University of Applied Sciences

ANALYSIS OF SUBCONTRACTOR´S MATERIAL MANAGEMENT PROCESS - HOW TO IMPROVE THE PROCESS USING LEAN SIX SIGMA TOOLS

Development of Generic Tool(s) to Improve Material Management Process and Incoming Quality Control (IQC)

NewIcon Oy

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SAVONIA UNIVERSITY OF APPLIED SCIENCES	THESIS Abstract

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Abstract

The background of this final thesis was to deepen the collaboration between NewIcon Oy and the Subcontractor by improving the material management process. The purpose of this final thesis was to study the Lean Six Sigma methodology, gather and analyze data, improve the incoming quality control, reduce lead time and develop generic tools to improve the subcontractor´s material management process.

The research data and used methods were based on the case study, including supplier audit results, SIPOC diagram of the order-to-delivery process, current state Value Stream Map of subcontractors' order-to-delivery process, and comparison of the material management process. The research data was gathered and analyzed during the case study. Qualitative information was gathered using joint development meetings and interviews and material management process observation (Gemba) performed by the author.

As a result of this final thesis project, several improvement ideas for subcontractor´s material management process and tools were created. The future state flow chart of the subcontractor´s material management process visualizes and predicts the improvement. Standard Operating Procedure (SOP) – Incoming Quality Control (IQC) for subcontractor operations was created to improve quality inspection procedures. SIPOC diagram was created regarding the future state of the material management process. The future state Value Stream Map of the material management process was created and it indicates a substantial lead time improvement in the material management process.

Keywords
Lean Six Sigma, Process, Material Management, Value Stream Mapping, Incoming Quality Control, Standard Operating Procedure

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

In today´s manufacturing processes, for example, the process flow, lead times, quality, and cost-effectiveness, need constant improvement to ensure the project delivery according to a planned schedule. All manufacturing processes are typically monitored and controlled using different methods and tools that include statistical methods, reporting, data, and feedback-related systematic approaches. A common factor of all process monitoring systems is to give the reliable status of the manufacturing process phases from order to delivery or the process phase to be considered.

This final thesis was conducted as a sub-project of the client (hereafter NewIcon Oy, or NI) Subcontractor´s Manufacturing Development Project which shall act as the case project regarding this final thesis project. The case project was launched at the beginning of September 2021 and the preliminary project closure was scheduled at the end of February 2022. The author of this final thesis was a member of the VSM team in this project and acted as a communicator between NewIcon Oy and Savonia University of Applied Sciences (SUAS). This project was launched using the Lean Six Sigma project management style using DMAIC which shall be introduced in the following chapters of this final thesis.

1.1 Client organization

NewIcon Oy is a health technology company founded in 2007 that has specialized in pharmacy automation systems by using advanced robotics and software. The main business area is to develop innovative and competitive medicine and pharmaceutical storage, distribution, and dosing automation systems and software related to them. NewIcon Oy is constantly innovating and developing its products, systems, and software in cooperation with customers to ensure continuous development and improvement. (Vilhunen 2021, 3.)

NewIcon Oy is the market leader in Finland with over 100 customers and the focus is to grow and target international markets. The health technology industry is a fast-growing business and NewIcon´s focus is to respond to the market demand. (Vilhunen 2021, 3.)

1.2 Background information

NewIcon Oy outsourced a substantial part of its production during 2019-2020 to the subcontractor whose operations are in Tallinn, Estonia. The collaboration covers all substantial production processes that include production planning, procurement, and purchase, material management, manufacturing, assembly on subcontractors' premises, packaging, and shipping operations.

To deepen the collaboration, development, and improvement regarding the quality of the operations between NewIcon Oy and the subcontractor, NewIcon´s management team decided to launch a subcontractor´s manufacturing development project that aims to reduce lead times from the order-to-delivery process regarding the project deliveries. The subcontractor´s manufacturing development project was launched at the beginning of September 2021 and acted as a case project for this final thesis.

1.3 Purpose

The main purpose of this final thesis is to study the Lean Six Sigma methodology, gather information, improve the incoming quality control of the subcontractor´s material management operations, reduce the lead time in the material management process, and encourage subcontractors to implement lean principles in their processes. The aim was to develop a generic tool(s) that can be applied to the material management process phase e.g., incoming quality inspection checklist and standardized work instruction(s). When these generic tools are applied to the material management process phase, the overall lead time shall be decreased and the overall quality control regarding the incoming goods will be improved.

1.4 Delimitation

This final thesis focuses on the subcontractor’s manufacturing process material management phase. All other contents and processes mentioned in this final thesis project are considered out of scope. However, all information and research results regarding processes from order-to-delivery are included in this final thesis for obtaining the best possible outcome. The scope of the material management phase starts with the substantial output from the production planning phase and continues to the assembly phase.

1.5 Confidentiality

All detailed information regarding the subcontractor´s operations is confidential. However, all data collected from interviews, process observations (Gemba walk), joint development meetings, and other background material regarding the final thesis project is valid and directly comparable for all subcontractor operations. Detailed operative instructions e.g. Standard Operational Procedures (SOPs) fall under a non-disclosure agreement and will not be published entirely. Minor parts of instructions with no confidential information regarding the subcontractors´ direct operations e.g. checklists and table(s) may be published the appendices of this final thesis.

2 THEORY

In this theory section, all relevant theories regarding the process and lean tools supporting this final thesis outcome are reviewed. The chosen process mapping tools e.g. SIPOC diagram, Statistical Process Control (SPC), and lean methods were selected to demonstrate the whole process under investigation and to review the effectiveness of chosen tools when applied to the manufacturing process to be improved. There are over twenty effective lean management tools that can be used to eliminate waste and improve the process flow.

In the theory section of this final thesis, it is focused on the process definition, Statistical Process Control (SPC), process improvement tools, and reviewing the most essential lean management tools regarding the outcome such as 5S, Value Stream Mapping, Continuous improvement (Kaizen), Waste recognition, and elimination (Muda), and Process observation (Gemba). The set of these lean tools will be the most supportive regarding the outcome of this final thesis.

2.1 Process definition

The process is a set of objectives and resources with multiple capabilities. Managers, supervisors, team leaders, and employees are responsible for process performance and obtaining the desired output at the target level. The process view of an organization, department, or single function e.g., accounting is an accurate practice to describe operation inputs and outputs. (Krajewski, Malhotra & Ritzman 2019, 29.)

Figure 1 shows how the processes work within an enterprise. There is a clear input before the processes or operations start, and clear outputs that consist e.g. goods or services. All these functions can be performed in the external or internal environment. (Krajewski, Malhotra & Ritzman 2019, 29.)

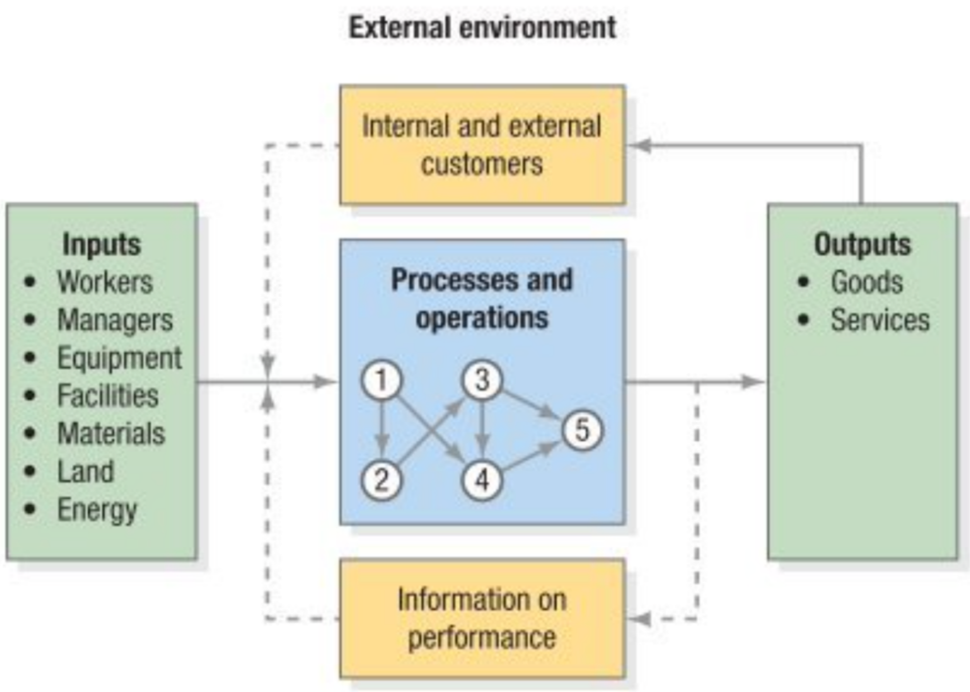

Figure 1. Processes and Operations (Krajewski, Malhotra & Ritzman 2019, 29)

2.2 Process mapping – SIPOC diagram

SIPOC is an effective process mapping tool meaning **S**uppliers-**I**nputs-**P**rocess-**O**utput-**C**ustomers. SIPOC is primarily used to describe the process and visualize the process starting with suppliers, and eventually after inputs, the process, and outputs, ending up with customers. The result shall be a simplified and readable diagram. The quality of the process output can be improved by analyzing the whole system inputs, developing the process under consideration, and focusing on the variables.

SIPOC can be used as an effective communication tool between the teams, subcontractors, or other stakeholders. SIPOC can provide the actual data that all stakeholders can see the process from the same perspective. This procedure helps the management team to make the right decisions and give the actual review of the functions between the teams and stakeholders.

The process can be described that SIPOC showing all the connections between the suppliers and customers. SIPOC method and the diagram help to identify the possible data gathering points from the process and provide needed information regarding the supplier, inputs, outputs, and the customers. (Karjalainen & Karjalainen, 2002, 100.)

SIPOC consist of the following elements:

Process description defines the process that produces required outputs that meet the customer requirements e.g., a product with the demanded specification or service.

Inputs and outputs interfaces define and set the limits of the process starting and ending point.

Suppliers produce all required inputs for the process. Supplier information must be accurate and defined as internal or external. All supplier information shall include the relation to the process input.

Input requirements and measurements are expected values that focus on the process in demand. The process inputs must meet the qualifications and requirements that the process is capable to produce the output level set by the customer.

Inputs are the set functions that the process needs to operate.

Outputs are the results of the process. Outputs must be related to the customer requirements.

Customer requirements and measurements are expectations of the process output. The process outputs must be measured, and these results must comply with customer requirements.

Customers are people or organizations (internal or external) that receive the process outputs and set the requirements for the outputs. (Karjalainen & Karjalainen, 2002, 100-101.)

2.2.1 Creating SIPOC diagram

Generating SIPOC diagram consists of eight main phases. The process interface and the guidelines shall be taken into consideration before generating the SIPOC diagram. The whole SIPOC diagram-making process is recommended to launch with the team and/or stakeholders that are involved in the process in question. The process scope shall be defined and agreed upon with all participants before making of SIPOC diagram.

Eight phases of generating SIPOC diagram:

1. Identify and name the process description
2. Define the process scope. Define the process borderlines (start and endpoints).
3. Make a list of outputs and requirements.
4. Make a list of the customers of each output.
5. Define the key features of the outputs to the customer and the key requirements of the process inputs. Customer requirements shall be documented on each output.
6. Make a list of needed inputs regarding the process and how these inputs can be measured.
7. Make a list of process suppliers (internal and external).
8. Define, identify, and name the key process phases. (Karjalainen & Karjalainen 2002, 101.)

Figure 2 shows each main step of SIPOC is listed and visually simplified. It is recommended to use more detailed information when starting to create a SIPOC diagram.

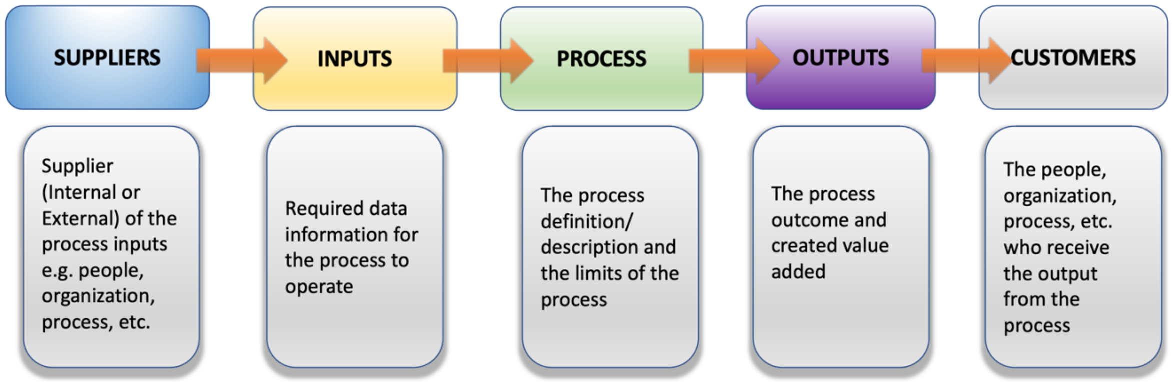

Figure 2. SIPOC main steps (Vilhunen Niko, 2022 CC BY-SA)

2.2.2 Statistical Process Control (SPC)

Statistical Process Control (SPC) was developed by Walter Shewhart in the 1920s. Statistical Process Control is a procedure to evaluate process variations despite the industry or market area. (Keller 2011, 9-10.)

Walter Shewhart defined statistical process control as follows:

"A phenomenon is said to be in statistical control when, through the use of past experience, we can predict how the phenomenon will vary in the future." (Keller 2011, 10).

Using the SPC method in process control, time is in one principal axis, and the data is collected during a short period of time. Each sample is categorized as a subgroup and tells us facts about the process such as the current amount of variation and its current location. When there is enough data collected from subgroups over a long period of time, short-term estimation can be used to predict process variations, and where the process location will be. The data can be calculated using standard or average deviation. The time component of the process is calculated using average, and subgroups are calculated separately using standard deviation. (Keller 2011, 10.)

SPC is one of the methods that is based on statistical mathematics. SPC also creates a concept of Walter E. Deming´s deep knowledge theory. By using the SPC method, the status of systems, and processes can be examined and analyzed. The variations in the process and/or system can be traced, and the possible root cause of the defect can be solved. (Karjalainen & Karjalainen 2000, 10.)

Deming has demonstrated the principle of SPC using white and red beads to simulate daily production. This simulation's purpose was to demonstrate the process variation. The white bead represents the approved products, and red beads were considered scrap. The sample size was set to 50 beads with a small percentage of red beads. This situation shall demonstrate the error rate of the process in the percentage rate of red beads that are considered scrap. (Keller 2011, 10-11.)

Figure 3 shows the control chart of the red bead error rate. Each 50-bead sample has a different count of white beads. The limits have been set between 0% and 22% in which "0" indicates the Lower Control Limit (LCL), and "22" indicates the Upper Control Limit (UCL). (Keller 2011, 11.)

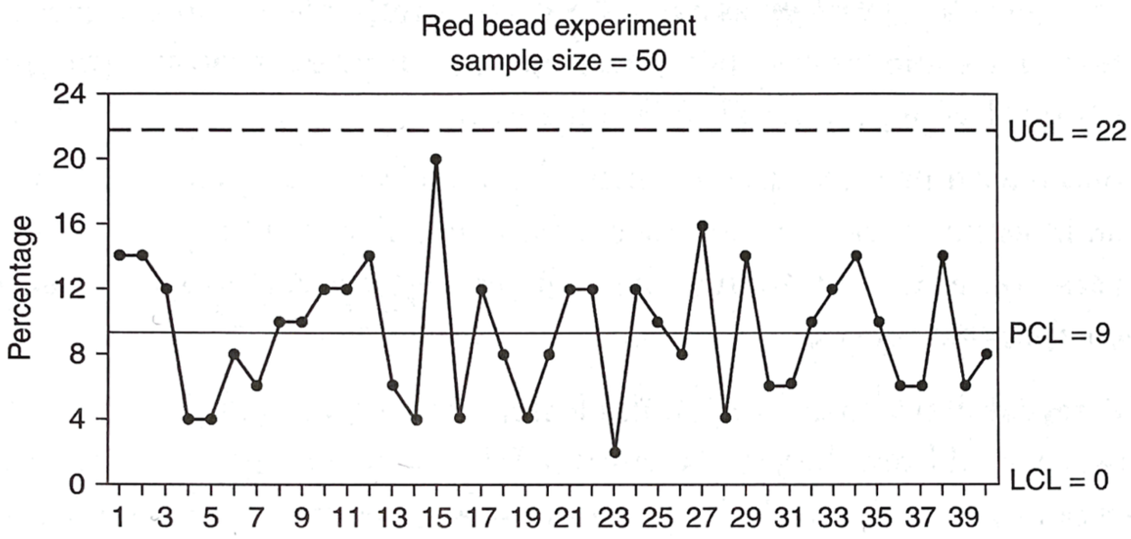

Figure 3. Deming control chart of the red bead experiment (Keller 2011, 11)

2.3 Lean philosophy

Lean is described in the Lean Enterprise Institute (LEI) as follows:

"Lean is a way of thinking about creating needed value with fewer resources and less waste. And lean is a practice consisting of continuous experimentation to achieve perfect value with zero-waste. Lean thinking and practice occur together." (Lean Enterprise Institute 2022.)

Waste elimination and flow improvement can be implemented using various methods. These methods are initially based on the Toyota Production System (TPS). Lean focuses to increase the value-added (VA) time, functions, and tasks to provide direct value to the customer and decrease the non-value-added (NVA) time, functions, and tasks. Value-added functions are the parts of the process where the value is created and on which customers are willing to pay. The most common procedure to apply a lean solution is that process, product, and/or service will be optimized that meet requirements of customers. All products and services will be delivered using the just in time (JIT) principle, which means that the customer is receiving the product or service at the right time, at the right place, and the product or service meets the quality requirements. (Cudney & Kestle 2011, 5-6.)

2.4 5S Philosophy

5S is a philosophy or methodology that aims for a factory or workplace to be clean, safe, well organized, and free of foreign objects or debris. Waste elimination is prioritized to optimize the productivity of the environment. 5S is specially designed for improving quality, safety, and productivity in working environments. (American Society for Quality 2022.)

Table 1 shows the 5S quality tool base pillars that are originally derived from Japanese terms beginning with the "S" letter. An english language version is a similar one and the purpose and the meaning remain the same. The 5S base pillars are easy to remember and effective when implemented. (American Society for Quality 2022.)

Table 1. The 5S definitions (Vilhunen Niko, 2022 CC BY-SA)

Japanese	Translated	English	Definition
Seiri	Organize	Sort	Eliminate all not needed items e.g., tools, parts, and instructions by sorting and separating needed ones.
Seiton	Orderliness	Set in Order	Organize and identify all remaining tools, parts, and instructions for easy access.
Seiso	Cleanliness	Shine	Clean the work area and make sure it remains neat.
Seikatsu	Stantardize	Standardize	Standardize scheduled (daily) cleaning and maintenance based on sort, set in order, and shine.
Shitsuke	Discipline	Sustain	Make 5S a continuous manner by following the first four S´s.

2.5 Value Stream Mapping

Value Stream Mapping (VSM) is a rough image of the whole process under consideration. It is one of the most effective lean tools to describe and analyze the current state of the whole process using visual methods. Before using the Value Stream Mapping method, the current state of the process must be defined and identified. (Torkkola 2021, 131.)

In the Value Stream Mapping method, all current state processes and procedures are needed that the product or service can be delivered to the customer. In a general perspective, Value Stream Mapping starts from the customer order and ends when the customer receives the product or service. All information, data, communications, integrated systems, etc., between the order and delivery, are processed through multiple phases that include various processes, stakeholders, and resources. (Torkkola 2021, 131.)

Figure 4 shows an example of the current state value stream map of Jensen Bearings Inc.'s order-to-delivery process. Detailed information is presented for each process and the flow direction is visible. The process characteristics and detailed resources are shown in this current state value stream map. (Krajewski, Malhotra & Ritzman 2019, 253.)

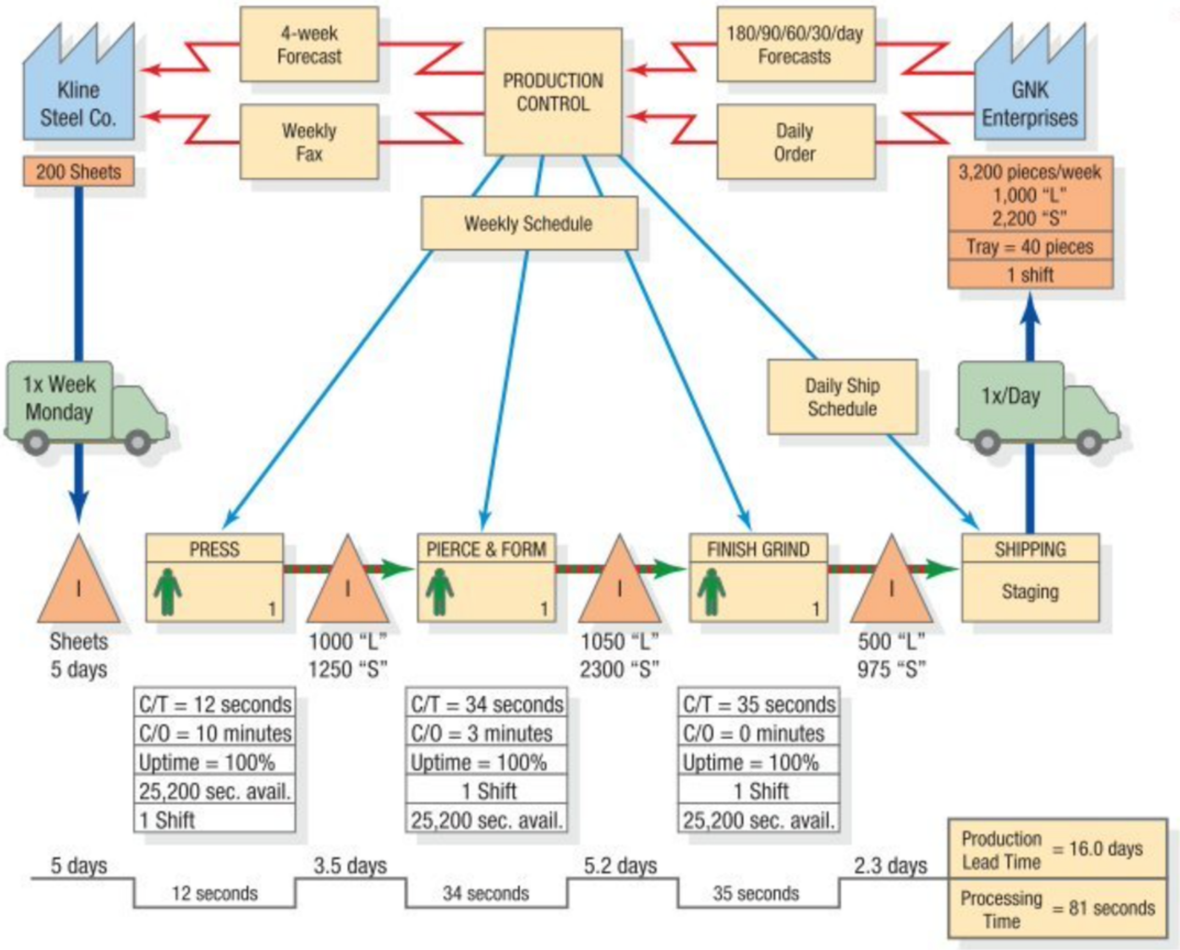

Figure 4. Current State Map (Krajewski, Malhotra & Ritzman 2019, 253)

2.6 Continuous improvement (Kaizen)

The word "kaizen" is a Japanese term and concept that stands for continuous improvement. Continuous improvement is the methodology for seeking perfection, and how to improve the process flow and its functions. These improvements can be done in various methods using lean system thinking. The aim of continuous improvement is to eliminate waste, decrease the lead time, and develop the process. These actions and improvements are usually done by launching development projects regarding the process in question. (Krajewski, Malhotra & Ritzman 2019, 127.)

The general belief of the continuous improvement methodology is that even the smallest phases and sub-phases of the process can be improved through "kaizen". Since continuous improvement is one of the base principles of lean thinking, people can use these effective tools to defeat the challenges ahead. When people are continuously developing and improving their knowledge base, behavior, skills, and practices using proper tools, it will lead to respect for each other. A respectful environment encourages people to grow and think independently. (Liker & Ross 2017, 394.)

One of the efficient process problem-solving tools for continuous improvement is the Plan-Do-Check-Act (PDCA) circle, often called the Deming cycle which was originally introduced by William Edward Deming in Japan in the 1950s (Nicholas 2018, 31). It is often called the alternatively Plan-Do-Study-Act (PDSA) cycle, however, the principle of using this problem-solving tool remains the same. (Liker & Ross 2017, 32.)

To understand the philosophy of the Plan-Do-Study-Act cycle is to use the diagram with simplified instructions. To simplify the phases of how to use the PDSA cycle can be described as follows:

1. **Plan** is the phase when hypotheses are made.
2. **Do** is the phase when the experiments are made.
3. **Study** is the phase of learning opportunities and studying the phenomena.
4. **Act** is the phase where the next actions are decided, and lessons learned are reviewed. (Liker & Ross 2017, 76.)

Figure 5 shows the Plan-Do-Study-Act cycle that is based on Deming´s original cycle.

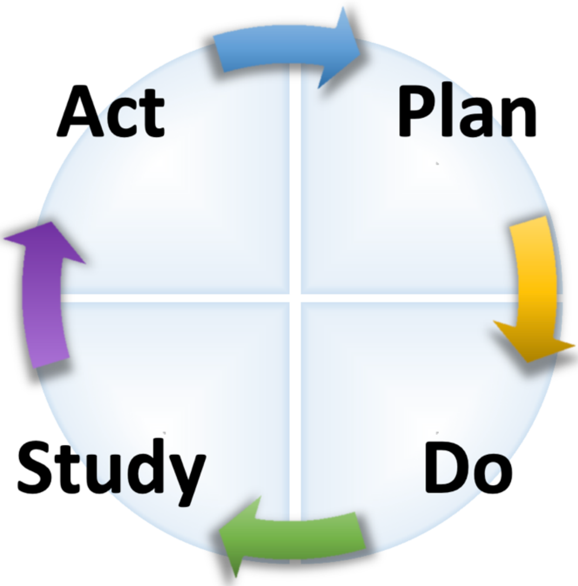

Figure 5. Plan-Do-Study-Act cycle (Vilhunen Niko, 2022 CC BY-SA)

When using the Deming cycle as a problem-solving and continuous improvement tool, the planning process starts with five-why questions. The purpose of asking these questions is to follow the procedure for finding the root cause of the problem. The idea is to find the actual reason for the defect, not just to investigate superficial symptoms. (Nicholas 2018, 33.)

The observed problem of the defective parts can be described as follows:

1. **Why** do these parts have defects?
2. **Why** do these machines not maintain uniform quality and tolerance?
3. **Why** are these machine operators trained and qualified properly?
4. **Why** these machine operators have lack motivation?

5. **Why** is the lack of motivation caused by the machine?

In most cases, the real problem and the root cause can be found after processing the five whys. If the lack of motivation is caused by the machine and that appears to be the root cause of the problem. The replacement of the machine can solve the problem in this case and increase motivation of the machine operators. (Nicholas 2018, 33-34.)

2.7 Waste identification and elimination (Muda)

In the lean methodology, one of the key principles is to identify and eliminate waste. The Japanese word "Muda" (waste) expresses the meaning of waste and is one of the lean principles, but lean is much more than waste elimination. The more important issue is understanding the waste effect in the system under consideration. There are seven critical types of waste that have been identified and the concept was created in The Toyota Production System (TPS). (Liker & Ross 2017, 156.)

The seven types of waste according to Taiichi Ohno, can be described as follows:

Overproduction

Producing more products that the customer or the next process needs is considered waste. Excess products usually trigger other six waste types.

Inventory

Excess inventory leads to the company overstocking and increasing storage and depreciation costs. The stock level exceeds the required level of the controlled pull system.

Transportation

Transportation can be considered as waste when materials and/or resources consist of excess movement and it does not add value to the product or the customer.

Defects

Defects may occur during the process and can include unscheduled inspections, design flaws, rework. All defects can cause major delays in the process.

Processing

The processing procedure is not implemented correctly or there is unnecessary or incorrect processing. Using inadequate tools, instructions or poor design often leads to overprocessing.

Waiting

Production is waiting for needed parts while machinery and resources are in an idle position.

Motion

Motion can be defined as an excessive movement of employees or machinery and is recognized as waste. Excessive motion leads often to extended production times, causes defects, and injuries. (Lean Enterprise Institute 2022.)

2.8 Observation of the process (Gemba walk)

The word "Gemba" is a Japanese term and means the "actual place". The purpose of Gemba or observation of the process is that an observer or the director walks through the process in the same order as to how the customer's work order flows through the process in the actual place. One of the key principles during the Gemba walk is to construct a big picture of the process and see how things happen in the real production environment. (Torkkola 2021, 125.)

The first step before starting the Gemba walk is to consider the customer´s needs and choose the process to be examined. Customer needs may include e.g. better quality, a lower price, faster delivery, and comprehensive customer support after delivery. The primary target during the process observation is to identify the features of the process to be changed or improved in point of the customer's perspective. The focus is to record the findings from the process and analyze the results afterward. Problems are not meant to be solved during the Gemba walk, however, analyses from the process functions shall be done, and the tools for problem-solving considered. (Torkkola 2021, 126.)

2.9 Lean Six Sigma philosophy

Lean Six Sigma is a business development strategy that focuses on continuous improvement by increasing customer satisfaction (Taghizadegan 2006, 1). Lean Six Sigma forms a new practice of how to operate at all organizational levels without increasing resources. The main principle is to adjust, develop, and improve the process efficiency using new innovations, ideas, and lean management tools instead of increasing resources or capital. Lean Six Sigma is a primarily knowledge-based improvement method that focuses on dispersion decreasing in the system which leads to a deeper knowledge of the process. (Karjalainen & Karjalainen 2020, 120.)

Lean Six Sigma is a combination of process improvement and management, information management, data-based methods, and change management. This philosophy includes a systematic improvement process, organizational structure, and objectives to improve the chosen process. (Karjalainen & Karjalainen 2020, 50.)

2.9.1 Six Sigma

Six Sigma is a set of data-driven philosophies for process improvement that can be measured and analyzed using various methods (Taghizadegan 2006, 1). Six Sigma tools and techniques include the following methods:

- Statistical Process Control (SPC)
- Stochastic control (related to probability)
- Data analysis
- Optimization methods
- Analysis of variance
- Lean manufacturing
- Statistical methods
- On-time performance (packing, shipping)
- Waste elimination

Six Sigma process improvement and its problem-solving tools include a lot of statistical, data, and mathematical methods to measure and improve the process. However, only 40 percent of problems can be solved based on rough mathematical and statistical data, and 60 percent are solved using innovative and imaginary problem-solving methods. (Karjalainen & Karjalainen 2002, 31.)

2.9.2 DMAIC – Improvement process

In Lean Six Sigma, development projects are implemented using a DMAIC problem-solving process. DMAIC is an abbreviation of **D**efine, **M**easure, **A**nalyze, **I**mprovement, and **C**ontrol. In each phase of the DMAIC improvement process, various statistical, quality, statistical analyses, and lean tools are used to improve the process. This collection of tools forms a consistent filter of the process that can reveal the bottlenecks and the root cause structure of the process. (Karjalainen & Karjalainen 2020, 216-217.)

Six Sigma and DMAIC methodology is also defined in ISO 13053-1:2011 standard; Quantitative methods in process improvement – Six Sigma – Part 1: DMAIC Methodology (International Organization for Standardization, 2022).

Table 2 shows the needed actions and preparations to be done on each phase of the DMAIC problem-solving process. The timing and use of proper tools performing these tasks are important in each DMAIC phase, and the problems in the current phase shall be solved before the next phase. (Cudney & Kestle 2018, 8.) Lean Six Sigma tools are highlighted as yellow and other supportive methods are underlined.

Table 2. Lean Six Sigma DMAIC process and tools (Cudney & Kestle 2011, 8)

Define	**Measure**	**Analyze**	**Improve**	**Control**
- Project Charter - Subcontractor/Stakeholder Analysis - SIPOC Diagram (Suppliers-Inputs-Process-Outputs-Customers) - Responsibilities Matrix - CTS Tree (Critical to Satisfaction - Project Plan	- Process Map - Data Collection - Pareto Diagram - Histogram - Scatter Diagram - Benchmarking - Process Capability - Cost of Quality - Current State Map	- Test for Normality - Cause & Effect Diagram - Failure Modes and Effects Analysis (FMEA) - 5 Whys - Correlation Analysis - Regression Analysis - 7 Wastes - Kaizen - 5S	- Action Plan - Cost and benefits Analysis - Quality Function Deployment - Future State Map - Main Effects - Scorecards and Dashboards - Design of Experiments	- Control Plan - Standard Work - Mistake Proofing - Training Plan - FMEA - Process Capability - Statistical Process Control (SPC) - Standard Operating Procedures (SOPs) - Lessons Learned

3 RESEARCH AND DATA GATHERING

In this chapter, all research methods and data-gathering functions are reviewed. These methods consist of the case project study of subcontractor´s manufacturing development project, supplier audit, SIPOC diagram of the subcontractor order-to-delivery process, VSM of subcontractor´s order-to-delivery process, joint development meetings, subcontractor's representative's interviews, and Gemba walk at subcontractor´s premises at Tallinn, Estonia.

This chapter includes the research results, analyses, and comments that support the purpose of this final thesis. However, some parts discussed in this chapter have not been considered in chapter 4 since the possible effect on the outcome has been considered minimal according to the author.

3.1 Case study

The data and all relevant information supporting this final thesis outcome are based on the subcontractor´s manufacturing development project data. The data and all other information were gathered during the workshop meetings and during the student project. The author has been a team member of the project organization from the beginning. All necessary data and information shall be used considering the scope of this final thesis. The current state VSM of the subcontractor manufacturing development project´s order-to-delivery process was used as the main data source.

3.2 Supplier Audit

A supplier audit was conducted at subcontractors´ premises in Tallinn, Estonia on 5-6.10.2021. The supplier audit results were used as source material for this final thesis. Gathered data were useful for the deeper analysis of subcontractors´ material management process. Based on the supplier audit report, the findings regarding the material management process or related functions are introduced below.

Figure 6 shows the opportunities for improvement are shown regarding the identification of the materials and indicate the areas that need improvement. The findings are related to product/material identification, traceability, and incoming procedures. In general, all improvement areas refer to the material management process.

Audit Question	COMPLIANT	OFI	MINOR N/C	MAJOR N/C	EVIDENCE	Opportunities for Improvement (OFI)
IDENTIFICATION						
Product/material is properly identified and traceable during all phases of process (Incoming, production, distribution).	x					Storage structure system or location is missing [redacted]
Material and product are traced by manufacturing date/lot code.	x					
Material status is identified by verification of acceptance or rejection and is traceable to inspection location.	x					
Procedures developed to distinguish the status of material (quarantined, rejected, approved).		x				Visual management [redacted]
Non-conforming materials are properly identified (tags or electronic) and segreated from good material.	x					Visual management [redacted]
Material status can only be changed by QA or by their authorization.	x					
Records are maintained that allow for review and traceability of materials from incoming throught to final distribution.	x					

Figure 6. Supplier audit – Identification (Vilhunen Niko, 2022 CC BY-SA)

Figure 7 indicates that there are no major or minor non-conformances, however, all indications refer to opportunities for further investigation of the material management process.

Audit Question	COMPLIANT	OFI	MINOR N/C	MAJOR N/C	EVIDENCE	Opportunities for Improvement (OFI)
RECEIVING INSPECTION						
Is each batch of material received subjected to receiving inspection?	x					
Inspectors are provided with adequate inspection instructions.	x					
Does a documentation system exist to trace batch of material received until batch is expended?	x					
Can evidence of receiving inspection acceptance be found in each batch of material as it moves through the manufacturing process?	x					
Drawings used by receiving inspection are legible and reflect the latest changes.	x					Do you always send latest drawings to your suppliers?
Sampling inspection, when applicable is performed in compliance with established recognized standards.	x					
IN-PROCESS INSPECTION						
Is there an in-process inspection record on each unit or batch?	x					
Do manufacturing and quality personnel annotate the inspection record for each operation performed?	x					
Adequate inspection instructions are made available to all in-process inspection personnel?	x					
Drawings used by inspection are legible and reflect the latest changes.	x					
The measuring devices, gauges and test equipment required for in-process inspection are available and are adequate.	x					
Sampling inspection, when applicable, is performed in compliance with established, recognized standards.	x					
The supplier maintains a system for the proper identification of the inspection status of in-process materials.	x					

Figure 7. Supplier audit – Inspections (Vilhunen Niko, 2022 CC BY-SA)

3.3 SIPOC diagram of the order-to-delivery process

SIPOC diagram of the subcontractor order-to-delivery process was prepared in workshop meeting with NewIcon Oy representatives and the Savonia UAS VSM team. This SIPOC diagram was prepared using the methods that were introduced in the theory section chapter 2.2.1 - Creating SIPOC diagram.

In this final thesis, it is focused on the material management process which is shown inside of the red rectangle area in figure 8.

NEW ICON

Process or Function Name: **Supply Chain & Production Transfer & Subcontracting**			Date: 8.10.2021 modified 1.11.2021	
Scope: **From customer order to delivery**		Notes: Latest Draft Modified by Niko Vilhunen		
SIPOC Diagram				
Suppliers	**Inputs**	**Processes**	**Outputs**	**Customers**
Who supplies the process inputs?	What inputs are required?	What are the major steps in the process?	What are the process outputs?	Who receives the outputs?
Sales (NI)	Project Specification / Modification (NI) / Delivery Deadline (rough)	Transfer Order to Production Project# Opening / Project Kickoff Meeting / Task Lists and Responsibilities / Project Starting time	Approved Product/Project Specification for Delivery Process	Configuration Planning/Project Management
SALES and Project Management (NI)	Approved Delivery / Project Specifications and Documentation (NI)	BOM Processing (Subcontractor) / Product Configuration (NI)	Part Lists (BOM) / Drawings and Pictures / Product Documentation	Procurement (NI) / Contract Manufacturer
Design & Development Team / Configuration Planning / Product / Project Manager (NI)	Project Name / Timetable for Delivery / Capacity and Leadtime Check (NI) / Item #	Release Purchase Order	Purchase Order / Sending BOM / Documentation / Assembly Instructions (NI)	Contract Manufacturer
Project Manager (Subcontractor)	Purchase Order (NI) / BOM (NI)	Production Planning (Subcontractor)	BOM Inputs / Factory Selection / MS Dynamics 365 Business Central ERP (Subcontractor)	Procurement (Subcontractor)
Production Planning (Subcontractor)	Final BOM in Subcontractor´s ERP (Subcontractor)	Ordering Material (Subcontractor)	Received Materials (Subcontractor)	Production (Subcontractor) / Production (NI)
External and Internal Suppliers (Subcontractor)	Material Reception (Subcontractor) / Goods Arrived (Subcontractor)	Receiving the Materials and Quality Check (Subcontractor)	Approved Materials for Production (Subcontractor)	Production (Subcontractor) / Production (NI)
Production Planning / Project Management (Subcontractor) / (NI)	Production Order / Materials Management / Assembly Instructions and Labour (Subcontractor)	System Assembly (Subcontractor)	Assembled System (Subcontractor)	Ramp-Up Team (NI)
Production / Assembly (Subcontractor) / Project Management (NI)	Assembled System (Subcontractor) / Instructions (NI)	System Ramp-Up and Testing (NI)	FAT Approved and Tested System (NI) / End Customer	Logistics Department (Subcontractor) / Disassembly Team (Subcontractor) / Packaging (External)
Production (Subcontractor) / Project Manager (NI)	Packaging Instructions / Material Check List / Physical Goods of System (Subcontractor)	Disassembly and Packing (Subcontractor)	Packaged Goods (Subcontractor)	Logistics Department (Subcontractor)
Production (Subcontractor) / Project Manager (NI)	Documentation (Subcontractor) / Shipment Instructions (NI)	Loading and Shipping (Subcontractor)	Shipment Loaded / Forwarding documentation (Subcontractor)	Freight Company (External)

Figure 8. SIPOC Diagram of order-to-delivery (Niko Vilhunen, 2022 CC BY-SA)

As shown in the SIPOC diagram the subcontractor has external and internal suppliers for items and components. Inputs to the process are material reception and, in the material management process, the materials are received, and the quality inspection is performed. The outputs from this process are approved materials that continue in production. This phase is a component critical to the assembly process. Material management process outputs must comply with the expected and ordered items that equal correct inputs to the assembly process.

For further investigation of the material management process, a new SIPOC diagram of the sub-processes needs to be prepared. Using this method, more detailed data were collected for further analyses. Detailed data were used to trace the possible root causes of occurring defects in the process.

3.4 Value Stream Map – Subcontractor´s order-to-delivery process

The current state Value Stream Map was prepared in a workshop meeting together with all mandatory stakeholders. The data for the Value Stream Mapping workshop was collected from the previous workshop where the SIPOC diagram was prepared. In this workshop, Value Stream Map was prepared using step by step method starting from the production planning phase and ending in the material management (packing, loading, and shipping) phase.

Figure 9 shows the current state VSM of subcontractors´ order-to-delivery process. The focus is on the material management phase which is inside the red rectangle.

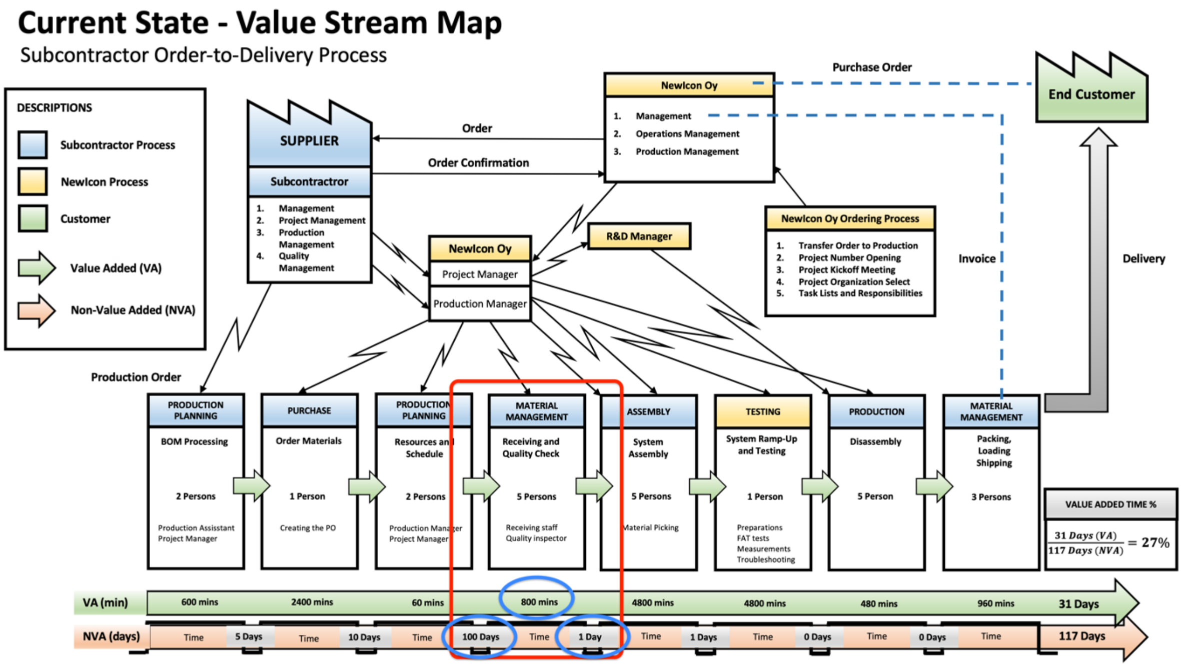

Figure 9. Current state VSM (Vilhunen Niko, 2022 CC BY-SA)

As the current state VSM shows, the material management process phase is the 4th process in the order-to-delivery process. The first major finding was the 100 days of NVA time between the production planning and material management processes. This gap indicates the possible delivery problems of needed components. Since the current global challenges of supply chain management, lack of resources, and lack of raw material of specific components will affect the whole order-to-delivery chain. These aspects have a major influence on all NewIcon´s delivery projects. Process improvement and the development of new tools and procedures to reduce lead time are critical tasks for the processes. Applying lean principles e.g. Just-In-Time could be challenging since the excess inventory of components is considered waste.

Subcontractor lead time in the material management process was 800 minutes (13,33 hours) and indicated the value-added time for 5 persons. This indicates a satisfactory level of performance regarding the process. The number of resources exceeds the level of the needed capacity, and the costeffectivity level needs to be improved. The data regarding this matter shall be introduced in subchapter 3.5 – Material management process comparison – Manufacturer vs. subcontractor.

There was also a delay in the material management process outputs. There was a 1-day NVA time between the material management and assembly processes that indicated a possible defect(s) in the process output. This indicated deviation in the process flow since both processes functioned in the same area. One of the possible reasons for this defect is the lack of communication between available resources and stakeholders.

3.5 Material management process comparison – Manufacturer vs. subcontractor

Data for material management process comparison was collected from the workshop meetings in cooperation with stakeholders. In this subchapter, the studied process is compared between the NewIcon Oy and the subcontractor material management process regarding the same product.

Figure 10 shows a clear indication of the difference between NewIcon Oy and the subcontractor although the process and the product are identical. NewIcon´s material management process lead time (VA) is 450 mins (7,5 hours) and subcontractors´ lead time (VA) is 800 minutes (13,33 hours). The difference between parties is 350 minutes (5,83 hours). There was also a 1-day (NVA) difference in process outputs.

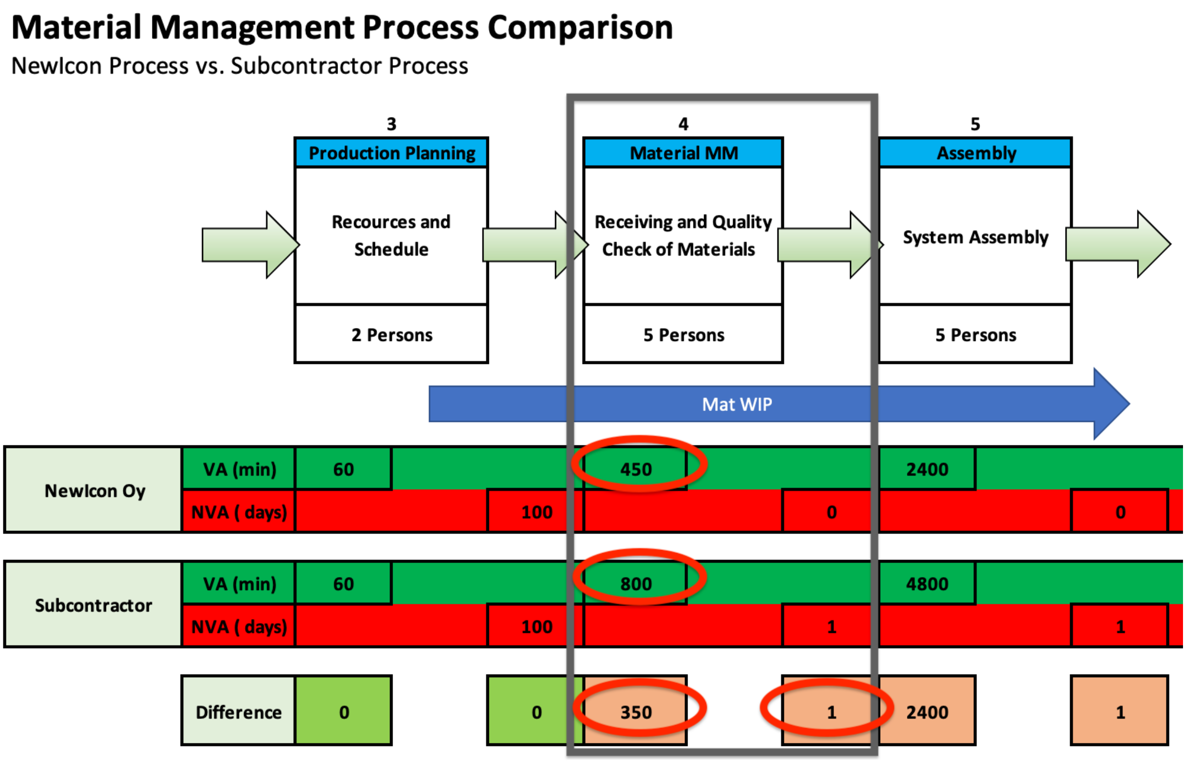

Figure 10. The material management process comparison (Vilhunen Niko, 2022 CC BY-SA)

Part of the VA time analyses and feedback from the initial results of the current state VSM based on the e-mail discussion with the subcontractors' Quality Manager. According to subcontractors QM, the lack of knowledge regarding NewIcon´s own material management process is the major reason for the difference in VA times. Also, labeling each component is a time-consuming process since all components are added to the ERP system separately. (Quality Manager, 2021.)

Based on the resource data between NewIcon Oy and the subcontractor, findings were critical. Although the main steps of the processes were the same, the variation in the resource figures was alarming. The comparison of the processes of VA times and resources can be seen in figure 11.

Resources per Processes

NewIcon Resources vs. Subcontractor Resources

VA/NVA Time	Process	NI	Subcontractor	Difference	NI Persons	Subcontractor reported persons
VA	BOM Processing	800	600	-200	1	2
VA	Order Materials	240	2400	2160	1	1
VA	Production Planning	60	60	0	1	2
VA	Receiving and IQC	450	800	350	1	5
VA	Assembly	2400	4800	2400	1	5
VA	Testing	2250	2250	0	2	1
VA	Dissassebly	480	480	0	1	5
VA	Packing Shipping	960	960	0	2	3
	Value Added Total	7640	12350	4710		

Figure 11. Resources per processes comparison (Vilhunen Niko, 2022 CC BY-SA)

The comparison data shows that NewIcon Oy needs 1 person to perform the material management process, and the subcontractor needs 5 persons for the same operation. The comparison data is based on the same product and project scope. The cost impact can be critical if the subcontractor needs four times more resources in the same process and perform similar tasks during the operation. This data indicates that NewIcon Oy can add and create value for the process with just one person. According to chapter 2.3 of lean philosophy, NewIcon Oy can establish to create more value with fewer resources and less waste. The subcontractor´s process must be improved and carried out with fewer resources by applying lean tools in their process.

3.6 Joint development meeting

The joint development meeting's purpose was to launch a workshop to collect data and define the current state of the material management process flow. In addition to the author, participants in this workshop were the subcontractor Key Account Manager (KAM), and Quality Manager (QM). The other important topic in this workshop meeting was setting the preliminary guidelines for Incoming Quality Control (IQC) procedure. Developing a functional IQC procedure was a high-priority task for NewIcon Oy, since the data is not available from subcontractors' components and material suppliers.

The current state material handling process flow was defined during this workshop. This process flow chart was made from the subcontractor's point of view representing the current state of process flow. The process map of the current state material handling process is shown in figure 12.

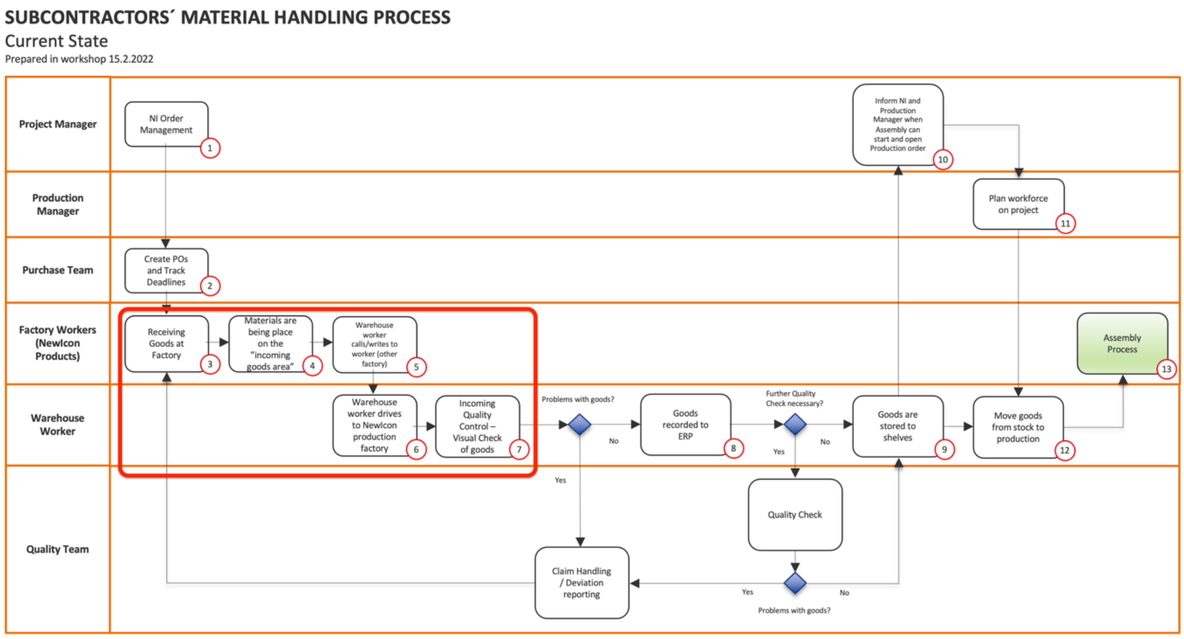

Figure 12. The subcontractor material handling process (Vilhunen Niko, 2022 CC BY-SA)

The subcontractor material handling process description was a success regarding the findings in the process. There were various steps in the process that need lean methods and tools to be applied e.g. 5S, waste elimination, Standard Operating Procedures (SOPs), and continuous improvement. There was also a lack of instructions for the incoming quality control (IQC) procedure. Using the right procedures and applying lean tools to steps 3, 4, 5, 6, and 7, the process can be improved and most of the waste eliminated.

The other topic was to set preliminary guidelines for the incoming quality control procedure. After a discussion regarding quality control, the workshop team made a preliminary list of major inspection items. The general idea was to keep the incoming quality inspection procedure efficient, reliable, and able to perform with existing resources. IQC procedure and quality training was also discussed during the workshop. The purpose of creating the IQC checklist was to keep it simple and clear, and only a few inspection steps were included in the workshop sketch version.

During the workshop, the team made a five (5) step preliminary IQC Checklist as follows:

Preliminary IQC – Checklist

1. The overall condition of items (date, quantity, packaging)
2. Document check (purchase order, cargo manifest)
3. Labeling (must be based on ERP data)
4. Project shelf (sorted and approved items)
5. Inform assembly team (clear communication between stakeholders)

3.7 Interviews

Interviews were conducted in February 2022 through face-to-face meetings during the author´s visit to subcontractors' premises in Tallinn, Estonia. The purpose of these interviews was to achieve qualitative data regarding the material management process for further analyses and conclusions. These interviews were conducted during a workshop meeting.

The following questions were prepared:

- How long does it take to complete the material receiving process?
- Who is responsible for deviation reporting regarding material defects?
- How is the communication carried out between the two factories?
- Who is responsible for material labeling?
- What information is given to the next process and to whom?
- Describe the current incoming inspection procedure?

To receive some preliminary data for the development of generic tools to improve subcontractor´s material management process, interviews were carried out with stakeholders in the process of material handling. The preliminary process flow of subcontractors´ material handling process was prepared before the interviews. The interviewed persons were the subcontractor´s Quality Manager (QM), and Key Account Manager, (KAM) who also acts as a Project Manager (PM) in operations between NewIcon Oy and the subcontractor.

Here below is a summary of the persons interviewed, more detailed information about the interviews falls under a non-disclosure agreement between stakeholders. However, the effect of this matter is considered non-critical regarding the outcome of this final thesis.

Quality Manager

The subcontractor´s Quality Manager (QM) is responsible for all quality-related issues regarding daily operations and coordinates the deviation reporting system.

According to QM, warehouse workers are responsible for receiving goods on-site and perform the labeling of the incoming goods. The communication between two factories is carried out by phone, Teams, or email. Warehouse workers inform when the incoming goods delivery arrives at the factory, and when the quality inspection can be performed. Quality inspections are done by the quality team member since there is no qualified staff at the factory where NewIcon´s products are manufactured. The current quality inspection procedure includes visual inspection and item quantity checks. Further inspections are made, if necessary, usually when defects occur. (Quality Manager, 2022.)

Key Account Manager / Project Manager

The subcontractor Key Account Manager (KAM) / Project Manager (PM) is responsible for project delivery and collaboration with NewIcon Oy. KAM/PM coordinates daily operations regarding the ongoing projects and is responsible for reporting to NewIcon´s Production Manager and the Project Manager.

According to KAM, the material management process takes some time when goods arrive in the factory. Warehouse workers are instructed to inform the project management regarding the shipment arrival. Once a day PM goes to the factory and checks the daily operations and manufacturing process flow. The project management office is located on subcontractors´ premises 10-15 kilometers away from NewIcon´s production line and the warehouse. Deviation reporting procedures belong to quality team responsibilities. When defects occur, warehouse workers will inform the quality team to launch the reclamation process. The next process, in this case, the assembly phase will begin when all needed parts have arrived. Quality inspection includes visual inspection, quantity check of items, and the overall condition of the goods. (Key Account Manager, 2022.)

Author comments

KAM/PM is overworked when resourcing and organizing employees during the delivery project. Communication between the two factory sites was at a good level, but misleading information can lead to production interruption. There was a lot of excess movement of employees between two factory sites depending on the roles and responsibilities. Some employees are located only in the factory where NewIcon´s products are assembled, but they are not qualified to receive materials nor perform quality inspections. This kind of arrangement increases employee movement, waiting time, and processing, and can cause defects, in other words, increase the waste in the process.

The QM was aware of the lack of communication problems between two factory sites. However, QM did not have any proper solution for the procedure. All qualified employees who can perform quality inspections are allocated to the main factory where the project management office is located.

3.8 Process observation – Gemba walk

Gemba walk was conducted at the subcontractor’s factory where NewIcon´s products are manufactured, assembled, and tested. The purpose of the Gemba walk was to gather on-site data on the material management process and walk through the functions. Another important topic was to analyze and screen the production environment from a “lean” perspective and study if there were any lean principles implemented.

The factory area was clean and relatively well organized and the overall first impression was good. There were no signs of implemented 5S procedures although the layout planning was well prepared for the material handling functions. The rotation of the floor plan was clear, but there was a lack of knowledge in the implementation of correct procedures. According to the author, the procedure shall be generated to improve the material management process at the factory site in question.

4 RESULTS AND DISCUSSION

In this section, the main purpose is to introduce the results and the outcome of this final thesis. The generic tools developed and are introduced during this final thesis project. The results and the recommendations of the outcome of this final thesis are based on the theory section, research, analyzed data from the case project, joint development meetings, interviews, and Gemba walk.

All lean tools mentioned in the theory, research, and data gathering sections have been considered when developing the process improvement tools introduced in the following subchapters.

4.1 Material management process flow chart – Future state

Based on the data, research, interviews, and Gemba walk on-site, the process flow chart of the material management process was prepared. There were a lot of improvement areas but the most significant was the removal of excess process steps and adding the tools and instructions part in the process flow chart. The tools and instructions part of the process chart below section will guide the personnel to follow the correct instructions and procedures provided by NewIcon Oy.

Figure 13 shows the future state of the material management process as a flow chart. In this process flow chart, improvements have been added in comparison to subcontractor´s current state material handling process. Waste has been eliminated and communication flow between the parties was improved.

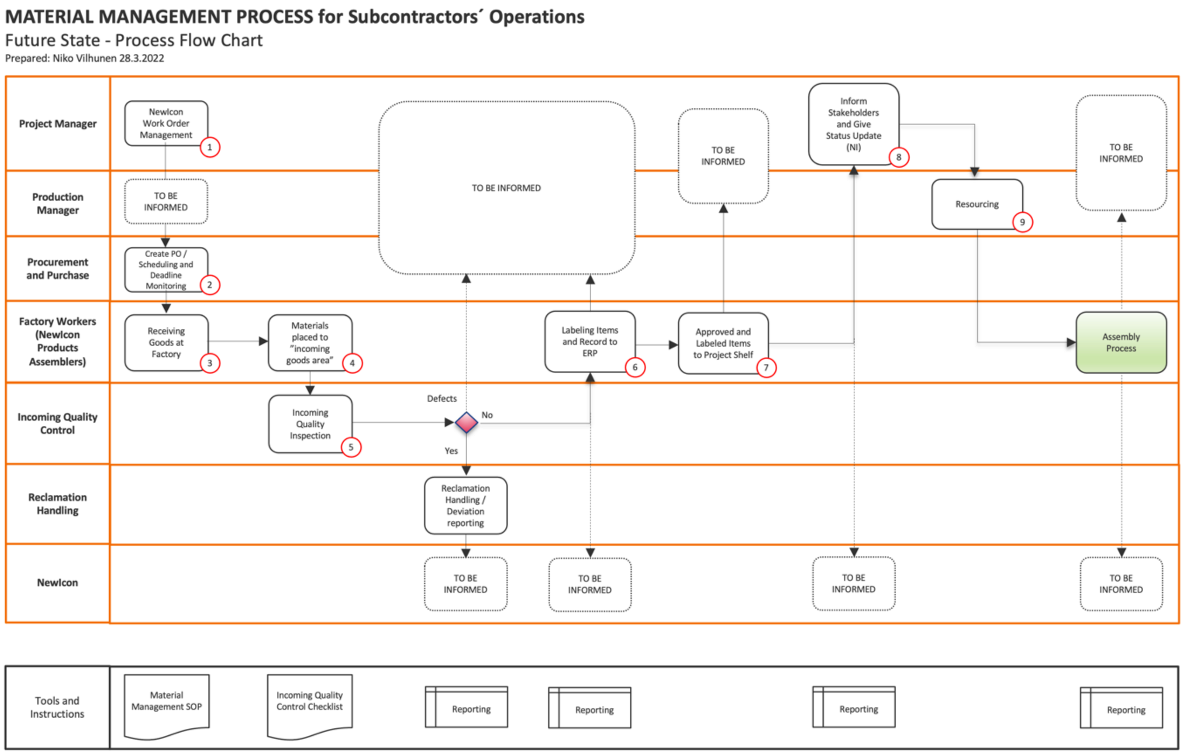

Figure 13. Material Management Process - Process flow chart (Vilhunen Niko, 2022 CC BY-SA)

4.2 Standard Operating Procedure (SOP) – Incoming Quality Control (IQC) for subcontractor´s operations

Standard Operating Procedure (SOP) – Incoming Quality Control (IQC) for subcontractor´s operations was prepared by the author during the final thesis project. It has been agreed with NewIcon Oy that the prepared SOP falls under a non-disclosure agreement and will not be published entirely. However, some sections e.g., appendixes in the SOP, are published in this final thesis e.g. Incoming Goods Quality Inspection - Checklist and sample inspections table(s) and instructions.

The contents, general parts, and complied standards of SOP will be reviewed here below. The structure and the contents of the SOP are described below.

- Introduction
- Guidelines
- Purpose
- Material management
- Layout plan recommendation
- Process flow
- External references
- Internal references

SOP – Incoming Quality Control for subcontractor´s operations was created and is based on the gathered data from the case project and supports this final thesis project. SOP complies with standards ISO-9001:2015 Quality Management Systems and ISO-2859-1:1999 Sampling procedures for inspection attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection. Incoming goods quality inspection – checklist can be found in APPENDIX 1. Incoming goods sampling inspection – checklist can be found in APPENDIX 2. Acceptance quality limit (AQL) table(s) can be found in APPENDIX 3. Sampling and acceptance limits table(s) can be found in APPENDIX 4.

4.3 SIPOC diagram of the material management process – Future state

SIPOC diagram of the material management process was prepared by the author and is based on the research results and process observations during the final thesis project. This procedure supports the final thesis result and will provide a more reliable comparison of the current state and future state processes since the material management process is divided into a small sub-process. The used data are based on the author´s on-site visit to the subcontractor´s premises and the supporting information was collected from the theory, research, and data gathering sections.

Figure 14 shows the phases of the whole material management process and is created step by step through the process starting from suppliers and ending with customers.

NEW ICON

SUPPLIERS - INPUTS - PROCESSES - OUTPUTS - CUSTOMERS (SIPOC) - Template

Intended for process improvement

Process or Function Name:	Date:	Revision	Remarks
Subcontractor Material Management	**24.3.2022**	Version 1.2	**NIL**
Scope:	**Prepared:**	**Approved:**	
Production Planning Output to Assembly Input	Niko Vilhunen	Niko Vilhunen	

SIPOC Diagram

Suppliers	**Inputs**	**Processes**	**Outputs**	**Customers**
Who supplies the process inputs?	**What inputs are required?**	**What are the major steps in the process?**	**What are the process outputs?**	**Who receives the outputs?**
PRODUCTION PLANNING PRODUCTION MANAGER / PROJECT MANAGER (NewIcon Oy)	Confirmed PO / Delivery Confirmation and Tracking Delivery / Schedule Monitoring	**INBOUND DELIVERY**	Items Delivered to Incoming Goods Area	Purchase and Procurement (Delivery Status) / Warehouse Employees
WAREHOUSE EMPLOYEES (Certified to Perform Inspections)	Received Material Ready for Inspection	**INCOMING QUALITY INSPECTION** Incoming Goods Quality Inspection (IQC - Checklist)	Inspected and Accepted Items / Rejected Items	Material Handling Personnel (Warehouse Employees)
MATERIAL HANDLING (Warehouse Employees)	Approved and Inspected Items for Sorting and Labeling	**MATERIAL LABELING AND SORTING** Inspected and Approved Materials and Components	Labeled and Sorted Items	ERP System Certified Warehouse Employees
MATERIAL HANDLING (Warehouse Employees)	Labeled and Sorted Items Ready for Recording	**ERP SYSTEM INPUTS** Material and Component Recording	Recorded, Labeled and Inspected Items	Warehouse Employees
MATERIAL HANDLING (Warehouse Employees)	Confirmed and Checked Materials (ERP and IQC)	**PROJECT STOCK** Delivery Project Materials are Placed to Stock	Sorted / Assembly Qualified Items Cross Checked with ERP System	Assembly Team

Figure 14. SIPOC of subcontractor material management process (Vilhunen Niko 2022, CC BY-SA)

4.4 Value Stream Map of the material management process – Future state

The optimal target mode of the subcontractor´s material management process shall lead to 74% of the value-added time. This can be carried out by following the precise instructions found in SOP – Incoming Quality Control for subcontractor´s operations (see chapter 4.1) and applying the lean tools in the process and following the training program of process development that is out of the scope of this final thesis.

The future state process of the material management process is shown in figure 15.

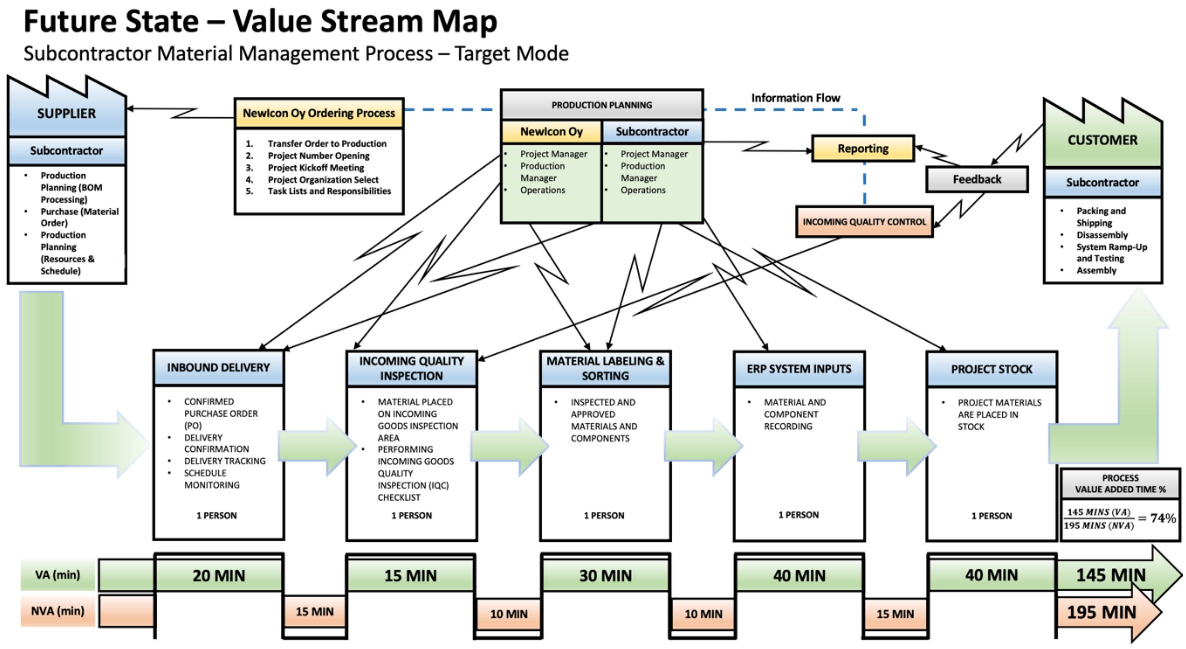

Figure 15. The material management process - Target mode (Vilhunen Niko, 2022 CC-BY-SA)

4.5 Results and further actions

The actual results and the outcome of this final thesis project can be further developed and analyzed after implementing the material management future state process flow chart (see figure 14) and using the Future State–Value Stream Map (see figure 16) a reference. The procedures are introduced in chapter 4.1. SOP – Incoming Quality Control for subcontractors´ operations. Implementation of these procedures and instructions needs to be done by applying lean thinking in daily operations and following the P-D-S-A cycle and continuous improvement principles.

5 CONCLUSION

Before this final thesis project was started the author already had many improvement ideas and a preliminary implementation plan for the whole project. The case project was researched, and more data was gathered during a visit to the subcontractor´s premises. However, the results of this final thesis project exceeded the target level set by the author. The outcome was excellent, including the usage of various process improvement and mapping tools, and lean six sigma tools to improve the subcontractor´s material management process.

The usage of these mentioned tools was studied in the final thesis, theory section, data was gathered in the research section supporting the theory section, and finally, the implementation of these tools was successfully done resulting in substantial improvement in subcontractor´s material management process. SOP – Incoming Quality Control for subcontractors´ operations was created and can be improved when the material management process is continuously monitored in future actions.

Reliability and ethics have been proven in various ways based on the outcome of this final thesis project. This final thesis project was a successful combination of theory, research, qualitative methods, and outcome results. However, the actual reliability and ethics can be measured when the subcontractors' material management process is monitored for the first time after the implementation of all generated tools. The theory and the research section of this final thesis have been proven reliable based on the outcome results.

This final thesis project was a substantial learning process for the author. There were a lot of new insights from the lean six sigma tools and a substantial part of the learning process came from the on-site visit to the subcontractors' premises. In the future, the planning of the whole project could be done more specifically resulting in cost and time savings.

REFERENCES

American Society for Quality 2022. What are the five S´s (5S) of lean? Internet Publication. https://asq.org/quality-resources/lean/five-s-tutorial. Accessed 10.3.2022.

Cudney, Elizabeth A. & Kestle, Rodney. 2011. Implementing Lean Six Sigma throughout the Supply Chain. The Comprehensive and Transparent Case Study. 1st Edition. New York. Productivity Press.

International Organization for Standardization 2022. Store. ISO 13053-1:2011 Quantitative methods in process improvement – Six Sigma – Part 1: DMAIC Methodology. Internet Publication. https://www.iso.org/standard/52901.html. Accessed 24.3.2022.

Karjalainen, Eero E. & Karjalainen, Tanja. 2000. Laatujohtamisoppien (TQM) soveltaminen PK-yritykseen. SPC, systeemiteoria, TOC-teoria. 2nd Edition. Hollola: Quality Knowhow Karjalainen Oy.

Karjalainen, Eero E. & Karjalainen, Tanja. 2002. Six Sigma. Uuden sukupolven johtamis- ja laatumenetelmä. 1st Edition. Hollola: Quality Knowhow Karjalainen Oy.

Karjalainen, Eero E. & Karjalainen, Tanja. 2020. Lean Six Sigma 2.0 ja Laatuteknologia. 1st Edition. Lahti: Quality Knowhow Karjalainen Oy.

Keller, Paul. 2011. Statistical Process Control DeMYSTiFieD. 1st Edition. The United States of America. McGraw-Hill Inc.

Key Account Manager 2022. Key Account Manager. Subcontractor 15.2.2022.

Krajewski, Lee, Malhotra, Manoj & Ritzman Larry. 2019. Operations Management. Processes and Supply Chains. 12th Edition. Harlow. Pearson Education.

Lean Enterprise Institute 2022. Seven Wastes. Internet Publication. https://www.lean.org/lexicon-terms/seven-wastes/. Accessed 12.3.2022.

Lean Enterprise Institute 2022. What is Lean. Internet Publication. https://www.lean.org/explore-lean/what-is-lean/. Accessed 24.3.2022.

Liker, Jeffrey K. & Ross Karyn. 2017. The Toyota Way to Service Excellence. Lean Transformation in Service Organizations. 1st Edition. The United States of America. McGraw-Hill Inc.

Nicholas, John. 2018. Lean Production for Competitive Advantage. A Comprehensive Guide to Lean Methods and Management Practices. 2nd Edition. Boca Raton. CRC Press.

Quality Manager 2021. Value Stream Mapping initial results. Email message 6.12.2021. Recipient: Niko Vilhunen

Quality Manager 2022. Quality Manager. Subcontractor. Interview 15.2.2022.

Taghizadegan, Salman. 2006. Essentials of Lean Six Sigma. Savonia Finna online service. https://ebookcentral-proquest-com.ezproxy.savonia.fi/lib/savoniafi/reader.action?docID=270378. Accessed 26.3.2022.

Torkkola, Sari. 2021. Lean Asiantuntijatyön Johtamisessa. 8th Edition. Helsinki. Alma Talent.

Vilhunen, Niko 2021. NEWICON OY – Internal Networks and Subcontractor Networks. Course Report. Supply Chain and Network Management. Savonia UAS.

Vilhunen, Niko 2022. Current state VSM. Photograph 30.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Material Management Process - Process flow chart. Photograph 29.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Material management process - Target mode. Photograph 27.2.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Material management process comparison. Photograph 29.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Plan-Do-Study-Act cycle. Photograph 16.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Resources per processes comparison. Photograph 29.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. SIPOC Diagram of order-to-delivery. Photograph 14.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. SIPOC main steps. Photograph 28.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. SIPOC of subcontractor material management process. Photograph 2.4.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Subcontractor material handling process. Photograph 29.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Supplier audit – Identification. Photograph 13.3.2022. Kuopio: Niko Vilhunen´s collections.

Vilhunen, Niko 2022. Supplier audit – Inspections. Photograph 13.3.2022. Kuopio: Niko Vilhunen´s collections.

APPENDIX 1: INCOMING GOODS QUALITY INSPECTION – CHECKLIST

NEW ICON

Supplier Incoming Quality Control Checklist

APPENDIX A - INCOMING GOODS QUALITY INSPECTION - CHECKLIST

Intended for Supplier Material Management Process Compliance

NEW ICON	**INCOMING GOODS DELIVERY**	**CHECKLIST**	**DOC-CL-001**	
		Date: 29.03.2022	**Prepared:**	**Approved:**
		Version 1.0	Niko Vilhunen	Niko Vilhunen

Factory / Delivery site:		**Received:**	**Delivery Date:**
Example Factory		**MM**	**29.3.2022**
Supplier Code and Name:	**Purchase Order No. / Shipment No.**	**Delivery No.**	**Batch No.**
Supplier	**91786-metal parts-shelf**	**330083**	**200013**
Item No.	**Item Description:**	**Quantity:**	**Pieces on pallet:**
203271D_0	**Shelf 10 product lines, W72**	**250**	**76**
Project No.	**Project Manager / Responsible person:**	**Process:**	**Process Owner:**
900324	**Name of Project Manager**	Material Management	**Name of Process Owner**

ITEM	FUNCTION	INSPECTION CHECK TASKS	CLASSIFICATION MA	CLASSIFICATION MI	CLASSIFICATION CP	NCR Yes/No	REMARKS
1	Packaging	1) Shipping marks are clear and legible. 2) Package is not physically damaged. 3) Packaking method meets the general requirements (Package handling can be done efficiently without possibility to defects).					
2	Labeling	1) Labels and markings are printed properly and located on the outer side of the package. 2) Labels and markings are clear and legible. 3) Purchase Order (PO) information match the packing list of the delivery (if applicable). 4) Quantity, size and weight of the package 5) Traceability • The name, address and information of the manufacturer / Supplier • The batch/lot number					
3	Visual Inspection	1) No visible damage on the package. 2) No sharp edges around the package. 3) Pallet condition.					
4	Material Handling	1) Remove the packing material from the delivery. 2) Perform visual inspection of the delivered items. 3) Check and match the packing list with Purchase Order (PO), Bill of Materials (BOM), Product configuration/specifications documents or any relevant documentary of delivered items. 4) Deliver items to material management process.					
5	Sample Inspection	1) Follow the procedures given in APPENDIX B - Incoming goods sampling inspections - Checklist					

Additional Comments:

If one or more items are marked as "MA" or "MI" gategory, NCR Procedure must be followed and all actions must comply with non-conformance/deviation reporting instructions and procedures. All questions regarding incoming quality control and inspections shall be forwarded to the applicable Quality/Production/Procurement/Logistic/Supplier representative or responsible person.	**Inspector Approval:**

APPENDIX 2: INCOMING GOODS SAMPLING INSPECTION – CHECKLIST

NEW ICON **Supplier Incoming Quality Control Checklist**

APPENDIX B - INCOMING GOODS SAMPLING INSPECTION - CHECKLIST

Intended for Supplier Material Management Process Compliance

NEW ICON	**SAMPLE INSPECTION**	**CHECKLIST**	**DOC-CL-002**
		Date: 08.03.2022	**Prepared:** Niko Vilhunen / **Approved:** Niko Vilhunen
		Version 1.0	
Factory / Delivery site: Example Factory		**Received:** MM	**Delivery Date:** 29.3.2022
Supplier Code and Name: Supplier	**Purchase Order No. / Shipment No.:** 91786-metal parts-shelf	**Delivery No.:** 330083	**Batch No.:** 200013
Item No.: 203271D_0	**Item Description:** Shelf 10 product lines, W72	**Quantity:** 250	**Pieces on pallet:** 76
Project No.: 900324	**Project Manager / Responsible person:** Name of Project Manager	**Process:** Material Management	**Process Owner:** Name of Process Owner
Sample size: 76	**Component Description:** Metal shelfs	**Inspection Level:** cat II	**Inspector:** Name of Inspector

ITEM	FUNCTION	INSPECTION CHECK TASKS	CLASSIFICATION MA	CLASSIFICATION MI	CLASSIFICATION CP	NCR Yes/No	REMARKS
1	Visual inspection	1) Shipping marks are clear and legible. 2) Package is not physically damaged. 3) Packaking method meets the general. requirements (Package handling can be done efficiently without possibility to defects).					
2	Sampling Size	1) Check the lot size (Number of ordered products). 2) Choose the level of inspection (use normal level cat II in normal conditions) refer to APPENDIX C - Acceptance quality limit (AQL) table(s). 3) Choose the letter code from the table based on the lot size (Number of ordered products). 4) Choose the acceptance quality limit (AQL) % (use 4,0% in normal conditions) refer to APPENDIX D - Sampling and acceptance limits table(s). 5) Use APPENDIX D - Sampling and acceptance limit table(s) to compare the letter code and lot size with acceptance % (Normal condition 4,0%). 6) Check the acceptance limits from the table.					
3	Sample Inspection	1) Perform sample inspection for each items • Overall condition, paint job, dimensions, etc. 2) Sort and mark accepted and non-accepted items. 3) Make notes of the defects 4) Launch reclamation process complied with company policy					
4	Reporting	1) Launch reporting process complied with this SOP reporting instructions found on Chapter 8.					

Additional Comments:

If one or more items are marked as "MA" or "MI" gategory, NCR Procedure must be followed and all actions must comply with non-conformance/deviation reporting instructions and procedures. All questions regarding incoming quality control and inspections shall be forwarded to the applicable Quality/Production/Procurement/Logistic/Supplier representative or responsible person.	**Inspector Approval:**

APPENDIX 3: ACCEPTANCE QUALITY LIMIT (AQL) – TABLES(S)

NEW ICON

Prepared: Niko Vilhunen 29.3.2022

Intended for Supplier Material Management Process Compliance

APPENDIX C - ACCEPTANCE QUALITY LIMIT (AQL) - TABLE(S)

BASED ON ISO-2859-1:1999 - Sampling procedures for inspection by attributes										
TABLE I			Sample Size Code Letters							
Lot size (Quantity of ordered products)			General inspection levels			Special Inspection Levels				
			I	II (Normal)	III	S-1	S-2	S-3	S-4
2	to	8	A	A	B	A	A	A	A
9	to	15	A	B	C	A	A	A	A
16	to	25	B	C	D	A	A	B	B
26	to	50	C	D	E	A	B	B	C
51	to	90	C	E	F	B	B	C	C
91	to	150	D	F	G	B	B	C	D
151	to	280	E	G	H	B	C	D	E
281	to	500	F	H	J	B	C	D	E
501	to	1200	G	J	K	C	C	E	F
1201	to	3200	H	K	L	C	D	E	G
3201	to	10000	J	L	M	C	D	F	G
10001	to	35000	K	M	N	C	D	F	H
35001	to	150000	L	N	P	D	E	G	J
150001	to	500000	M	P	Q	D	E	G	J
500001	to	and over	N	Q	R	D	E	H	K

APPENDIX 4: SAMPLING AND ACCEPTANCE LIMITS TABLES(S)

NEW ICON

Prepared: Niko Vilhunen 29.3.2022

Intended for Supplier Material Management Process Compliance

APPENDIX D - SAMPLING & ACCEPTANCE LIMITS TABLE(S)

TABLE II	Number of Samples	BASED ON ISO-2859-1:1999 - Sampling procedures for inspection by attributes – Acceptance Quality Limits (AQL) in %																																	
		0,015		0,025		0,04		0,065		0,1		0,15		0,25		0,4		0,65		1		1,5		2,5		4,0		6,5		10		15		25	
		✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #	✓ #	✗ #
A	2																											0	1					1	2
B	3																									0	1					1	2	2	3
C	5																							0	1					1	2	2	3	3	4
D	8																					0	1					1	2	2	3	3	4	5	6
E	13																			0	1					1	2	2	3	3	4	5	6	7	8
F	20																	0	1					1	2	2	3	3	4	5	6	7	8	10	11
G	32															0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15
H	50													0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22
J	80											0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22		
K	125									0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22				
L	200							0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22						
M	315					0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22								
N	500			0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22										
P	800	0	1					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22												
Q	1250					1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22														
R	2000			1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22																

✓ 1 Acceptance

✗ # Rejection