaatetus
	x	x	x	x	Teränvaihto töissä käytettävä viiltosuojahanskoja		Huolto ja teränvaihto töissä käytettävä kolhulippistä			

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Vaihe	Vaiheen kuvaus		Avainasiat	
	Vaiheen	Kokonaisaika	Toimenpide	Huoltoväli
203	AUTOMAATTINEN KESKUSVOITELU		TARKISTA ÖLJYMÄÄRÄ	JOKA VIKKO
			Turvallisuus	

Taul1 | 101 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 301 | 302 | 303

IMAGE 3. The lates idea of preventive maintenance sheet

Because of the extent of preventive maintenance created before (number of pages), the image above (IMAGE 3.) presents the latest and approved version. Their new idea about pointing out the maintenances was to indicate them through density of maintenances, using numbers like 101, 102, 201 and so on.

The numerical maintenance gap is defined the following way:

- 100
  For example, 100 means that the maintenance check needs to be done in every shift
- 200
  200 means, that the maintenance check needs to be done every week
- 300
  300 means, that the maintenance needs to be done in every three months

The logic with these numbers goes on to 800 which indicates the maintenance gap to be 1 year. The first number indicates the time gap between maintenances and the last number indicates that it has the same maintenance gap but the maintenance is to a different part of that same machine.

Using this numbering system is part of the preventive maintenance check-up system, which has already been active in their factory. So, this way it's logical to integrate the preventive maintenance sheets to the same system.

6.3.1 Results of PM

The implementation of preventive maintenance system succeeded well and the personnel of JELD-WEN Kuopio have been satisfied with the results and positive changes what the improved maintenance system has brought.

With help of this new preventive maintenance system there has been found new items on production lines what needs repairing and maintenance. It has increased the knowhow and capabilities of operators and maintenance personnel.

While writing this thesis report the new PM system has already benefited the production lines by increasing their usability and by minimizing all bigger faults which could cause major breakdowns or shutdowns.

The model of preventive maintenance sheets is proven to be good and functional, and the same model will be used in a Logout/Tagout procedure which is at state of development at the moment.

Only criticism what these preventive maintenance sheets have faced so far is that the controlling and modifying of sheets like changing the details, pictures and information is quite a challenge and time-consuming task.

The system is under continuous improvement and there has been found many new targets of maintenance which are then added to this maintenance program. The problem with modifying the documents is also been taken into consider and some corrective actions are already done. (Ovaskainen, 2017.)

7 CONCLUSIONS

The objectives of this thesis project were fulfilled as scheduled and the desired end-result for Standard Operating Procedure and Preventive Maintenance were achieved. The LPA system was only examined in this thesis project and it gives a base to the development and implementation which will be done inside the company starting from May 2017.

All the effort and end-results, that were achieved in time, were satisfying for the company. SOPs and preventive maintenance documents can be easily modified and they are under continuous surveillance and development to become even more beneficial for the production lines and company.

This thesis project has brought a lot of insight about the different phases of production and factors that has impact on good productivity. The project has also increased insight about the requirements that any company needs when pursuing LEAN manufacturing and LEAN principles.

During this thesis project, understanding of different production factors increased, which helped the writing of theory part. Researching and writing felt much easier and certain after the actual work of developing and implementating the standardized operation manuals were done. The actual work backed-up the researching and theoretical work.

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