TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Mechanical and Industrial Engineering

IMPROVEMENT OF MANUFACTURING OPERATIONS TRACKING PROCESS IN KITMAN THULEMA AS

TOOTMISOPERATSIOONIDE JÄLGITAVUSE PARENDAMINE ETTEVÕTTES KITMAN THULEMA AS

MASTER THESIS

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Tallinn 2020

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THESIS TASK

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Thesis topic:

(in English) Improvement of manufacturing operations tracking process in Kitman Thulema AS

(in Estonian) Tootmisoperatsioonide jälgitavuse parendamine ettevõttes Kitman Thulema AS

Thesis main objectives:

1. Analyse the current process of tracking operations in Kitman Thulema AS
2. Propose a new approach for tracking operations in Kitman Thulema AS
3. Compare the AS-IS and TO-BE processes
4. Evaluation of the approach implementation

Thesis tasks and time schedule:

No	Task description	Deadline
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2.	Modeling of AS-IS and TO-BE processes	31.03.2020
3.	Analyzing results	30.04.2020
4.	Conclusions. Formatting	15.05.2020

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CONTENTS

PREFACE

This thesis was initiated by Jana Lodjak who has a Bachelor's degree in wood- and textile technology and a work experience in a furnishing company. The author wished to research a relevant topic in a company in the field of furnishing and due to the need of reducing waste in order to stay competitive it was needed to improve the manufacturing operations tracking process in Kitman Thulema AS.

I would like to thank my supervisor Tatjana Karaulova for the guidance, helping with ideas and keeping me motivated during the whole process. I would also like to thank Tarmo Liloson for providing me with information and letting me conduct this thesis in Kitman Thulema AS.

Keywords: Manufacturing digitalization, Details tracking, Operations tracking

INTRODUCTION

1.1 Background and motivation

Kitman Thulema AS is a company based on Estonian capital manufacturing different furnishing solutions made of wood and metal. The company was founded in 1936 and is owned by NG Investeeringud. Kitman Thulema produces commercial furnishings, special solutions for public space interiors, metal furniture, office furniture and cold equipment. The plant is located in Tallinn, Estonia. [1] Thulema is trademark in Estonia for office and public space furniture. The emphasis is on using people and environmentally friendly materials while making ergonomic and innovative furniture. Nevertheless, Kitman Thulema AS has the longest history in producing metal products. Their portfolio consists of lockers, shelves, post-boxes, professional kitchens, military furniture etc. [2] In addition, Kitman Thulema AS is able to offer special solutions ranging from concept development, completion of design and production, to installation and maintenance of the product. Most of the produce is being exported to the Baltic countries, Finland, Sweden, Germany, Spain, Italy, France and Russia. [1]

In order to stay competitive in today's market it is important for companies to promote a vision of the process industry with green, smart and efficient manufacturing. Process industry refers to elementary raw material industries that are fundamental for the national economy and are also important for the success of the economy of the world's manufacturing economy. In order to improve the process industry, modern information technology can be used to optimize the processes for manufacturing, management and marketing. Smart and optimal manufacturing aims to realize four goals: agility, high efficiency, environmental sustainability and safety. [3]

Most economies face the digital revolution where in addition to routine work, advanced job tasks are also being automated [4]. Process Industry has a great impact on Estonia's economy. Analysts from Swedbank have found that between 2015 and 2018 the labor costs have increased by 6-8% per year. In addition, the labor is also increasingly difficult to find. This means that manufacturing companies need to focus on digitalization and automation of the manufacturing processes and warehousing. [5]

Currently Kitman Thulema AS does not have a system implemented that provides an overview of the manufacturing in real time. The company has thought about implementing a technology for tracking the details in manufacturing but has not followed through with it due to complications in the finishing line. The finishing line is where Kitman Thulema AS encounters issues regarding traceability of the details and operations. The details have identifying marks that are readable prior to being loaded into the line but these get covered with finishing. When the details are being unloaded from the line there are no identifiable markings.

1.2 Structuring the problem

Kitman Thulema AS currently has no standardized system for tracking the manufacturing operations in metal products line. This means there is no real time information available about manufacturing which makes it difficult to make informed managerial decisions and react fast to any market changes or client demands.

The lack of information causes problems in finding the details in the manufacturing area which in turn causes delays in deliveries. The company cannot presume delays as these entail additional costs in terms of transportation and sometimes even fines.

In order to improve the situation, the author analyzed current processes in Kitman Thulema AS. First, it was needed to determine to what extent the details are currently marked, how the information is reported and what is the time spent on it. Next, literature study was commenced to find the most suitable solution considering company's manufacturing process. Finally, the author selected the new system and analyzed it.

1.3 Objective and tasks of the study

The objective of this work is to propose a new approach for real time tracking of operations in the metal products manufacturing line at Kitman Thulema AS. Also, to find modern technologies that will make this process more efficient, transparent and less dependent of the human factor. To achieve this aim it is necessary to identify and analyze the current state of tracking the details in metal products manufacturing and have an overview of manufacturing process in all its phases. It is essential for the company for being flexible and competing on the market successfully. The absence of real-time manufacturing process data makes the control and scheduling of the plant meaningless and results in many issues.

By implementing a system for tracking the details in manufacturing the company benefits by:

1. Having a possibility in making better managerial decisions by having an exact up to date overview of the manufacturing at all times;
2. Improved delivery accuracy;
3. Lowering the cost on transportation due to delays;
4. Lowering the cost of the products through identifying defects and the causes of defects fast;
5. Possibility to compare planned and actual costs;
6. Possibility to implement automatic manufacturing planning system;

Research tasks were:

1. The study of available methods and technologies;
2. Analysis of the current process;
3. Decision matrix development for choosing the most suitable marking method from all options; the experts assessment by using of Kendall coefficient of concordance.
4. Comparison of AS-IS and TO-BE models;
5. Evaluation of the approach implementation.

1.4 Research approach, used methods and work structure

Methods used:

1. SWOT analysis
2. Process modeling methods IDEF0, NTD(Node Tree Diagram)
3. Decision matrix analysis
4. Kendall’s coefficient of concordance for estimation of the expert’s decisions
5. Payback analysis

The structure of current thesis can be seen on Figure 1.1.

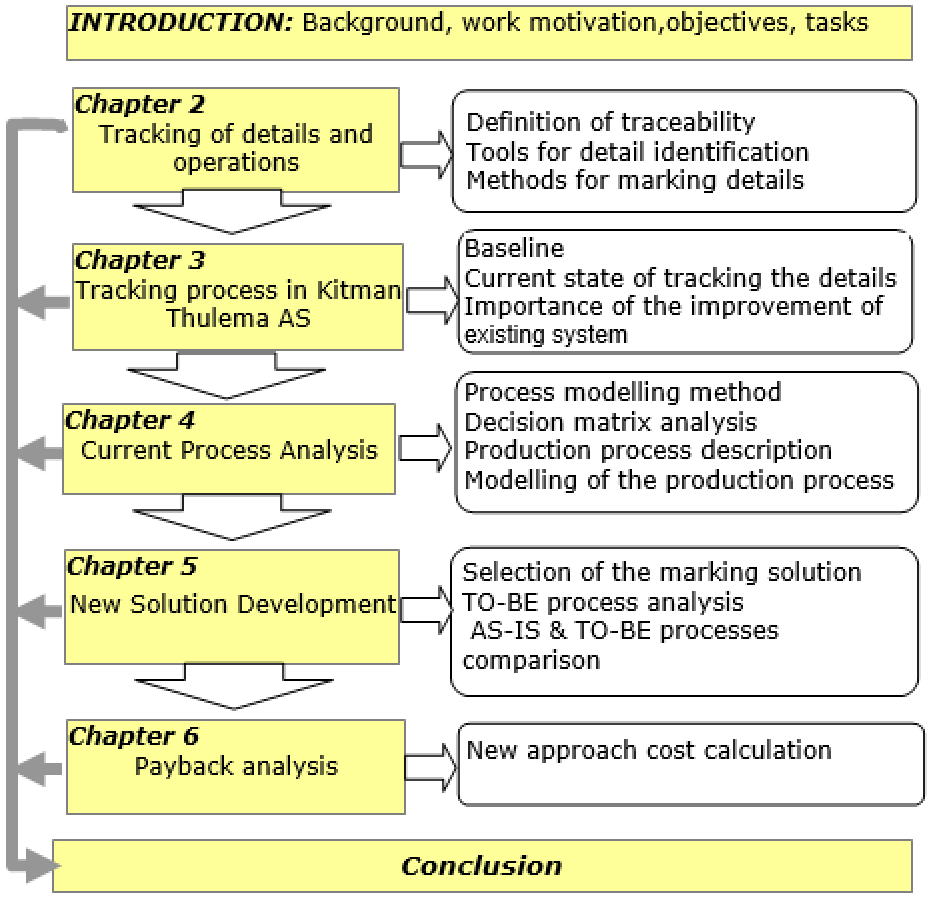


Figure 1.1 Structure of the thesis

2 TRACKING OF THE DETAILS AND OPERATIONS

2.1 Definition of tracking

In supply chain management the term traceability means following a good's path upwards to its origin. Tracking is following operations from raw materials to end products. There are several information systems used for storing, sharing and managing related data. For example, warehouse and transport management systems focus on internal operations and Enterprise Resource Planning systems include many other functionalities. [6]

In order to track details the physical goods need to be related to their digital representations. To achieve this, identification mechanisms are fundamental. The ISO 28219:2017 standard defines guidelines for choosing globally recognized identifiers such as QR codes and RFID tags. Following this standard is only necessary if the aim is to trace and track the products throughout the whole supply chain and not only internally. [6]

2.2 Tools for detail identification

2.2.1 Barcode readers

There are numerous barcode scanners for various purposes on the market. The selection of barcode scanners is very wide and they differ in their capabilities, durability and power source. Some are able to scan 1D barcode, which is a linear barcode and others are able to scan both, 1D and 2D barcodes like Data Matrix or QR code or PDF417. Scanners can be wired or Bluetooth wireless which makes the pairing with any computer system easy and relatively inexpensive. [7]

For industrial purposes, there are both stationary and hand-held 1D and 2D barcode scanners (Figures 2.1, 2.2, 2.3).

Figure 2.1. Datalogic DS2100N Industrial laser scanner for 1D barcode reading in shopfloor and OEM applications [8]

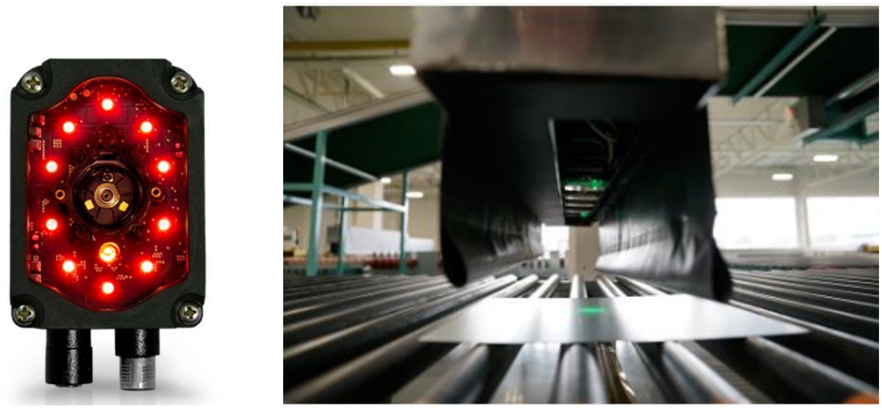


Figure 2.2. Datalogic Matrix 300N 2D imager for industrial applications [9]

Figure 2.3. Datalogic Skorpio X4 hand-held 1D barcode scanner [10]

2.2.2 Internet of Things

Internet of things (IoT) enables real-time manufacturing visualization within a smart factory using embedded devices like sensors, actuators and network connectivity. These enable real-time interaction and data exchange between different smart objects. One of the key elements in IoT is radio frequency identification (RFID) technology. In the data collection process, RFID tags and readers are able to record the time and location of the occurred event. For this system it is necessary to predefine the logic between different events. [11]

RFID reader is necessary for any RFID system to function. These are the devices that transmit and receive radio waves in order to communicate with RFID tags. It is possible to have either fixed integrated readers that are mounted on walls, desks or machines and it is also possible to use mobile RFID readers. [12]

2.3 Methods for marking details

Marking details is an important part of modern manufacturing cycle. Details need to be marked in order to identify these and follow up the information about the manufacturing in any operation. There are several methods for marking the details including removable labels, tags, control tapes or stamps. There are also many different permanent marking methods called direct part marking that include indenting, coining, chemical and electrochemical etching, dot peen and laser services. [13]

Desired information can be linked to details in many different ways. It is possible to write the whole information on the detail but it would be reasonable to save the space by using barcodes for that. Using barcodes reduces the risk of errors that may appear when entering data manually and it is also possible to save time on data entry. There are many types of barcodes that can be used and the selection has to be made based on the field of application.

2.3.1 Removable markings

Thermal transfer printed labels

Using printed labels for marking details is easy and does not need high investments. Usually roll labels are used because this eliminates the need for inserting labels into printer one by one. Thermal transfer printing is a fast and easy process for generating the labels with no warm-up or cooling time required. [14]

The difference between direct thermal and thermal transfer is that a direct thermal printer uses heat from the dots in the print head to activate a chemical coating in thermal label, which darkens the area in contact with dots (Figure 2.4). A thermal transfer printer uses a thermal ribbon. In order to print labels with a thermal transfer printer both thermal transfer ribbon and thermal transfer labels are needed. [15]

Thermal transfer ribbon is a clear plastic (PE) roll coated with a colored pigment on one side. There are two types of ribbons on the market: coated side out (CSO) and coated side in (CSI). This refers to on which side of the ribbon the ink coating is placed. The selection has to be made according to the type of the printer. [15]

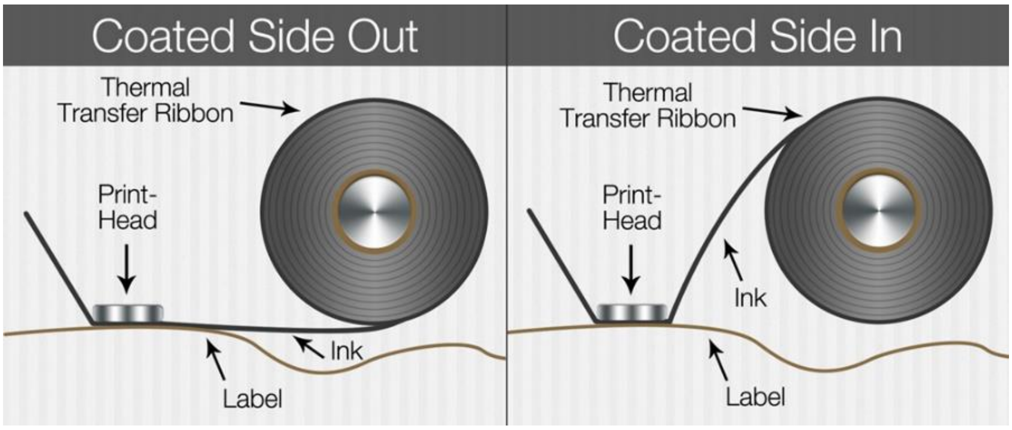


Figure 2.4. Thermal transfer ribbon types [16]

It is also important to select the right ribbon material based on the application. The usage determines the strength and durability needed from the thermal transfer ribbon. This is an important step in ensuring that the labels are scannable, readable and reliable. There are three main categories, see Table 1. [16]

Table 1. Ribbon material selection [16]

Material	Pros	Cons
Resin-enchanced wax(a full wax thermal transfer ribbon coated with a wax-based ink)	• Inexpensive • Light print • Ideal for temporary use • Can hold up to indoor use • Suitable for general uses(shipping, warehousing labels)	• Not very durable
Durable wax-resin(a wax-resin thermal transfer ribbon is coated with a combination of wax and resin)	• Durable • Resistant to scratching, abrasion, contact with moisture, sunlight, moderate temperature changes • Suitable for barcode, shipping and shelf labels	• Hard print • Intermediate price
Full resin(a full resin thermal transfer ribbon is coated with a resin-based ink)	• Extremely durable • Suitable for medical applications, chemicals, textiles, automotive • Ideal for long-term use	• Melt at high temperature • Dissolves into the material • Expensive

RFID label

Radio Frequency Identification (RFID) is the wireless non-contact use of radio frequency waves in order to transfer data [12]. RFID technology is widely used for traceability applications. This technology allows to locate a product on a manufacturing line and know its status within that manufacturing line. The main advantage of this technology is that it is possible to read data from a distance and also possible to re-use the RFID labels. [17]

RFID tags can be classified as passive, semi-passive or active (Table 2). Passive tags usually consist of an integrated circuit and an antenna so they are powered by electromagnetic energy transmitted from RFID reader. Semi-passive tags contain an integrated circuit, an antenna and a battery but can contain even more pieces. Active tags consist an integrated circuit, antenna, battery and onboard transmitter. [18]

Table 2. RFID tags classification [12] [19]

Type	Power source	Primary Frequency Range	Read range	Average cost per tag
Passive	No internal power source.	860 - 960 MHz	1 cm to 25 m	0.08 – 19 €
Semi-passive	Comprised of a power source incorporated into a passive tag configuration.	860 MHz – 960MHz	Up to 50 m	Up to 50 €
Active	Transmitter and power source on tag	433 MHz and 915 MHz	30 - 100+ Meters	23 – 47 €

The way a passive RFID tag works is that after the tag receives the transmission from the reader the energy runs through the internal antenna to the tag's chip. The energy activates the chip modulating the energy with the information, and then transmits a signal back toward the reader. [12]

There are three primary frequency ranges used for RFID transmissions, see Table 3.

Table 3. RFID transmissions [12]

Type	Frequency Range	Read range	Avg cost per tag
Low frequency	125 - 134 kHz	1 cm to 10 cm	0.07 – 5 €
High Frequency	13.56 MHz	1 cm to 1 m	0.2 – 10 €
Ultra-High Frequency	865 – 960 MHz	5 - 100+ m	23 – 47 €

2.3.2 Permanent markings

Indenting and coining

Marking can be done on metal details by application of uniaxial or multiaxial compressive forces such as indenting and coining. [20]

Indenting is a permanent marking method where information is written on the material by applying force to the material with a certain tool (Figure 2.5). This forms a permanent mark on the material. [21]

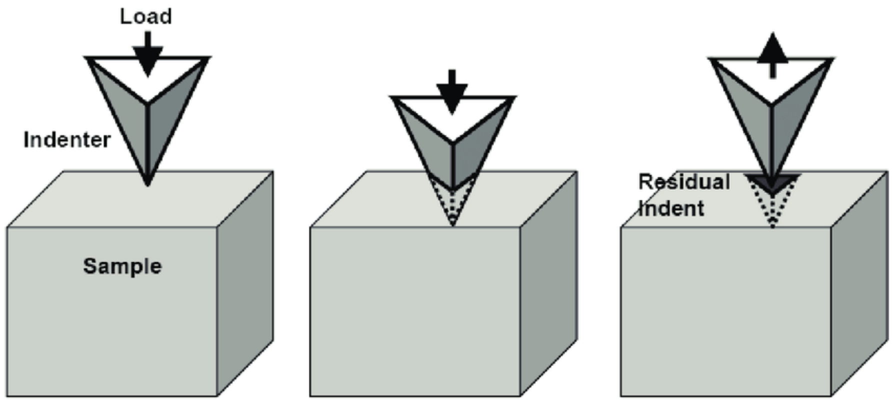


Figure 2.5. Schematic illustration of the process of indenting [22]

Coining is a closed-die forging operation where all surfaces of the workpiece are restrained and results in a well-defined imprint of the die on the workpiece (Figure 2.6). [23]

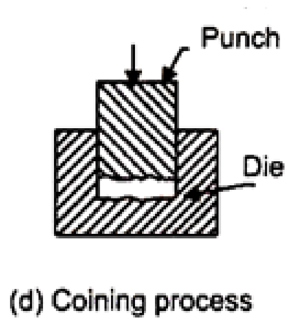


Figure 2.6. Schematic illustration of the process of coining [20]

The disadvantages of using compressive forces for marking the details is that the set up costs can be relatively high and these processes cause the mechanical distresses to the material.

Chemical etching

Chemical etching is engraving permanent image in a metal by using high-pressure high-temperature chemical spray to remove material [24]. Chemical etching offers greater design flexibility and lower set up costs than many hard tooling manufacturing processes. The chemical etching does not cause any mechanical distress to the material, also the material grain structure and magnetic properties. [25]

A mask or resist is applied to the surface of the metal and is selectively removed which results in exposing to metal to create the desired image or figure. [24]

The exact process is following (Figure 2.7):

1. Lamination – The material is cleaned to remove any contamination from the material and then laminated with a UV sensitive photoresist film.
2. Exposure – A tool containing the desired image is placed on the laminated material end then exposed to UV light. The UV light passes clear areas of the tool hardening the laminated film.
3. Developing – Resist film on the non UV exposed area is chemically developed and reveals the desired image. The resist coated area is then heated in order to improve acid resistance.
4. Etching – The material is being sprayed with a high pressure temperature regulated chemical spray. This solution etches the unprotected parts of the material in order to bring out the desired image.
5. Stripping – The resist film is stripped off the material. [24]

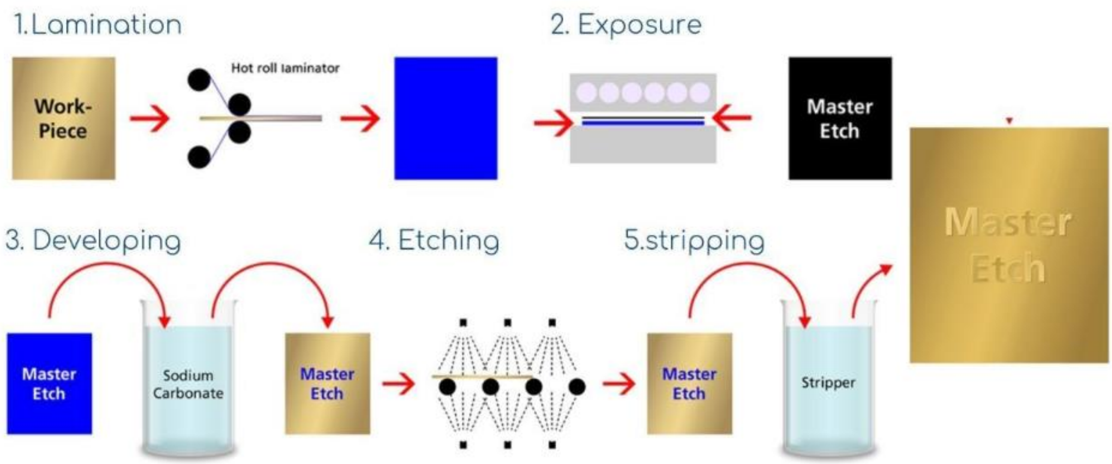


Figure 2.7. Chemical etching process [24]

Chemical etching is suitable for almost all types of metal and it is also possible to process extremely thin material. [24]

Electrochemical etching

Electrochemical etching is used only on conductive metal surfaces. It is a process where an electrolyte is used to etche the surface that is not covered by a protective flat.

The process is following (Figure 2.8):

1. A template with the desired labeling pattern is created
2. The template is placed tightly on the surface of the detail so that only the area of the surface to be marked can be reached by the processing fluid

3. The detail and the stamp are electrically charged and the stamp pad is soaked with electrolyte
4. The stamp is then pressed against the stencil. The current conducted through the stamp through the die into the work piece cuts its surface by etching. [26]

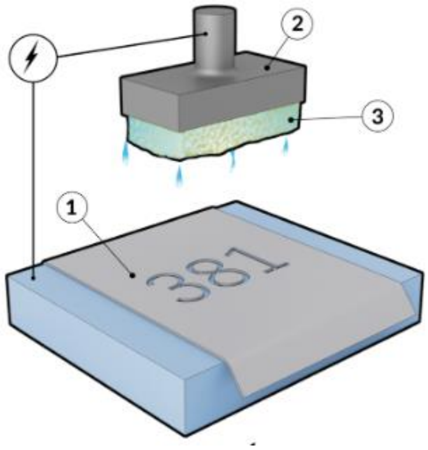


Figure 2.8. Electrochemical etching [26]

Dot peen marking

The result of a dot peen marking is a succession of dots to create digits, text, 2D data matrix codes etc (Figure 2.9). Dot peen engraving machines strike a carbide or diamond stylus assembly electromechanically against the surface of a part to be marked. Each dot is a result of a pulsed current that runs through a solenoid, punches magnet toward the surface of the material and returns the stylus to its starting position. Dot peen marking is relatively cheap, high speed, required no consumables and will mark any material. [27]

The dot peen systems are good for writing of alphanumeric serial numbers and 2D barcodes but are not usually used for writing 1D barcodes. This is because 1D barcode readers require a higher level of writing contrast which cannot be achieved by dot peen marking. [28]

Figure 2.9. Dot peen marked detail [29]

There are both hand-held dot peen markers and integrated dot peen marking solutions. Hand-held markers are suitable for manufacturing processes where maneuverability is essential (Figure 2.10). Integrated systems are designed for producers who need rather high speed for marking the details. [30]

Figure 2.10. Pneumatic hand-held dot peen marking machine TELESIS TMM4215 [31]

Laser services

Laser services provide a permanent marking solution adding distinction to details and products. These divide into laser marking, laser etching and laser engraving which are different by what each process does to the marking surface. Laser marking discolors the surface of the material, etching and engraving remove a portion of the surface area of the material. [32]

Laser marking is achieved by the beam interacting with the surface of a material altering its properties of appearance. It is popular in the medical device industry and is suitable for bar codes, UID codes, QR codes, logos etc. [32]

Laser engraving is a process where the laser beam removes the surface of the material to expose a cavity [32]. It is one of the most utilized methods for marking details in modern production as it is non-contact, fast, and usable on many different metallic and nonmetallic materials. It does not require any toxic solutions, thus can reduce environmental pollution. [13]

Laser etching is a process of melting the surface of the material with a laser beam, as a result the melted material expands and causes a raised mark. This process removes only 0.03 mm of the material. [32]

UV-barcode

It is possible to track the details using a combination of UV fluorescent ink-jet printing and UV barcode reading [33]. This marking is invisible in daylight and can be read only under illumination with UV lamps (Figure 2.11). This way of marking details is used when it is important to distinguish original products (for example, pirate products or counterfeit products) but is also used for purely aesthetic reasons as this marking will not be visible on the finished product. [34]

With UV ink it is possible to print on all smooth surfaces including paper, cardboard, metal, plastic, glass, curved surfaces, coated labels. [34]

The benefits of marking details with the UV ink is that is invisible in the daylight and the imprint can be removed without any residue. It is also possible to mark the details wirelessly. [35]

Figure 2.11. UV-barcode marking [36]

2.4 Risks in tracking operations and details

Risk is the effect of uncertainty which can have either positive or negative effects [37]. There are many risks that need to be considered before implementing an operations tracking system into manufacturing. In order to raise awareness of all the factors involved a SWOT analysis was carried out (Table 4).

Table 4. SWOT analysis of improving the tracking process of operations and details

S	W	O	T
Strengths	**Weaknesses**	**Opportunities**	**Threats**
• Getting a real-time overview of the production • Possibility of reacting fast to changes • Reducing waste • Development of the workers	• Human factor • Counteractions of the personnel • Additional expenses • Need for competent personnel • Difficulties in integration with old system	• Further digitalization • Implementing LEAN principles in the manufacturing • Optimization on the plant floor • Optimization of processes • Motivating workers • Implementing Key Performance Indicators	• Data security • False data entry • Getting hacked into the system

The biggest risk is related to data security. Today's barcodes can contain a lot of data. 2D barcodes for example can enable 50 to 70 ASCII characters. As the information cannot be read by eye, it may happen that by scanning a barcode some malware may get into the information systems which in turn is a big threat to the company. [38]

There is also a risk of false data entry and causing confusion on plant floor. It may also happen when the barcodes turn illegible.

The risks when implementing a new tracking system in the manufacturing are that the working personnel may counteract with any new systems as it is out of their comfort zone. The existing work instructions need to be changed and new standards established.

In addition, there may occur some technical difficulties integrating new systems to the old ones. It is necessary to invest in data security and the possibilities for processing high volumes of data. This results in additional expenses and need for new competent personnel.

It is important to be aware of all of these risks and take the necessary measures to reduce them as much as possible.

3 TRACKING PROCESS IN KITMAN THULEMA AS

3.1 Baseline

As the objective of this thesis was to analyze different possibilities for improving the tracking of details in Kitman Thulema AS, it was necessary to describe its manufacturing.

Kitman Thulema AS has implemented the quality and environmental management system certified by ISO 9001 and ISO 14001 international standards in order to improve customer satisfaction and environmental performance. The working environment complies with international safety and health standard OHSAS 18001. [39]

The Enterprise Resource Planning software used in Kitman Thulema AS is Axapta 2012(Microsoft Dynamics AX 2012). This software is used for sales, procurement and manufacturing processes.

The manufacturing planning system in the Kitman Thulema AS plant is mainly pull manufacturing which means that most products are made to order. Product designers complete drawings according to the clients' wishes and manufacturing capabilities. They also assign the suitable work centers for the products manufacturing process.

The product drawings are created in Autodesk AutoCad and Siemens Solid Edge. Constructor compiles a MS Excel file on a template with all of the information related to the product including the routing. This Excel file is uploaded to Axapta and the system generates a formalized BOM and routing for the product. In addition, the drawing is also uploaded to Axapta.

The manufacturing planner makes a general plan for next week's production in Microsoft Excel and the manufacturing supervisor prints out the manufacturing orders from Axapta according to the plan. There is no advanced planning system implemented in Kitman Thulema AS, therefore, the manufacturing supervisor releases the orders to production in the way that seems the most optimal to him.

3.2 Current state of tracking the details

3.2.1 Marking metal details

During the manufacture of metal products the details are being marked at each machine center by the machine operator. If the manufacturing order has more than one detail of the same kind, only the detail on the top of the pile is marked. The operator gets the detail information from a printed out copy of the manufacturing order. For marking the details white permanent markers are being used (Figure 3.1).

The information marked on the detail is not fixed by standard but usually includes:

1. Number of the manufacturing order
2. Time of delivery
3. Detail code
4. Quantity of details on manufacturing order
5. Edge banding information
6. Color
7. Other information

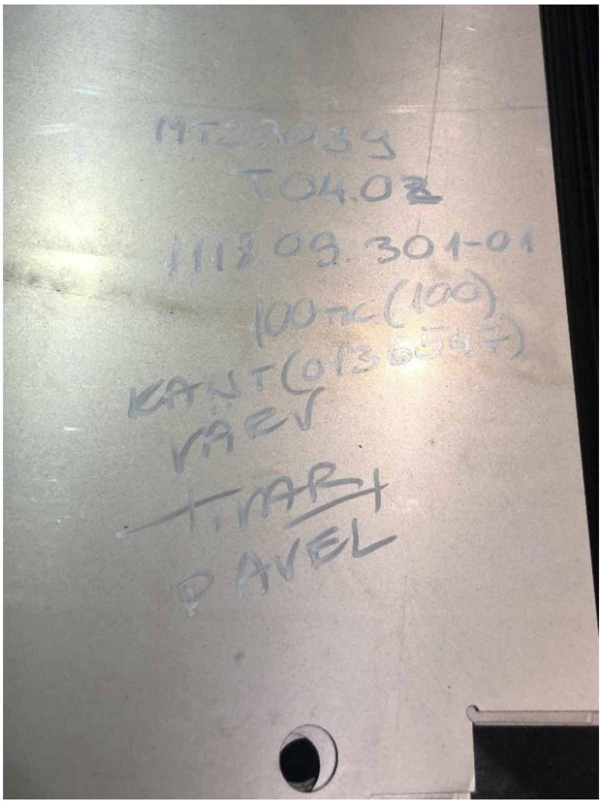


Figure 3.1. Example of a manually marked detail

Risks of this marking method:

1. Mixing up information from different manufacturing orders
2. Not having all the necessary information on the detail
3. Misunderstandings because of the handwriting
4. Misunderstandings because of verbal interaction
5. The deterioration of the marking
6. Losing the one detail with the information
7. Mixing up details
8. Markings get painted over in the finishing line
9. Wasted time spent identifying details

3.2.2 Operations reporting

In the plant there are several computers set up where the operations on the manufacturing order have to be reported in the ERP system. The computers are equipped with Birch BS-970 hand-held laser scanners (Figure 3.2).

Figure 3.2. BS-970 hand-held laser scanner [40]

In order to report the completed operations the worker walks to the computer located in the corner of the manufacturing area and scans the barcode from the manufacturing order. It is also possible to type manually the number of the manufacturing order in the system. Next the ERP system displays the content of the whole manufacturing order, names and quantities of the details. The worker changes the quantities if necessary and confirms.

The problems with the current reporting system:

1. Walking to the scanner can be considered waste;
2. Reporting is not made right after finishing operation;
3. No standardized process;
4. Making mistakes due to manually inserting numbers;
5. Decisions are based on untimed, incomplete or wrong data.

3.2.3 Tracking the details through manufacturing

Currently the traceability of details and finished products in manufacturing is absent. Information sharing is primarily verbal which is inconsistent and can easily result in misunderstandings. It is not possible to determine the exact location of the specific detail or product. This is due to there being no reporting done at the start of the operation and is only being made after finishing the operations. Further, the reporting is only performed 1 or 2 times a day.

In order to determine where in the manufacturing process the detail is, it is possible to find from Axapta where it was last reported and then ask the manufacturing supervisor for its exact location.

Reporting only upon completion causes several potential problems in manufacturing:

1. There is no overview of the location of the detail;
2. There is no option for a sudden change in manufacturing;
3. Not possible to optimize manufacturing;
4. Delays in deliveries.

As details are not always correctly marked it can cause problems in the manufacturing area as many of the details look similar but have slightly different measurements. A lot of time is then spent on finding the drawings, measuring and identifying the details.

3.3 Importance of improvement of existing system

Every manufacturing company needs to take steps towards automation due to labor shortages caused by the decreasing prevalence of skilled workers. It is important to first get an actual overview of the production in order to further improve it. By having an overview, it is also possible to win customers over by giving them realistic promises on delivery times. Today, the most striking cost for Kitman Thulema AS related to delays from manufacturing is the cost of ordering additional express transportation.

Tracking the details and operations in Kitman Thulema AS helps reduce waste in all seven categories of Six Sigma 7 wastes:

1. Overproduction:
   a. Having a real time overview of the manufacturing helps react to any changes caused by the client and therefore helps reducing cost;
   b. Having a real time overview of manufacturing can help in optimizing it.
2. Inventory:
   a. Helps having an actual overview of Work In Progress (WIP) details and details/products in the warehouse.
3. Over-processing:
   a. Having an overview of all the operations completed and taking appropriate measures.
4. Motion:
   a. Workers will not waste time walking to reporting stations and can do it by the machine center;
   b. Reporting processes can be automated and it then requires no movement of the workers.
5. Waiting:
   a. It is possible to detect the exact times when the details are completed in a work station and start processing them in the next working station;
   b. The details can be easily found in the manufacturing area and less time is spent searching for details.
6. Transportation:
   a. There will be no need for moving details around on plant floor if it is known exactly when the processes are completed and where the details are.
7. Defects:
   a. It is possible to detect and eliminate the cause of defects which helps reducing cost;
   b. Actual net cost can be calculated when all the defects will be reported.

4 TRACKING PROCESS ANALYSIS

4.1 Manufacturing process modelling method

Author chose IDEF0 method (Figure 4.1) for modelling the manufacturing process of a selected product as it is a method that is simple to understand without a reference to any supporting documents. IDEF0 was used for creating a functional model displaying structure and functions of the process. In addition the model displays the flow of information and materials connecting the functions. [41]

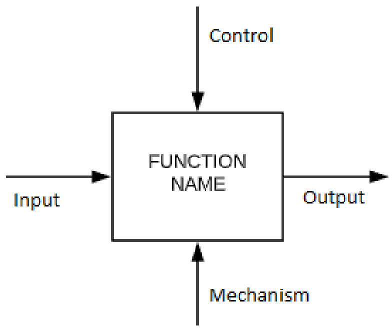


Figure 4.1. IDEF0 method [42]

The IDEF0 concepts include following:

1. Graphic representation. Boxes on the diagram show function and the interfaces to or from the functions are represented by arrows.
2. Communication. Diagrams are based on boxes and arrows and English is used as language. Hierarchical structure is used and a node chart provides index for locating details in this hierarchical structure.
3. Compactness. The documentation of the system must be described concisely.
4. Precision. IDEF0 requires rigor and precision by rules.
5. Methodology. Step-by-step procedures are provided for modeling, review and integration tasks.
6. Separation. Organization must be kept separate from the function. [43]

The IDEF0 model created for this paper was made using a software named AllFusion Process Modeler, which is a tool for modelling, analyzing, documenting and optimizing business processes. IDEF0 model was composed based on the routing of the product and the observed time measurements.

4.2 Decision matrix analysis

In a situation where there is a list of options and it must be narrowed down to a single choice the weighted decision matrix, the tool of decision matrix analysis, can be used (Figure 4.2).

		Options		
Criteria	Weight	Option 1	Option 2	Option 3
Criteria 1	50%			
Criteria 2	25%			
Criteria 3	15%			
Criteria 4	10%			

Figure 4.2. Weighted decision matrix

Creation of the decision matrix consists of following steps:

1. Compiling a list of appropriate criteria. First, all potential criteria is brainstormed and then refined.
2. Assigning weights to each criterion. Evaluating the importance of the selected criteria based on the current state.
3. Drawing the matrix. Writing criteria and their weights along one axis and the list of potential options to be considered on the other.
4. Evaluation of each option against the criteria. It is important to be consistent and fair with ratings.
5. Determining each option's overall rating by multiplying each option's rating by the corresponding weight. Adding up the points and the options with highest points shall be further discussed. [44]

Using a weighted decision matrix it needs to be considered that the rating of the options will only be as good as the assumptions about the solutions. In addition, the results may vary depending on the assessors opinion and the results must be discussed until the group of assessors reaches an agreement.

The author used the weighted decision matrix for determining the best optimal solution from the options discovered from literature that would satisfy Kitman Thulema AS's needs. For assigning weights, the Kendall's coefficient of concordance was used.

4.3 Manufacturing process description

In order to analyze and compare the AS-IS and TO-BE processes a test case was selected. Criteria for the test case was chosen so it would be possible to simulate the basic manufacturing process.

The criteria for a test case was as following:

1. The product is being produced in different measurements;
2. The product is being produced in high volume;
3. The product has historically caused problems in manufacturing;
4. The product is made of metal;
5. The product is being finished in the finishing line.

In Table 5 it can be seen that 931 products in the same product family were produced in 2019. This product is being produced in many different measurements and can be easily confused if not marked correctly.

Table 5. Extract of Kitman Thulema AS 2019 sales statistics

Item code	Name	Quantity	Unit of measure
750.01.600-01	Pole kp T leg H=1408x90x30/500	35	pcs
750.01.600-02	Pole kp T leg H=1408x90x30/600	27	pcs
750.01.610-01	Pole kp T leg H=1664x90x30/500	47	pcs
750.01.620-01	Pole kp T leg H=1792x90x30/500	3	pcs
750.01.620-02	Pole kp T leg H=1792x90x30/600	89	pcs
750.01.630-01	Pole kp T leg H=2048x90x30/500	68	pcs
750.01.630-02	Pole kp T leg H=2048x90x30/600	372	pcs
750.01.640-01	Pole kp T leg H=2176x90x30/500	280	pcs
750.01.640-02	Pole kp T leg H=2176x90x30/600	2	pcs
750.01.650-02	Pole kp T leg H=2432x90x30/600	8	pcs
	Total	**931**	**pcs**

Based on the chosen criteria the product 750.01.620-01 Pole kp T leg H=1792x90x30/500 from this product family was selected at random.

For modeling the current process, bill of materials and routing of the test case were used. The drawing of the test case can be seen in Appendix 1, the bill of materials in Appendix 2, and the routing in Appendix 3.

4.4 Modeling of the manufacturing process

The manufacturing processes of product 750.01.620-01 Pole kp T leg H=1792x90x30/500 have been described in AllFusion model including machining times, marking the details and reporting operations. The set-up times and waiting times were excluded as the aim of this thesis was to find a solution for optimizing the process of tracking the operations. It was taken into consideration that not every detail of the batch is being marked and reported so for the sake of illustration the author used a batch of 30 products.

The whole manufacturing process of product 750.01.620-01 Pole kp T leg H=1792x90x30/500 can be seen on Figure 4.3 and is described in Table 6. The Node Tree Diagram (NTD) of it is shown in Appendix 4.

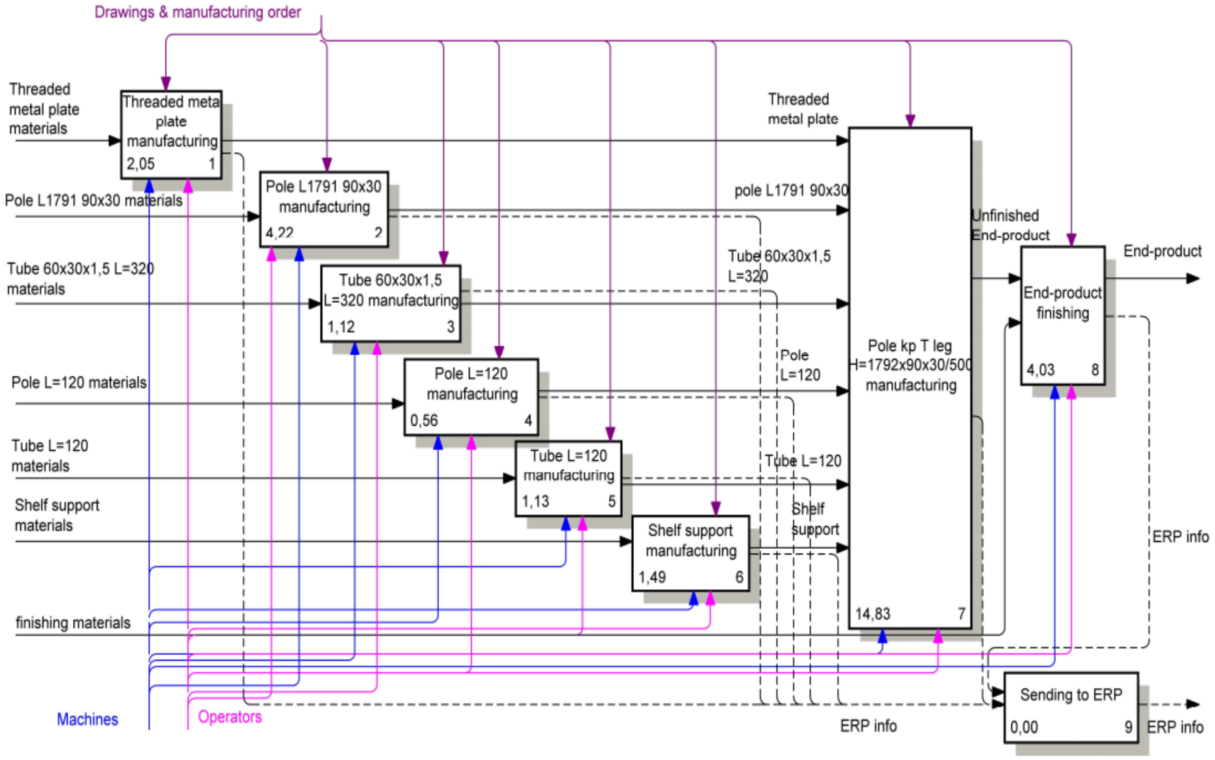


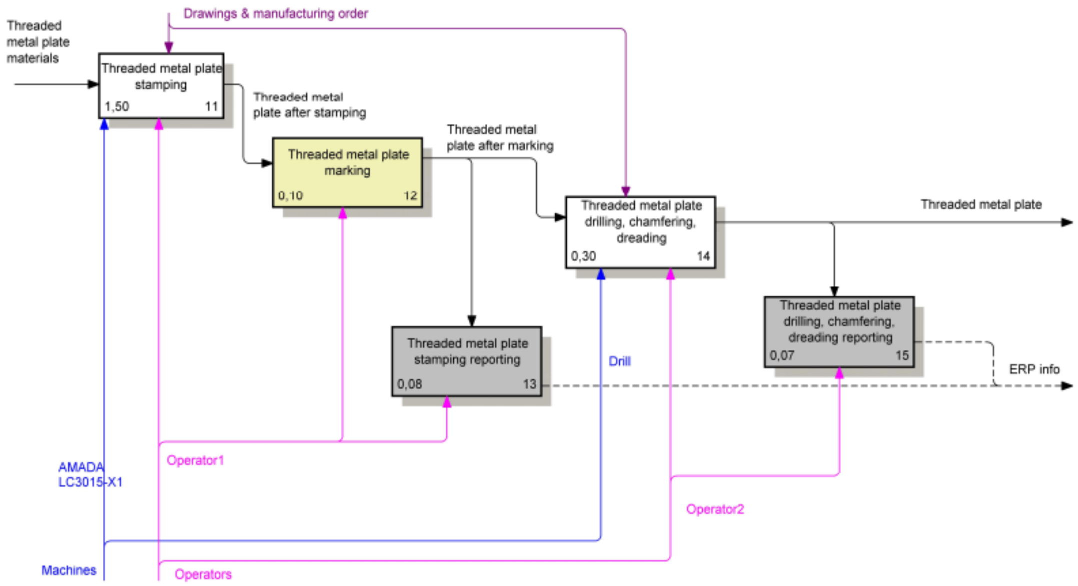
Figure 4.3. 750.01.620-01 Pole kp T leg H=1792x90x30/500 manufacturing

Table 6. Activities in 750.01.620-01 Pole kp T leg H=1792x90x30/500 manufacturing

Activity name	Activity Number	Materials	Control name	Output name	Mechanism
Pole kp T leg H=1792x90x30/500 production	0	Threaded metal plate materials	Drawings and manufacturing order	ERP info	Machines
		Pole L1791 90x30 materials		End product	Operators
		Tube 60x30x1,5 L=320 materials			
		Pole L=120 materials			
		Tube L=120 materials			
		Shelf support materials			
		finishing materials			
Threaded metal plate manufacturing	1	Threaded metal plate materials	Drawings and manufacturing order	Threaded metal plate	Machines
				ERP info	Operators
Pole L1791 90x30 manufacturing	2	Pole L1791 90x30 materials	Drawings and manufacturing order	Pole L1791 90x30	Machines
				ERP info	Operators
Tube 60x30x1,5 L=320 manufacturing	3	Tube 60x30x1,5 L=320 materials	Drawings and manufacturing order	Tube 60x30x1,5 L=320	Machines
				ERP info	Operators
Pole L=120 manufacturing	4	Pole L=120 materials	Drawings and manufacturing order	Pole L=120	Machines
				ERP info	Operators
Tube L=120 manufacturing	5	Tube L=120 materials	Drawings and manufacturing order	Tube L=120	Machines
				ERP info	Operators
Shelf support manufacturing	6	Shelf support materials	Drawings and manufacturing order	Shelf support	Machines
				ERP info	Operators
Pole kp T leg H=1792x90x30/500 manufacturing	7	Threaded metal plate	Drawings and manufacturing order	Unfinished End-product	Machines
		Pole L1791 90x30		ERP info	Operators
		Tube 60x30x1,5 L=320			
		Pole L=120			
		Tube L=120			
		Shelf support			
End-product finishing	8	Unfinished End-product	Drawings and manufacturing order	End-product	Machines
		finishing materials		ERP info	Operators
Sending to ERP	9	ERP info			
		ERP info		ERP info	

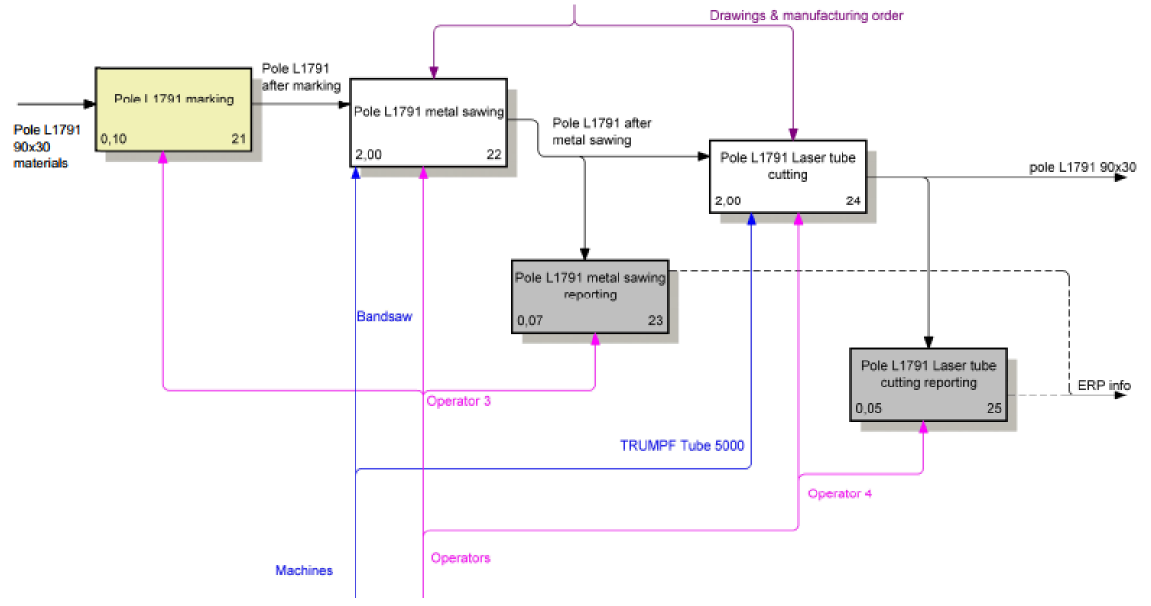
When describing the manufacturing processes of all the details it was important to focus on detail marking and operations reporting as those are the processes that will be targeted. In Tables 7-14, the IDEF0 diagrams of each detail manufacturing can be seen as well as all the activities carried out with durations and definitions.

Table 7. Threaded metal plate manufacturing



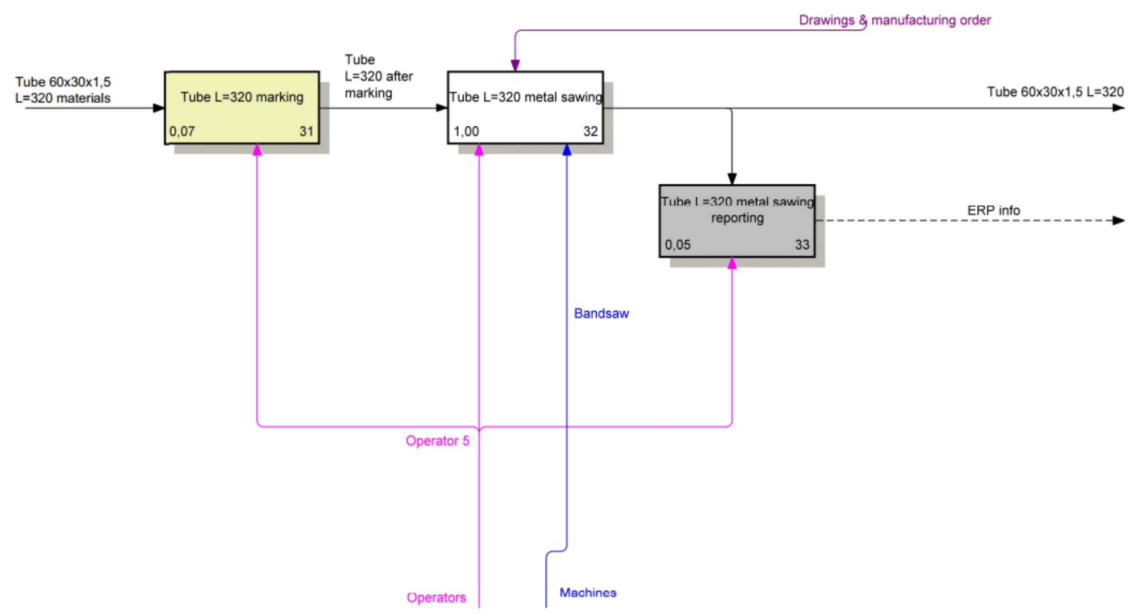
Activity Number	Activity Name	Duration (Minutes)	Activity Definition
1	Threaded metal plate manufacturing	2,05	
11	Threaded metal plate stamping	1,50	
12	Threaded metal plate marking	0,10	Information is written on detail using white permanent marker. This process is going to be changed.
13	Threaded metal plate stamping reporting	0,08	Worker walks 20 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.
14	Threaded metal plate drilling, chamfering, dreading	0,30	
15	Threaded metal plate drilling, chamfering, dreading reporting	0,07	Worker walks 15 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 8. Pole L1791 90x30 manufacturing



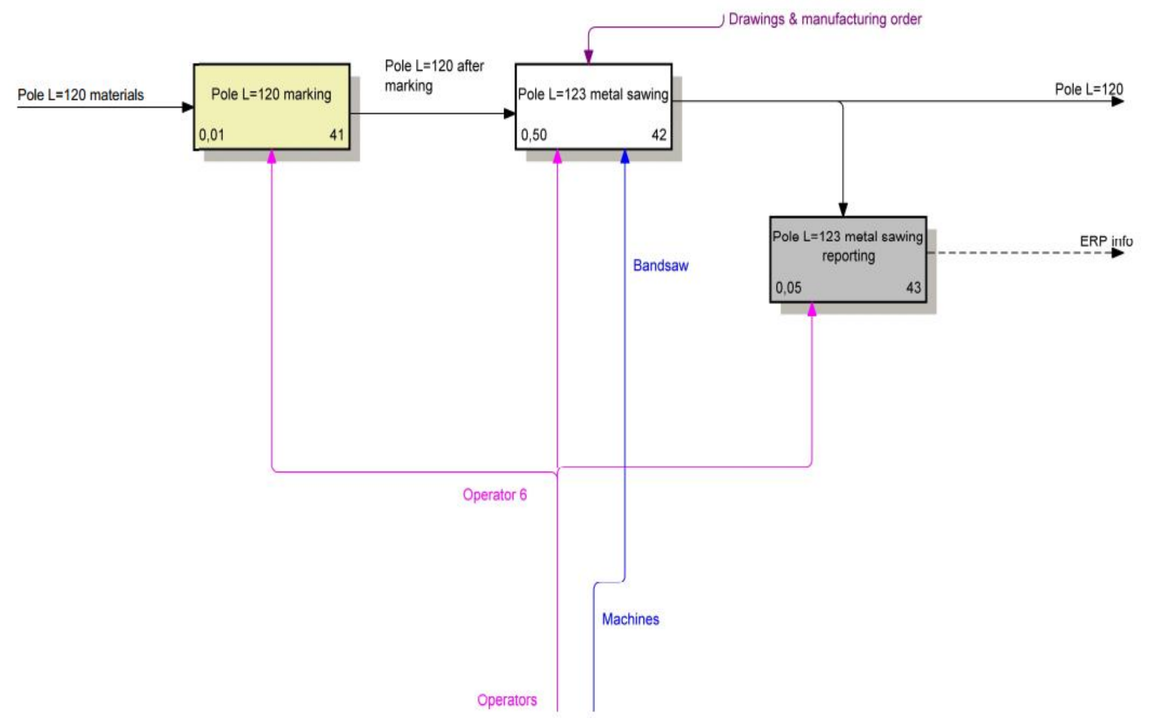
Activity Number	Activity Name	Duration (Minutes)	Activity Definition
2	Pole L1791 90x30 manufacturing	4,22	
21	Pole L1791 marking	0,10	Information is written on detail using white permanent marker. This process is going to be changed.
22	Pole L1791 metal sawing	2,00	
23	Pole L1791 metal sawing reporting	0,07	Worker walks 15 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.
24	Pole L1791 Laser tube cutting	2,00	
25	Pole L1791 Laser tube cutting reporting	0,05	Worker walks 10 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 9. Tube 60x30x1,5 L=320 manufacturing



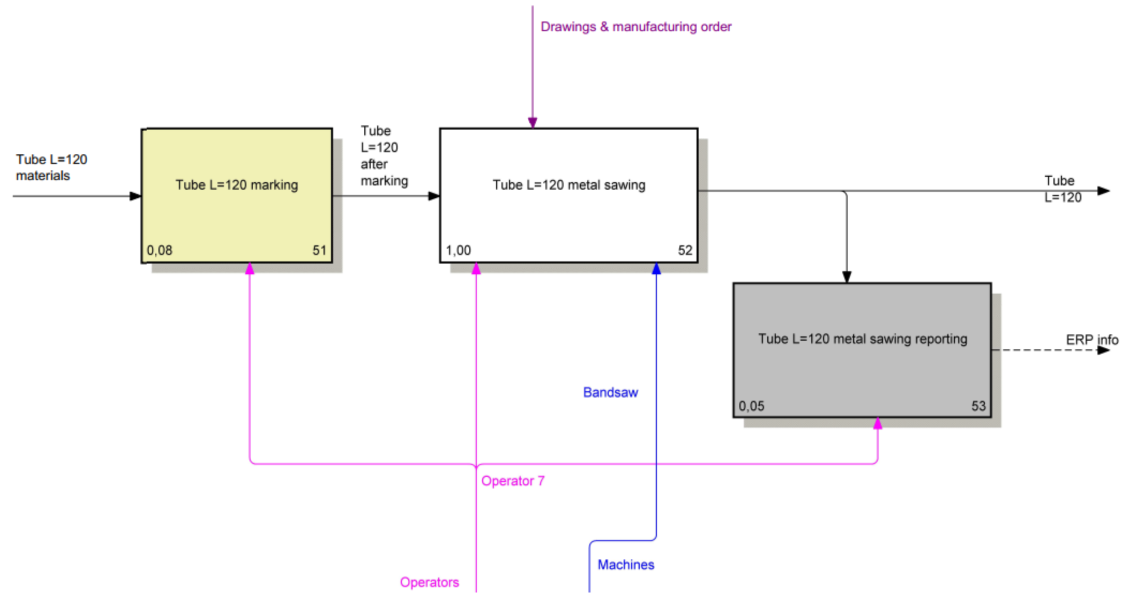
Activity Number	Activity Name	Duration (Minutes)	Activity Definition
3	Tube 60x30x1,5 L=320 manufacturing	1,12	
31	Tube L=320 marking	0,07	Information is written on detail using white permanent marker. This process is going to be changed.
32	Tube L=320 metal sawing	1,00	
33	Tube L=320 metal sawing reporting	0,05	Worker walks 10 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 10. Pole L=120 manufacturing



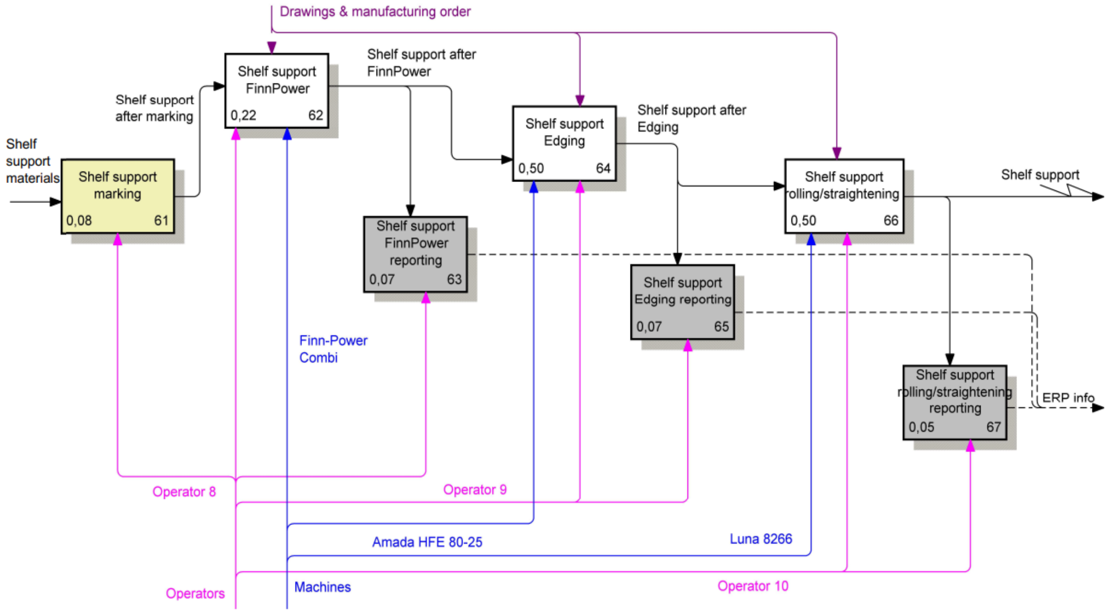
Activity Number	Activity Name	Duration (Minutes)	Activity Definition
4	Pole L=120 manufacturing	0,56	
41	Pole L=120 marking	0,01	Information is written on detail using white permanent marker. This process is going to be changed.
42	Pole L=123 metal sawing	0,50	
43	Pole L=123 metal sawing reporting	0,05	Worker walks 10 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 11. Tube L=120 manufacturing



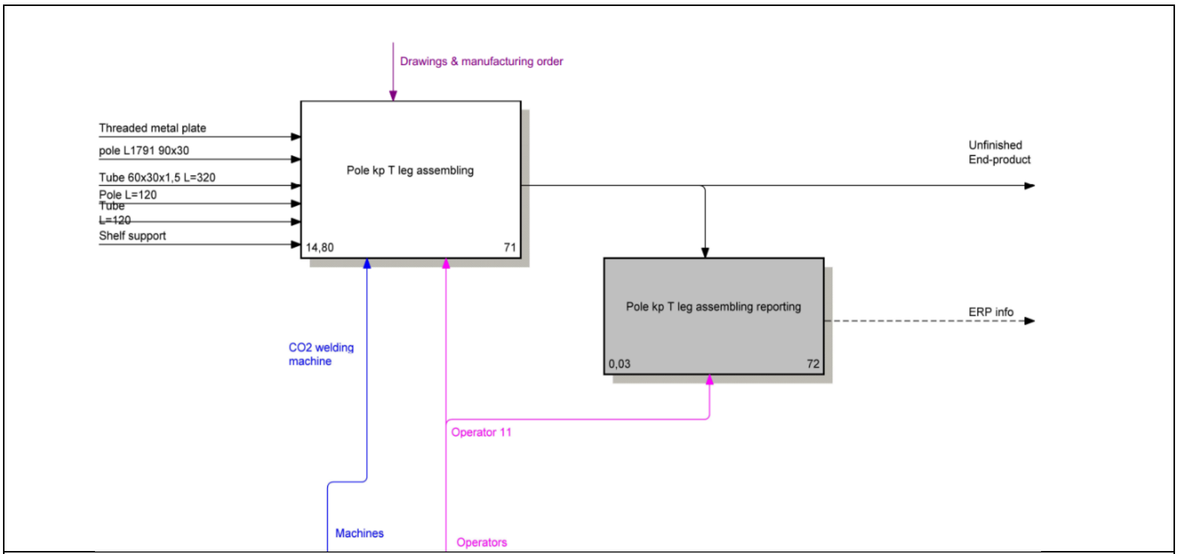
Activity Number	Activity Name	Duration (Minutes)	Activity Definition
5	Tube L=120 manufacturing	1,13	
51	Tube L=120 marking	0,08	Information is written on detail using white permanent marker. This process is going to be changed.
52	Tube L=120 metal sawing	1,00	
53	Tube L=120 metal sawing reporting	0,05	Worker walks 10 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 12. Shelf support manufacturing



Activity Number	Activity Name	Duration (Minutes)	Activity Definition
6	Shelf support manufacturing	1,49	
61	Shelf support marking	0,08	Information is written on detail using white permanent marker. This process is going to be changed.
62	Shelf support FinnPower	0,22	
63	Shelf support FinnPower reporting	0,07	Worker walks 15 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.
64	Shelf support Edging	0,50	
65	Shelf support Edging reporting	0,07	Worker walks 15 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.
66	Shelf support rolling/straightening	0,50	
67	Shelf support rolling/straightening reporting	0,05	Worker walks 10 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 13. Pole kp T leg H=1792x90x30/500 manufacturing



Activity Number	Activity Name	Duration (Minutes)	Activity Definition
7	Pole kp T leg H=1792x90x30/500 manufacturing	14,83	
71	Pole kp T leg assembling	14,80	
72	Pole kp T leg assembling reporting	0,03	Worker walks 5 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

Table 14. End-product finishing

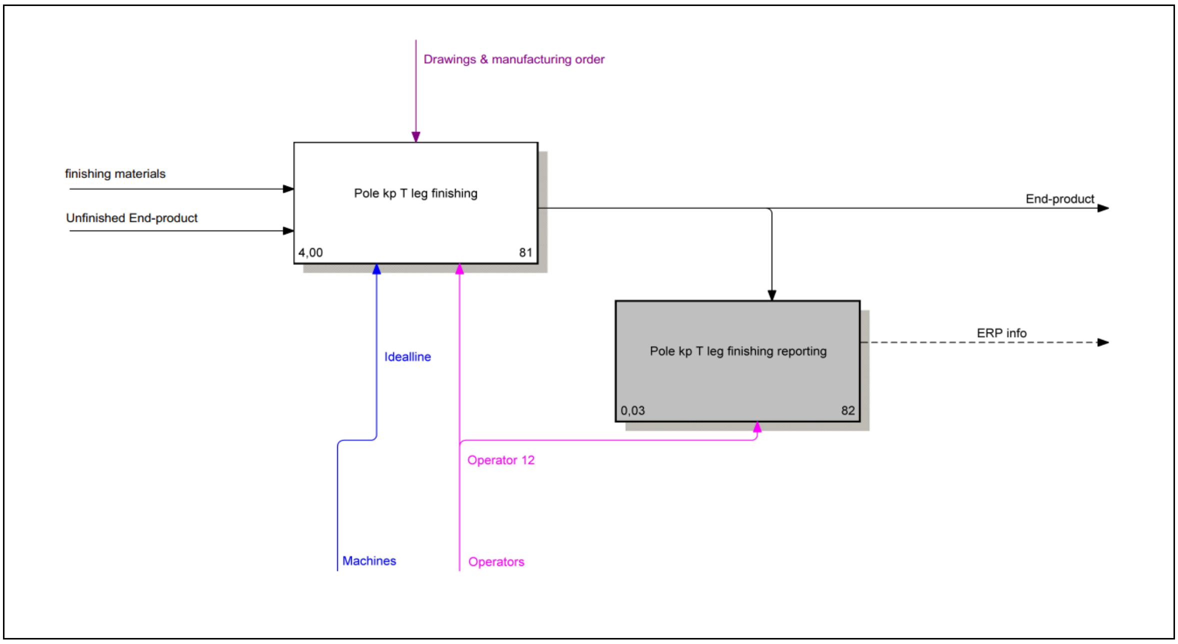


Table 14 continuation. End-product finishing

Activity Number	Activity Name	Duration (Minutes)	Activity Definition
8	End-product finishing	4,03	
81	Pole kp T leg finishing	4,00	
82	Pole kp T leg finishing reporting	0,03	Worker walks 5 meters up to a computer and scans work order or inserts data manually to report operation. This process is going to be changed.

5 DEVELOPING A NEW SOLUTION

5.1 Selection of a suitable marking solution

The author researched different methods for marking details suitable for metals. In order to select the optimal method for the Kitman Thulema AS plant, the weighted criteria matrix was used.

5.1.1 Formation of the weighted criteria matrix

The criteria for forming the matrix was chosen based preferences collected from discussions with 4 Kitman Thulema AS employees. The people involved in the discussions were the head of the development department, manufacturing manager, manufacturing supervisor and manufacturing planner. The team managed to decide on 14 criteria for compiling this matrix. The criteria can be seen in Table 15.

For determining the weights assigned to the criteria, the Kendall’s coefficient of concordance was used. This is a measure of the agreement upon several variables that assess a set of objects of interest. The coefficient of concordance varies in the range of $0 \leq W \leq 1$, where 0 is incoherence and 1 is complete unanimity [45]. This approach was needed to determine that the team of experts agrees on the importance of the criteria.

As a first step, the author asked each team member to rank the criteria from 1 to 14, where 1 has the biggest impact on choosing the new marking method and 14 the least. The results are shown in Table 15.

Table 15. Rankings assigned to criteria by the team of experts

	Experts			
	Head of the development department	Manufacturing manager	Manufacturing supervisor	Manufacturing planner
Criteria	**Ranking**	**Ranking**	**Ranking**	**Ranking**
Need for additional space in plant	1	2	2	2
Effect on material quality	2	3	3	3
Hire new employees. Skills not currently held in organization	3	1	4	4
Time spent on marking	4	5	1	1
Cost of system implementation	5	4	5	5
Time of system implementation	7	6	7	8
Ease of marking application	6	7	8	7
Usability in finishing line	8	8	6	6
Eco-friendliness	9	9	9	10
Need for maintenance	10	11	10	9
Need for changing workcentre configuration	11	10	12	11
Easiness of implementation	12	12	11	12
Need for changes in software	13	14	13	13
Ease of marking removal	14	13	14	14

Next, the S′ was computed from the row-marginal sums of ranks R_i:

$$S' = \sum_{i=1}^{n} R_i^{\,2}, \tag{5.1}$$

where S′ is a sum-of squares statistic over the row sums of ranks R_i.

Then the Kendall's *W* statistic can be calculated using following formula:

$$W = \frac{12S' - 3m^2 n(n+1)^2}{m^2(n^3 - n) - mT}, \tag{5.2}$$

Where n is the number of criteria and m the number of experts. T is a correction factor for tied ranks but in this case there were no tied ranks in any of the experts ratings.

The consistency of the opinions of experts can assess the magnitude of the coefficient of concordance. The coefficient of concordance varies in the range of 0 $< W <$ 1:
0 - the total incoherence, 1 - complete unanimity.

If $W \geq 0,7$ - 0,8 opinions are consistent,

If $W < 0,2$ - 0,3 opinions are not consistent,

If $W = 0,3$ - 0,7 average consistency. [45]

The calculations were following:

$$S' = 420^2 = 16096$$

$$W = \frac{12 * 16096 - 3 * 4^2 * 14 * 15^2}{4^2(14^3 - 14) - 4 * 0} = 0{,}9604$$

The result W=0,96 indicates that the opinions of experts are highly consistent and the mean of their rankings can be used in order to create weights for criteria.

The determination of weights can be seen in Table 16. First, the means of experts rankings for each criteria were calculated based on Table 15. The criteria with the highest ranking (1) has to have the biggest impact on the calculations. The calculation of lowest ranking (14) minus the mean of experts rankings for each criteria was made in the third column. Finally, the weight of each criteria was calculated.

Table 16. Determination of weights

Criteria	Mean of experts ranking	Difference between lowest ranking and the mean of experts ranking	Weight (%)
Need for additional space in plant	1,75	12,25	13,46
Effect on material quality	2,75	11,25	12,36
Time spent on marking	2,75	11,25	12,36
Hire new employees. Skills not currently held in organization	3	11	12,09
Cost of system implementation	4,75	9,25	10,16
Time of system implementation	7	7	7,69
Ease of marking application	7	7	7,69
Usability in finishing line	7	7	7,69
Eco-friendliness	9,25	4,75	5,22
Need for maintenance	10	4	4,40
Need for changing workcentre configuration	11	3	3,30
Easiness of implementation	11,75	2,25	2,47
Need for changes in software	13,25	0,75	0,82
Ease of marking removal	13,75	0,25	0,27

Next, the decision-making matrix was formed. This matrix uses a grading system where "5" is excellent, "4" is good, "3" is average, "2" is poor and "1" is very poor (Table 17).

Table 17. Weighted criteria matrix

		Options															
		Thermal transfer printed labels		RFID labels		Indenting and coining		Chemical etching		Electrochemical etching		Dot peen marking		Laser marking		UV-barcode	
Criteria	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Need for additional space in plant	13,46%	5,00	0,67	5,00	0,67	1,00	0,13	1,00	0,13	1,00	0,13	5,00	0,67	1,00	0,13	5,00	0,67
Effect on material quality	12,36%	4,00	0,49	4,00	0,49	1,00	0,12	1,00	0,12	1,00	0,12	1,00	0,12	3,00	0,37	5,00	0,62
Time spent on marking	12,36%	3,00	0,37	3,00	0,37	2,00	0,25	1,00	0,12	1,00	0,12	4,00	0,49	4,00	0,49	4,00	0,49
Hire new employees. Skills not currently held in organization	12,09%	5,00	0,60	5,00	0,60	2,00	0,24	2,00	0,24	2,00	0,24	5,00	0,60	2,00	0,24	4,00	0,48
Cost of system implementation	10,16%	5,00	0,51	3,00	0,30	1,00	0,10	2,00	0,20	4,00	0,41	5,00	0,51	1,00	0,10	3,00	0,30
Time of system implementation	7,69%	5,00	0,38	5,00	0,38	2,00	0,15	2,00	0,15	3,00	0,23	5,00	0,38	2,00	0,15	4,00	0,31
Ease of marking application	7,69%	3,00	0,23	3,00	0,23	1,00	0,08	1,00	0,08	1,00	0,08	4,00	0,31	4,00	0,31	3,00	0,23
Usability in finishing line	7,69%	1,00	0,08	1,00	0,08	5,00	0,38	5,00	0,38	5,00	0,38	5,00	0,38	5,00	0,38	1,00	0,08
Eco-friendliness	5,22%	2,00	0,10	2,00	0,10	3,00	0,16	2,00	0,10	1,00	0,05	5,00	0,26	5,00	0,26	3,00	0,16
Need for maintenance	4,40%	5,00	0,22	5,00	0,22	3,00	0,13	3,00	0,13	3,00	0,13	4,00	0,18	4,00	0,18	4,00	0,18
Need for changing workcentre configuration	3,30%	5,00	0,17	4,00	0,13	1,00	0,03	1,00	0,03	1,00	0,03	5,00	0,17	1,00	0,03	3,00	0,10
Easiness of implementation	2,45%	5,00	0,12	4,00	0,10	1,00	0,02	1,00	0,02	1,00	0,02	5,00	0,12	1,00	0,02	4,00	0,10
Need for changes in software	0,82%	3,00	0,02	3,00	0,02	3,00	0,02	3,00	0,02	3,00	0,02	3,00	0,02	3,00	0,02	3,00	0,02
Ease of marking removal	0,27%	2,00	0,01	2,00	0,01	1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00	5,00	0,01
	100%		**3,98**		**3,72**		**1,84**		**1,76**		**1,99**		**4,23**		**2,71**		**3,76**

5.2 Results presentation, analysis and justification

The most important criterion for Kitman Thulema AS was that the implemented system should not require additional floorspace in the plant. Thermal transfer printed labels, RFID labels, dot peen marking and UV-barcoding got the best score ("5") in this area.

Three other criteria of equal importance were effect on material quality, time spent on marking and hire new employees, skills not currently held in organization. The best score ("5") in the effect on material quality was given to UV-barcoding as this leaves no visible mark. Thermal transfer printed labels and RFID labels were also rated high ("4") because these are both removable and do not leave a permanent marking on the detail. For the criterion; time spent on marking, high ratings ("4") were given to dot peen, laser marking and UV-barcode because these markings take less time than the other options. As for the hire new employees, skills not currently held in organization the best scores ("5") were given to thermal transfer printed labels, RFID labels and dot peen marking because these markings can be done by the same worker who does the current work operation.

Another very important criterion was the cost of system implementation. The best ("5") scores were given to thermal transfer printed labels and dot peen marking, as these are relatively simple systems, do not necessarily need to be fully integrated to the workstations and do not need very high initial investments.

5.3 Results interpretation

In order to determine the most suitable detail marking method, a decision making matrix was composed. Evaluation of the results was done based on the manufacturing needs of Kitman Thulema AS. According to the decision making matrix, the optimal solution for marking the details is the dot peen marking system as this method got the highest score. The difference between dot peen marking and hand thermal transfer printed labels was only about 6 percent but as thermal transfer printed labels are not usable in the finishing line this method was not preferred.

Due to the results of the decision making matrix, the decision has been made to further analyze the implementation of the dot peen marking system into the Kitman Thulema AS manufacturing process.

5.4 Equipment need for marking and reporting system

Based on the routing of the selected test case the author mapped the workstations that needed to be equipped with detail marking and reporting equipment. As a result it was found that 6 workstations need to be equipped with detail marking equipment and 9 with operation reporting equipment, see Table 18.

Table 18. Equipment need for implementing the new system by operations

Operation	Machine	Detail marking equipment (pcs)	Operations reporting equipment (pcs)
Stamping	AMADA LC3015-X1	1	1
Drilling, chamfering, threading	Manual hand tools	-	1
Metal sawing	Bandsaw	1	1
Laser tube cutting	TRUMPF Tube 5000	-	1
FinnPower	Finn-Power Combi	1	1
Edging	Amada HFE 80-25	-	1
Rolling/straightening	Luna 8266	-	1
CO welding	Manual hand tools	1	1
Powder finishing	Idealline	-	1
	Total	**4**	**9**

In Kitman Thulema AS manufacturing there are no automated production lines and every machine center is separate. As it is made-to-order manufacturing it is important that the system is very flexible and efficient at the same time. The location of the marking on the detail needs to be determined by the constructor and can be positioned on details very differently. Therefore, it is not reasonable to integrate the detail marking devices with machine centers. However, it would make sense to integrate as many operations reporting points as possible to reduce working time on reporting and minimize errors.

Author further examined the machines used in the manufacturing process of test case 750.01.620-01 Pole kp T leg H=1792x90x30/500. The results are shown in Table 19. It was found that there are 4 work centers where the process of identifying the detail and reporting operation can be made fully automated using QR code readers. Marking process needs to be manual in all 4 work centers where this is being done. There are 5 work centers where the operations reporting has to be completed using manual solutions.

Table 19. Need of automatic and manual marking and reporting equipment

Machine	Detail marking equipment (pcs)		Operations reporting equipment (pcs)	
	Automatic	Manual	Automatic	Manual
AMADA LC3015-X1		1	1	
Manual hand tools		1		2
Bandsaw		1		1
TRUMPF Tube 5000			1	
Finn-Power Combi		1	1	
Amada HFE 80-25			1	
Luna 8266				1
Idealline				1
Total	**0**	**4**	**4**	**5**

5.5 Markings on details

Taking into consideration the fact that the markings should be small as the details can be small, it was decided that it is reasonable to take two-dimensional barcodes into use. 2D barcodes are small and contain small individual dots, which are suitable for the selected dot peen marking system. Another advantage of 2D barcodes is that they can hold a lot of information and the amount of information on them can be easily changed if necessary, keeping the dimensions of the marking the same.

The information that needs to be included in the 2D barcode in order to successfully track the details through manufacturing is following:

1. Number of the detail
2. Number of the product
3. Number of the manufacturing order

5.6 Selection of dot peen marking system

There are two different kinds of dot peen marking systems, pneumatic and electromechanical. Pneumatic systems are ideal for achieving deep marking on metal products that will be painted and the systems can be either fixed or mobile. Electromechanical systems are driven by electricity and are designed for light marking on soft metals. [46]

There are several materials used in Kitman Thulema AS metal manufacturing line. In the current thesis the selected test case is manufactured using stainless steel. Taking into account the properties of the material and the manufacturing conditions, the pneumatic dot peen marking system is required. The deep and high-quality marking provides the possibility of achieving the readable QR code for scanning systems.

In order to keep the process flexible for all sizes of details it was decided that the best option is to select a non-fixed pneumatic dot peen marking system. Based on the needs for Kitman Thulema AS the author chose the model of KT-PH3 (Table 20).

Table 20. Technical parameters of dot peen marking system KT-PH03 [47]

Model	**KT-PH03**
Standard marking area	80mm x 25mm
Base support	With frame windows
Marking Speed	30mm~40mm/s
Impact Frequency	300 times/s
Repeated Accuracy	0.001mm
Marking Depth	0.1mm~2mm（depends on material）
Power supply	AC220V 50HZ or AC110V 60HZ
Air power request	0.2Mpa ~ 0.6Mpa
Humidity	0-90% (Non-condensing)
Temperature	From 0 to 40 Centigrade Degree.

Table 20 continuation. Technical parameters of dot peen marking system KT-PH03 [47]

Model	KT-PH03
Marking content	English characters, number, all kinds of graphic, logo,dot matrix 2D codes, Barcode, Serial Number, circle Letter and etc.
Software compatible	Windows 98/XP/7

5.7 Selection of scanners

For the new solution there are two types of scanners required for Kitman Thulema manufacturing: stationary and hand-held scanners. An important criterion for the device selection was the presence of technical support in Estonia.

Taking into consideration the needs of Kitman Thulema AS for the hand-held scanner the DataLogic Skorpio X4 was selected (Table 21). It is a wireless scanner that runs on Windows Embedded Compact OS and has a 2D imager. The scanner has color display touch screen which enables the workers to insert the needed quantities on the screen of the scanner. Another important factor in choosing the scanner was drop resistance which for this model is 1.8 m onto concrete. The cost is 1150 € per unit. [48]

Table 21. DataLogic Skorpio X4 technical specifications [49]

WIRELESS COMMUNICATIONS	
Local Area Network (WLAN)	TI Wi-Link 8, IEEE 802.11a/b/g/n
Personal Area Network (WPAN)	Bluetooth v4 with BLE (Android models)
DECODING CAPABILITY	
1D / Linear Codes	Auto discriminates all standard 1D codes including GS1 DataBar™ linear codes.
2D Codes	Aztec Code, Data Matrix, MaxiCode, PDF417, MicroPDF417, Micro QR Code, QR Code
ELECTRICAL	
Battery	Removable battery pack with rechargeable Li-Ion batteries
ENVIRONMENTAL	
Drop Resistance	Withstands drops from 1.8 m onto concrete
Particulate and Water Sealing	IP64
Temperature	Operating: -10 to 50 ºC; Storage: -20 to 70 ºC

Table 21 continuation. DataLogic Skorpio X4 technical specifications [49]

READING PERFORMANCE	
2D Imager (Standard Range)	Megapixel sensor for extended range; White LED Illumination Optical Resolution: 1D codes: 3 mils; 2D codes: 6.6 mils Depth of Field (typical): 4.5 to 74 cm (13 mil/EAN), depending on bar code density and type
2D Imager (DL Focus)	Megapixel sensor for extended range; White LED Illumination Optical Resolution: 1D codes: 3 mils; 2D codes: 6.6 mils Depth of Field (typical): 4.5 to 42 cm (13 mil/EAN), depending on bar code density and type; DPM Support; DotCode Support
1D Imager	2,500 pixel sensor; Sharp green LED scan line Optical Resolution: 2.5 mils (linear codes) Depth of Field: 4.0 to 74 cm (13 mil/ EAN), depending on bar code density and type

The selected stationary scanner is DataLogic Magellan 1100i. It is a high performing scanner with fast reading performance of 1D and 2D bar codes. This scanner is small and it is possible to integrate this onto manufacturing lines as the precise reading area helps reducing accidental misreads improving productivity. Technical specifications can be seen in Table 22. The cost of DataLogic Magellan 1100i is 300 € per unit. [50]

Table 22. Technical specifications of DataLogic Magellan 1100i [50]

DECODING CAPABILITY	
1D / Linear Codes	Autodiscriminates all standard 1D codes including GS1 DataBar™ linear codes
2D Codes	Aztec Code, Data Matrix, MaxiCode, QR Code
Stacked Codes	GS1 DataBar Composites; GS1 DataBar Expanded Stacked; GS1 DataBar Stacked; GS1 DataBar Stacked Omnidirectional; Micro PDF417, PDF417
ELECTRICAL	
Current	Operating (Typical): < 400 mA Standby/Idle (Typical): < 300 mA
Input voltage	4.5 - 14.0 VDC
ENVIRONMENTAL	
Drop Resistance	Withstands repeated drops from 1.2 m onto a concrete surface
Humidity (Non-Condensing)	5 - 95%
Particulate and Water Sealing	IP52
READING PERFORMANCE	
Image capture	Optional: 752 x 480 pixels; Graphic Formats: JPEG
Print contrast ratio (min)	25%
Read rate (max)	1,768 digital scan lines/sec.
Reading indicators	Beeper (Adjustable Tone and Volume); Datalogic 'Green Spot' Good Read Feedback; Good Read LED
Resolution (max)	0.130 mm / 5 mils

5.8 Comparison of AS-IS and TO-BE approach

In order to compare the AS-IS and TO-BE processes, the author modeled the TO-BE manufacturing process of product 750.01.620-01 Pole kp T leg H=1792x90x30/500 using the selected dot peen marking method.

In creating the TO-BE process the author evaluated the time spent on the marking process based on the technical parameters of a KT-PH series pneumatic portable dot peen marking system. This tool has a marking speed of 30-40 mm/s which is about 25 seconds for creating a QR code on one detail, depending on the complexity of the QR code. In addition, the author considered 40 seconds spent on looking for information about the detail and setting up the dot peen marker for one batch of 30 details. Node Tree Diagrams of manufacturing processes of all details can be seen on figures 5.1-5.9 and the more general presentation of the new process is shown in Appendix 5 and activities are described in Appendix 6.

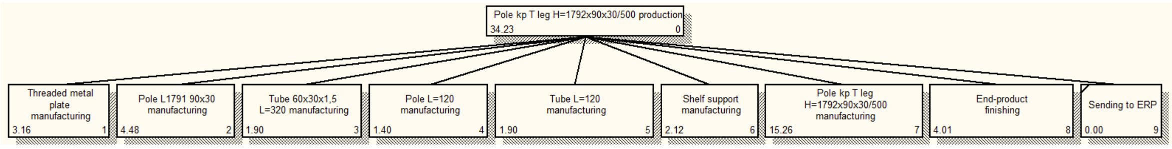


Figure 5.1. TO-BE Node Tree Diagram of Pole kp T leg H=1792x90x30/500 manufacturing

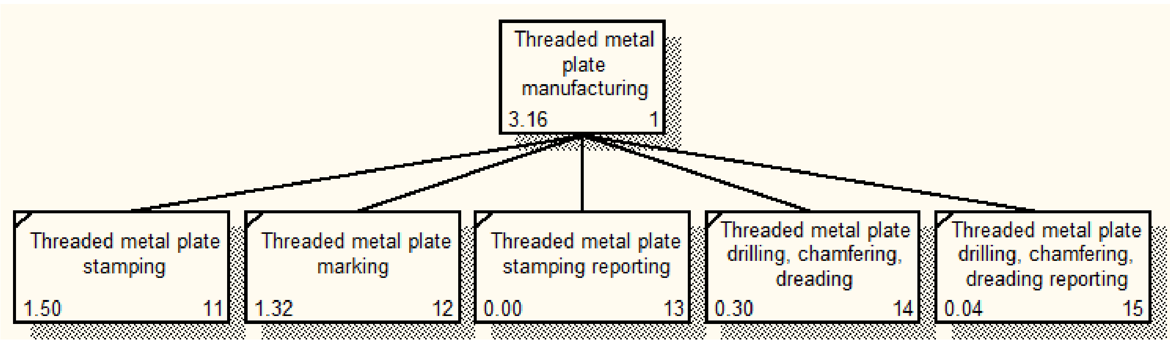


Figure 5.2. TO-BE Node Tree Diagram of Threaded metal plate manufacturing

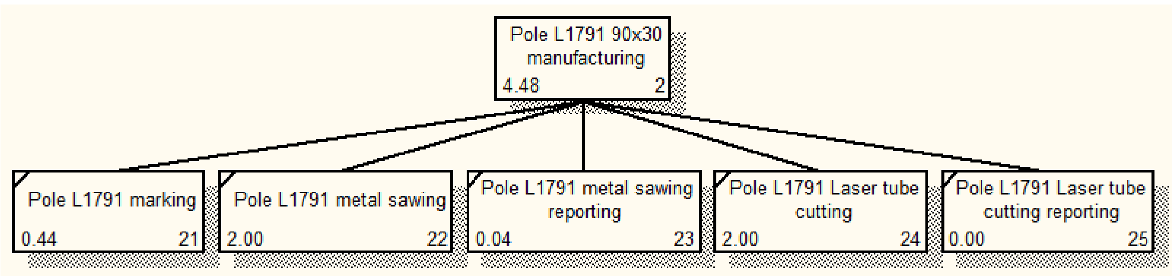


Figure 5.3. TO-BE Node Tree Diagram of Pole L1791 90x30 manufacturing

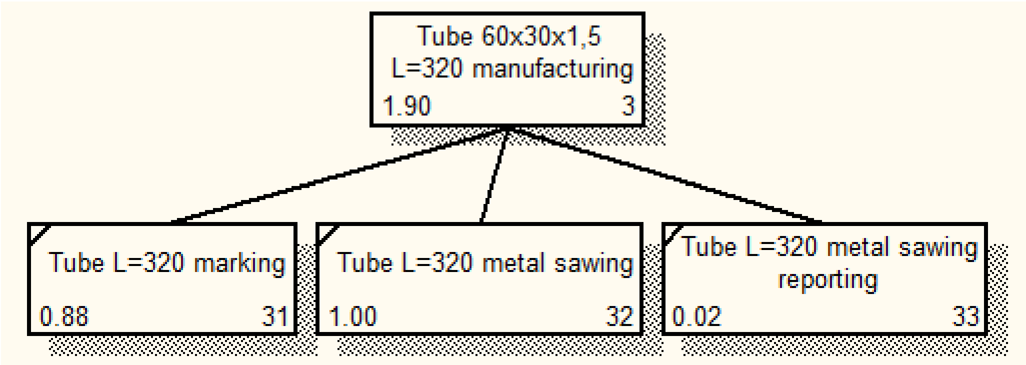


Figure 5.4. TO-BE Node Tree Diagram of Tube 60x30x1,5 L=320 manufacturing

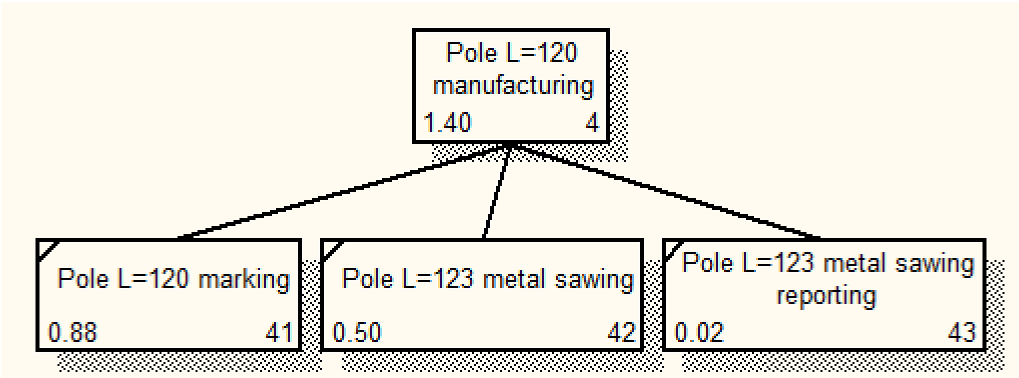


Figure 5.5. TO-BE Node Tree Diagram of Pole L=120 manufacturing

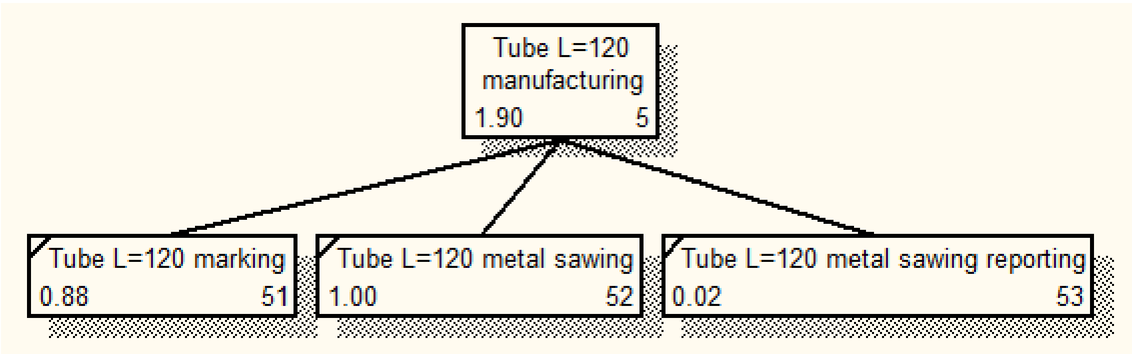


Figure 5.6. TO-BE Node Tree Diagram of Tube L=120 manufacturing

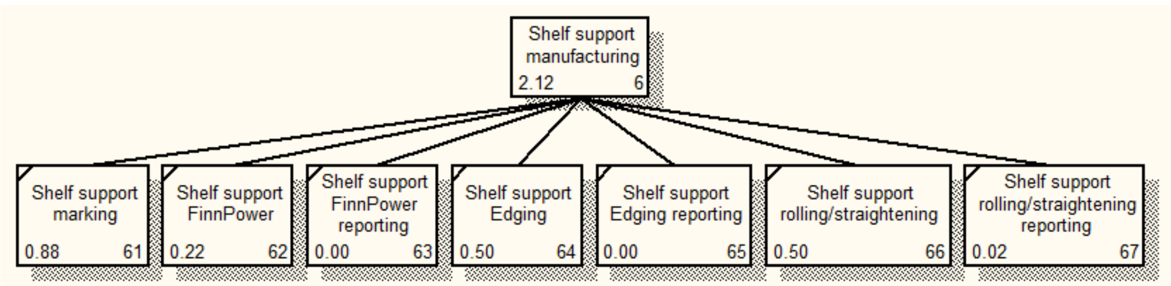


Figure 5.7. TO-BE Node Tree Diagram of Shelf Support manufacturing

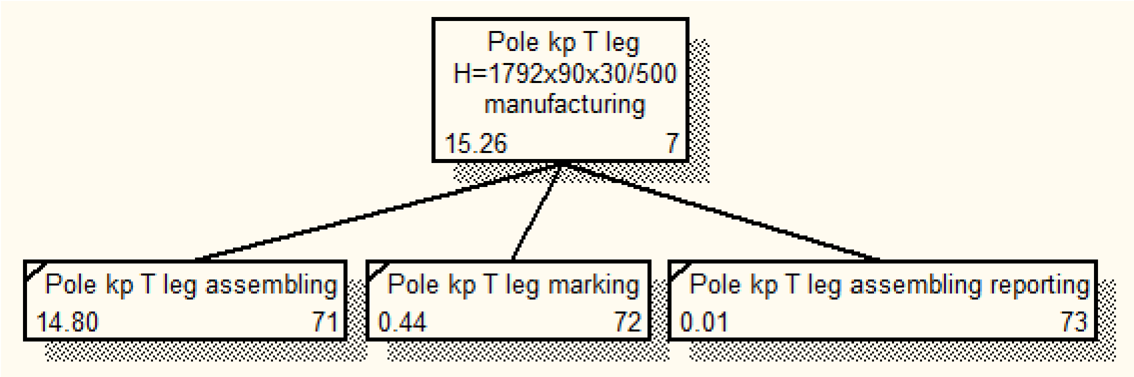


Figure 5.8. TO-BE Node Tree Diagram of Pole kp T leg H=1792x90x30/500 manufacturing

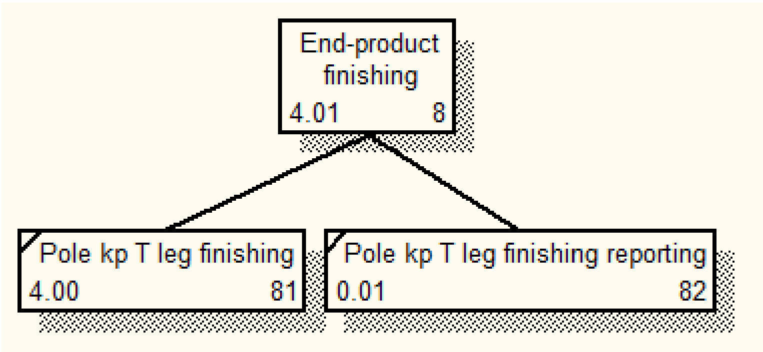


Figure 5.9. TO-BE Node Tree Diagram of end-product finishing

In AS-IS and TO-BE processes the details processing time for one product remained the same. The total time of manufacturing one product in AS-IS process was 29,44 minutes and in TO-BE process 34,23 minutes (Figure 5.10). The total time of the manufacturing process increased by 16,27%.

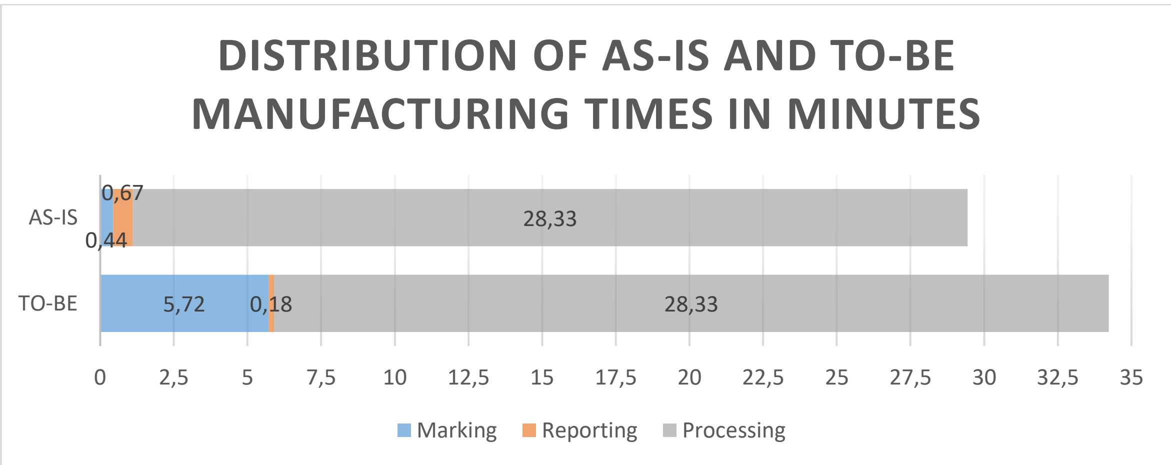


Figure 5.10. Distribution of AS-IS and TO-BE manufacturing times in minutes

It was found that by implementing the new marking method, the marking time of the details of one product increased greatly, from 0,44 minutes to 5,72 minutes. The time spent on reporting, however, decreased by 73,13% (Figure 5.11).

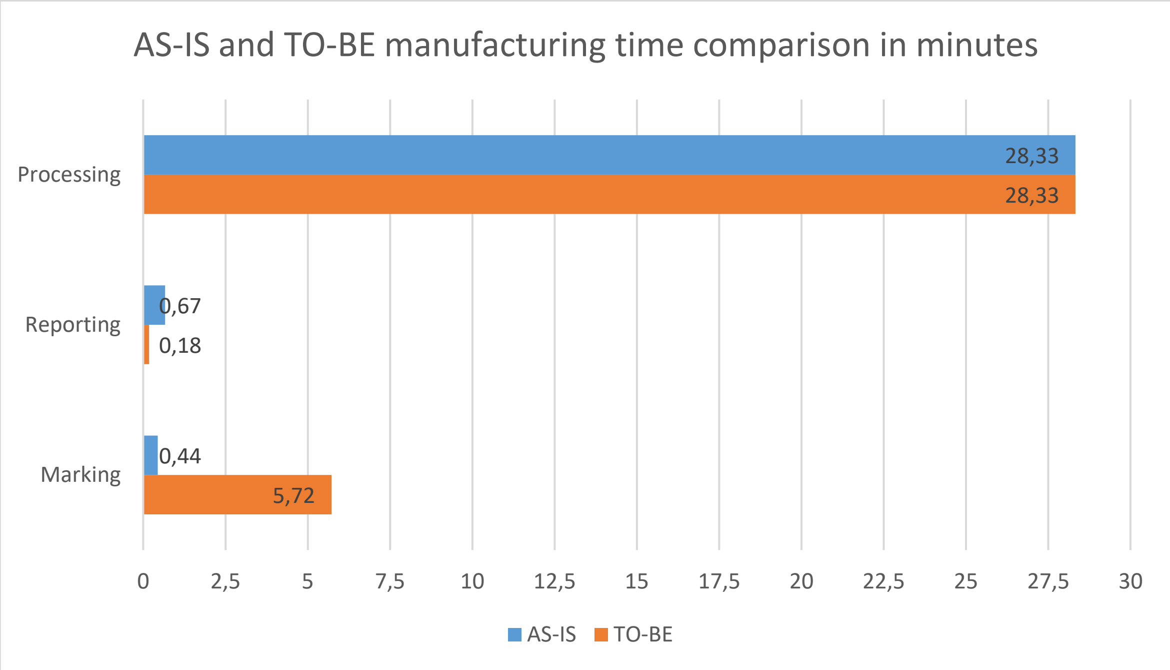


Figure 5.11. AS-IS and TO-BE manufacturing time comparison in minutes

From this comparison, the author found that the manufacturing process of one product lengthens considerably. This was an expected outcome as in the current process there is no proper way of marking all the details that are being processed, also, in the existing process there are no times attributed to searching for the right details on plant floor. However, the total time spent on manufacturing did not increase so much so that it would not be possible to deliver the products to the customer in the same time as in the current process. With the new marking system there is always a real-time overview of the manufacturing, the details cannot be lost easily, waste can be reduced and a lot of money can be saved.

6 PAYBACK ANALYSIS

The author selected some devices in order to compose a payback analysis on the implemented detail marking and tracking system. The devices selected are illustrative as the selection of the exact devices was not the aim of this thesis. In order to make the exact choice on the devices, some further research and several tests with the details have to be carried out.

According to the price inquiry made to Wuxi Kuntai Automation Co., Ltd the price for dot peen marking system KT-PH03 is 462€ and it uses marking pins and pin sleeve as consumables. Marking pin should be changed in every 3 months and pin sleeve in every 12 months. The cost for a marking pin is 14€ and pin sleeve is 19€. The cost of consumables will be included in the cost of maintenance.

The scanner cost of DataLogic Skorpio X4 is 1150 € per unit and DataLogic Magellan 1100i is 300 € per unit. [48] [50]

The total costs of required devices are shown in Table 23.

Table 23. Total cost of devices needed for the new system

Device	Amount	Price (1 pcs)	Price
Dot peen marking system KT-PH3	4	462 €	1 848 €
Hand-held scanner DataLogic Skorpio X4	5	1 150 €	5 750 €
Stationary scanner DataLogic Magellan 1100i	4	300 €	1 200 €
		SUM	**8 798 €**

In Table 24 it is shown that the cost of current process is 352 520 € in a year. For the annual wage calculation it was taken into account that the estimated gross wage in Kitman Thulema AS is 1648 € and there are 12 operators involved in the manufacturing of the test case [51]. In Kitman Thulema AS there is no official statistic about the expenses that are caused by the waste in manufacturing resulting in delays. The estimated expense on ordering additional transportation for the items delayed from manufacturing in year 2019 was 35 000 €.

It can also be seen in Table 24 that the number of workers will not be decreased due to the implementation of the new system so that the annual wage and taxes will remain the same. The set-up costs are composed of development costs to the ERP system and any other services that are needed for setting up devices. Maintenance costs consist of consumables and additional expenses on fixing any errors on the marking or scanning devices. The aim of this project was to decrease the expenses related to any kinds of delays by at least 35%.

Table 24. Costs of AS-IS and TO-BE systems

Type of cost	Cost of AS-IS	Cost of TO-BE
Investment costs	0 €	8 798 €
Annual wage and taxes	317 520 €	317 520 €
Set up costs	0 €	10 000 €
Maintenance	0 €	1 300 €
Expenses related to delays	35 000 €	26 000 €

From Table 25 it can be seen that the initial costs of implementing the new system are higher than the current system but it pays back on the third year of using the new system. The calculations did not take into account that the new system has a possibility of having a real-time overview of manufacturing which enables greater optimization and greater output which, in turn, decreases the payback period.

Table 25. Payback period of dot peen marking system

Year	AS-IS expenses	Total AS-IS expenses	TO-BE expenses	Total TO-BE expenses
1	352 520 €	352 520 €	363 618 €	363 618 €
2	352 520 €	705 040 €	344 820 €	708 438 €
3	352 520 €	**1 057 560 €**	344 820 €	**1 053 258 €**

CONCLUSION

The main goal of this thesis was to find and propose the best suited system for tracking the manufacturing operations in Kitman Thulema AS.

For the purpose of finding the solution, the following tasks were done:

1. **Analyzing the current process**

For the implementation of the main goal, it was necessary to analyze the current manufacturing process in Kitman Thulema AS and find the bottlenecks in the process of tracking the manufacturing operations in order to improve this process. It was found that the current process is insufficient as not all details are currently being marked and the operations reporting process is manual. This causes confusion on the plant floor which results in delays to customer deliveries and is considered waste. Also, it is currently not possible to react quickly to market changes and optimize the manufacturing. The need to reduce waste caused by insufficient operations tracking process was the motivation for finding a new and better solution.

2. **Choosing the most suitable marking method for Kitman Thulema AS**

In order to find the most suitable detail marking method all the desired criteria of the new system were decided during the discussions with group of experts from the company. In comparing different detail marking methods against the chosen criteria, it was found that the dot peen marking method suits Kitman Thulema AS's needs the best. Also, the author suggested suitable equipment for the implementation of the new system, but it must be noted that there is also other equipment offered on the market that is suitable for the same operations tracking system.

3. **Comparison of AS-IS and TO-BE models**

The author found that by implementing the new marking method the marking time for one product significantly increases. The time spent on operations reporting decreases by 73,13%. The total time of manufacturing one product increases by 16,27% by using the new system for marking the details. This was an expected outcome as in the current process there is no standardized process for marking the details. However, the total time of manufacturing did not increase so much that it would not be possible to deliver the products to customer in the same time as in the current process. With the new system it is possible reduce waste and optimize manufacturing which results in greater manufacturing output.

4. **Evaluation of the approach implementation**

A payback analysis was conducted based on the equipment suggested by the author. According to the calculations the break-even point of the investments on the new dot peen marking system for tracking the manufacturing operations in Kitman Thulema AS plant is reached in the 3rd year of its usage. However, the calculations did not take into account in that, due to the possibility of optimization, the output of the manufacturing may be greater which shortens the payback period even more.

For further development of the selected system it would be reasonable to involve more operations in the analysis process and consider all exceptions in the manufacturing processes of different products. In order to fully digitalize the system the company could consider greater investments in order to implement the marking and detail identifying systems fully into the workstations. The more digitalized the system, the less errors occur and the more reliable the system is. Before making the investment, the selected equipment also needs to be tested on Kitman Thulema's details.

By implementing the system for tracking the details in the manufacturing, the company will have accurate real time data of every manufacturing operation. Also, the accuracy of deliveries will be improved and delays in transportation will decrease. This new operations tracking system gives the company the ability to compare the planned and actual costs and, in the future, the possibility of implementing an automatic manufacturing planning system.

In conclusion, the author considers this thesis successful because the aim of proposing Kitman Thulema AS a suitable new system for improving the manufacturing operations tracking process, taking into account all their expectations and needs, was fulfilled.

KOKKUVÕTE

Käesoleva töö põhieesmärk oli leida parim sobiv lahendus tootmisoperatsioonide jälgitavuse parendamiseks ettevõttes Kitman Thulema AS.

Parima sobiva lahenduse leidmiseks tuli lahendada järgmised ülesanded:

1. **Olemasoleva protsessi analüüs**

Töö põhieesmärgi täitmiseks oli vajalik analüüsida hetkel olemasolevat tootmisprotsessi ettevõttes Kitman Thulema AS ja leida kitsaskohad tootmisoperatsioonide jälgitavuse protsessis, et seda parendada. Leiti, et olemasolev protsess on ebaefektiivne, sest ei tähistata tootmises kõiki detaile ja operatsioonide raporteerimine on manuaalne. See tekitab segadust tootmisalal, mis omakorda põhjustab hilinemisi toodete väljastuses klientidele. Seda loetakse raiskamiseks. Lisaks ei ole võimalik praeguse süsteemi järgselt reageerida kiiresti turumuutustele ja seetõttu ka optimeerida tootmist. Ebaefektiivsest tootmisoperatsioonide järgimise protsessist tingitud raiskamine oli motivatsiooniks uue ja parema süsteemi leidmisel.

2. **Kitman Thulema AS jaoks sobivaima tähistusmeetodi valimine**

Selleks, et leida sobivam detailide tähistamise meetod määrati esmalt diskussioonide käigus ettevõttes moodustatud ekspertide rühmaga kriteeriumid uuele süsteemile. Vastavalt valitud kriteeriumitele võrreldi erinevaid detailide tähistamise meetodeid ning leiti, et metallimarkeerimise meetod sobib Kitman Thulema AS vajadustega enim. Lisaks soovitas autor töös ka sobivaid seadmeid uue süsteemi implementeerimiseks. Tuleb siiski märkida, et turul pakutakse ka mitmeid teisi seadmeid, mis on samuti sobilikud valitud metallimarkeerimise meetodi kasutamiseks.

3. **Olemasoleva ja tulevase protsessi võrdlus**

Autor leidis, et uue detailide tähistamise meetodi kasutusele võtmisega suureneb tähistamise aeg ühe toote kohta märgatavalt. Operatsioonide raporteerimisele kulutatud aeg kahaneb 73,13% ning ühe toote kogu tootmisaeg suureneb 16,27%. Tulemus oli oodatav, sest olemasolevas protsessis puudub standardiseeritud meetod detailide tähistamiseks. Sellele vaatamata ei kasva toote kogu tootmisaeg nii palju, et ei oleks võimalik toimetada kaupasid kliendini sama ajaga nagu seda on võimalik teha olemasolevat süsteemi kasutades. Uue süsteemi kasutusele võtmisega on võimalik vähendada raiskamist ja optimeerida tootmist, mille tulemusena on võimalik saavutada suurem tootlus.

4. **Implementeeritava süsteemi hindamine**

Investeeringu tasuvuse analüüs koostati põhinedes autori poolt valitud seadmetele. Arvutuste tulemused näitasid, et metallimarkeerimise meetodi investeeringute kasumi nullpunkt saavutatakse süsteemi kolmandal kasutusaastal. Arvutustes ei võetud arvesse seda, et uue süsteemi kasutamine võimaldab optimeerida tootmist ning suurendada tootlust, mis omakorda lühendab investeeringu tasuvuse perioodi.

Valitud süsteemi edasiseks arendamiseks oleks mõistlik kaasata protsessianalüüsi rohkem tootmisoperatsioone ning võtta arvesse kõiki erandeid, mis võivad tulla ette tootmisprotsessis. Protsessi täielikuks digitaliseerimiseks võib ettevõte kaaluda suuremate investeeringute tegemist, et evitada detailide tähistamise ja identifitseerimise süsteem täielikult töökeskustega. Mida digitaliseeritum on süsteem, seda vähem tekib inimeste poolt põhjustatud vigu ja seda usaldusväärsem see on. Enne investeeringute tegemist tuleb testida kõiki valitud seadmeid Kitman Thulema AS detailidel.

Detailide jälgimise süsteemi juurutamine annab ettevõttele täpsed andmed tootmisoperatsioonide kohta reaalajas ning seeläbi paranevad tarnetäpsus ja vähenevad hilinemised kaupade väljastamisel. Uus tootmisoperatsioonide jälgimise süsteem annab ettevõttele võimaluse võrrelda planeeritud kulusid tegelikega ning tulevikus ka võimaluse juurutada automaatset tootmise planeerimise süsteemi.

Kokkuvõtteks võib väita, et töö oli edukas, sest töö eesmärk soovitada ettevõttele Kitman Thulema AS uut süsteemi tootmisoperatsioonide jälgitavuse parendamiseks, võttes arvesse nende ootuseid ja vajadusi, sai täidetud.

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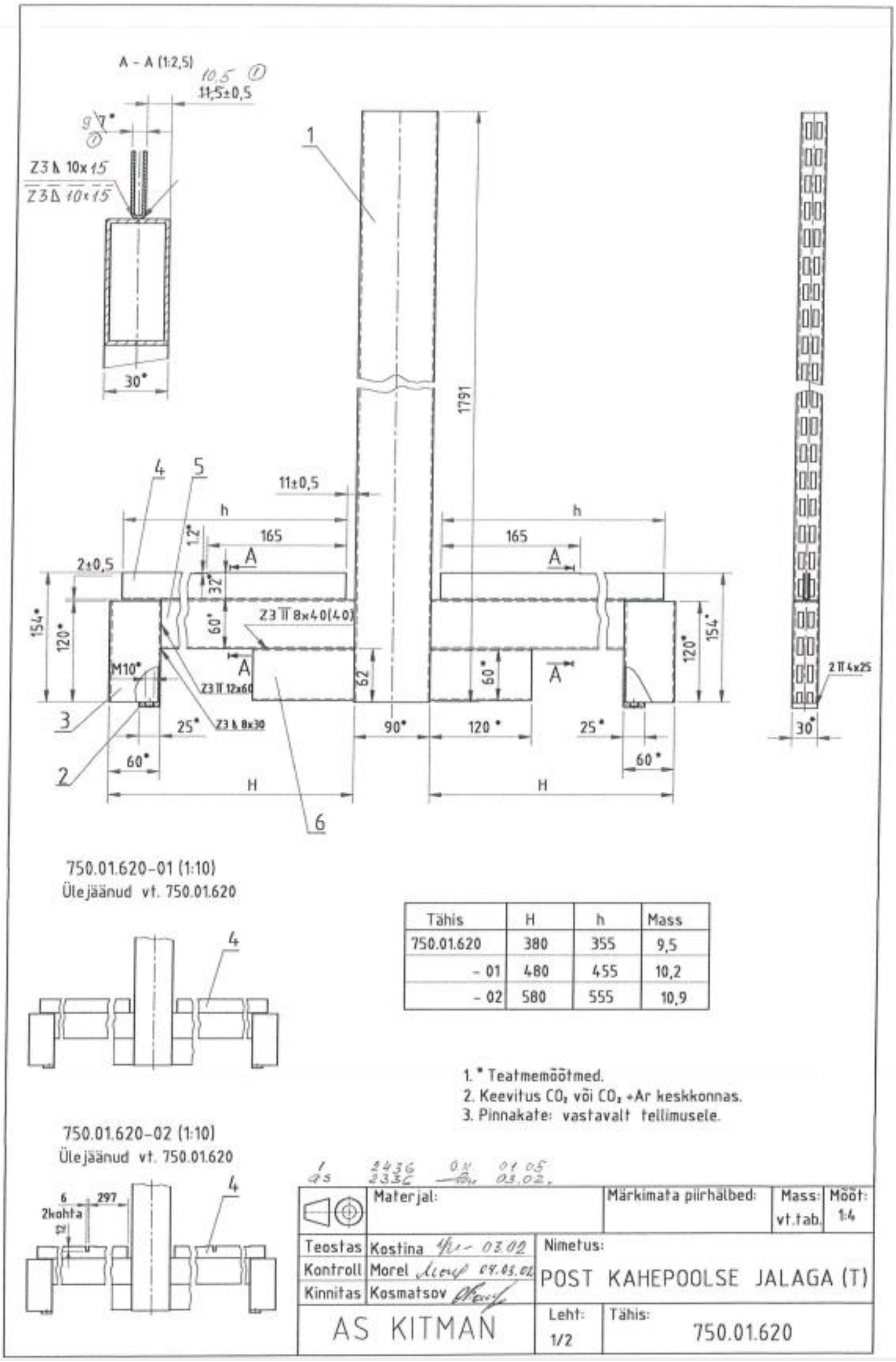
APPENDICES

Appendix 1 Drawing of test case 750.01.620-01 Pole kp T leg H=1792x90x30/500



F	POS	NIMETUS,MATERJAL	TÄHIS	HULK VARIANDIS			MÄRKUS
					-01	-02	
A3	1	Post	750.01.410 - 02	1	1	1	
A4	2	Lapp	276.02.003	2	2	2	
A4	3	Post	725.02.111	2	2	2	
A4	4	Tugi	775.02.113	2			
A4	4	Tugi	775.02.113 - 01		2		
A4	4	Tugi	775.02.113 - 02			2	
	5	Toru 60x30x2 St37-2 DIN2395					
		L = 320	725.01.501	2			0,86
		L = 420	- 01		2		1,13
		L = 520	- 02			2	1,4
	6	Toru 60x30x2 St37-2 DIN2395 L=120	725.01.521	2	2	2	0,31

Posti 750.01.410A-02 (toruside) kasutamisel lisada joonise numbrile A (750.01.620A)

Posti 750.01.410B-02 (S=2,5 lattside+rist.) kasutamisel lisada joonise numbrile B(750.01.620B)

Posti 750.01.410BA-02 (S=2,5 toruside) kasutamisel lisada joonise numbrile BA (750.01.620BA)

TEOSTAS	Kostina	POST KAHEPOOLSE JALAGA(T)
KONTROLL	Kasemets	
KOOSKÕL.	Kosmatsov	
AS KITMAN	LEHT 1/2	750.01.620

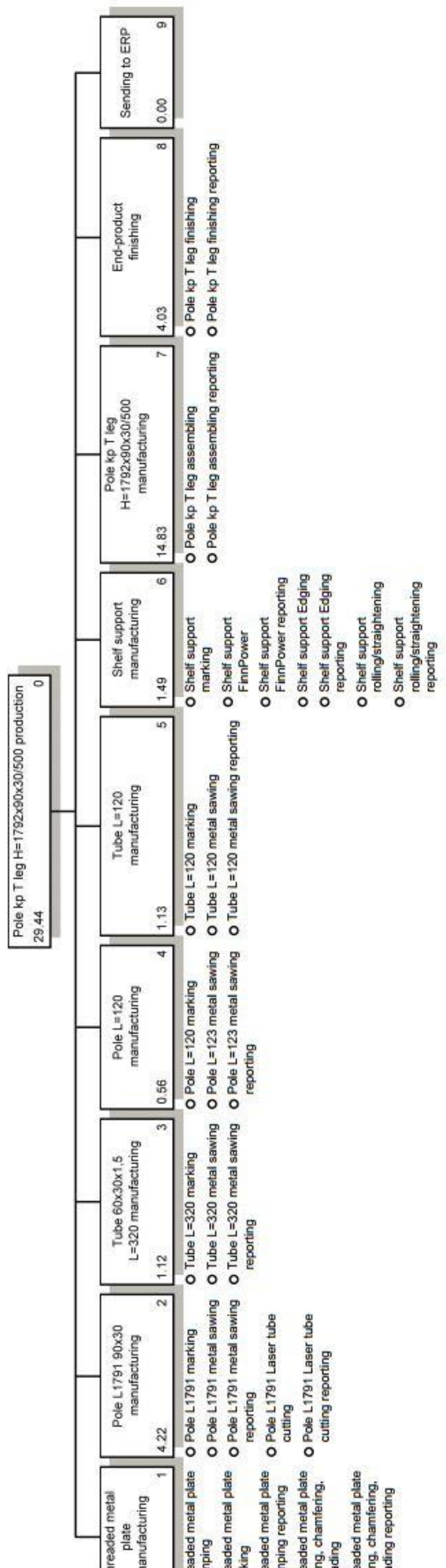
Appendix 2 Bill of Materials of the test case

PRODUCT		MATERIAL CODE	MATERIAL NAME				QUANTITY	UNIT OF MEASURE (QUANTITY)
750.01.620-01		S_810100	Powder paint RAL7045				0,0733	kg
DETAIL	**DETAIL NAME**	**MATERIAL CODE**	**MATERIAL NAME**	**HEIGHT (mm)**	**WIDTH (mm)**	**THICKNESS (mm)**	**QUANTITY**	**UNIT OF MEASURE (QUANTITY)**
PT_276.02.003	Threaded metal plate			30	25		3	pcs
		S_544005	Stainless steel strip		25	6	0,037	kg
PT_750.01.411-02	Pole L1791 90x30			1792	90		1	pcs
		S_5341060	Perforated tube	90	30	2	2	m
PT_725.01.501	Tube 60x30x1,5 L=320			320	60		2	pcs
		S_534009	Square tube	60	30	2	0,33	m
PT_725.02.111	Pole L=120			120	60		2	pcs
		S_534102	Perforated tube	60	30	2	0,13	m
PT_725.02.121	Tube L=120			120	60		2	pcs
		S_534009	Square tube	60	30	2	0,13	m
PT_775.02.113	Shelf support			355	66		2	pcs
		S_502004	Cold rolled steel			1,5	0,33	kg

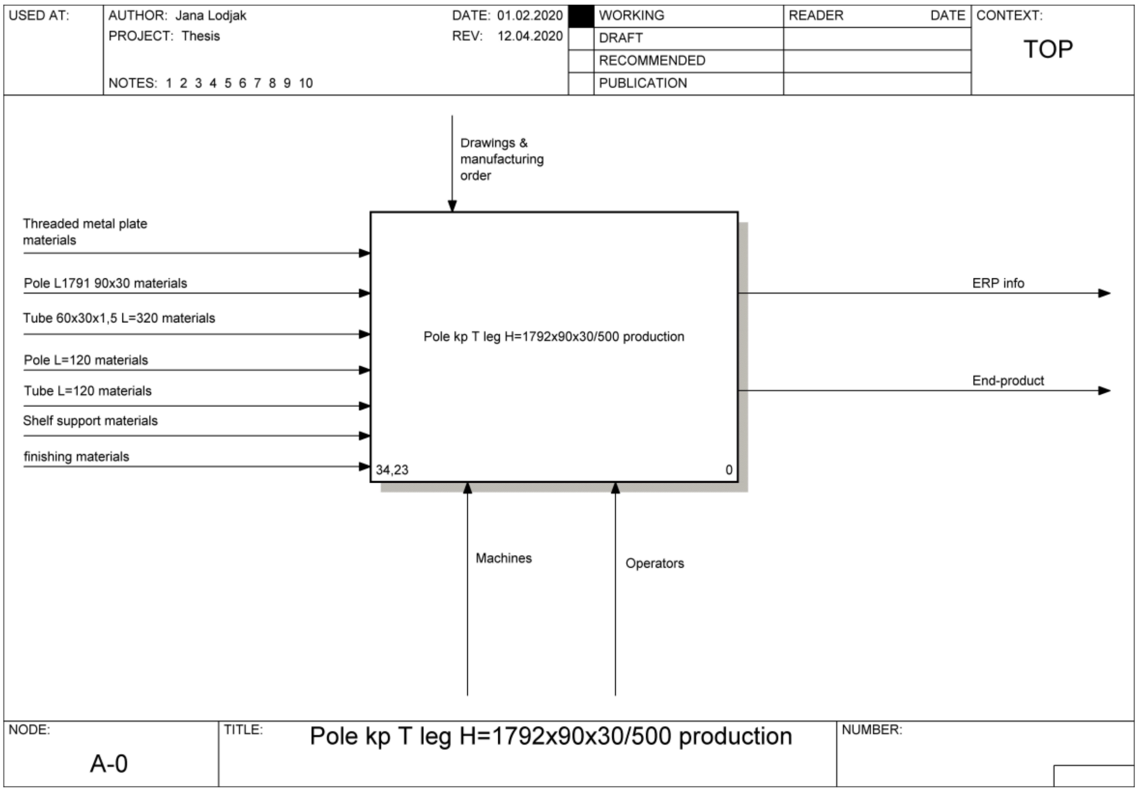
Appendix 3 Routing of the test case

CODE	OPERATION NO	OPERATION NAME	RUNTIME(MIN)	RESOURCE
750.01.620-01	10	CO welding	14,8	Manual work
	20	Powder finishing	4	Idealline
PT_276.02.003	10	Stamping	0,5	AMADA LC3015-X1
	20	Drilling, chamfering, threading	0,1	Manual work
PT_750.01.411-02	10	Metal sawing	2	Band saw
	20	Laser tube cutting	2	TRUMPF Tube 5000
PT_725.01.501	10	Metal sawing	0,5	Band saw
PT_725.02.111	10	Metal sawing	0,25	Band saw
PT_725.02.121	10	Metal sawing	0,5	Band saw
PT_775.02.113	10	FinnPower	0,11	Finn-Power Combi
	20	Edging	0,25	Amada HFE 80-25
	30	Rolling/straightening	0,25	Luna 8266

Appendix 4 Node Tree Diagram of test case 750.01.620-01 Pole kp T leg H=1792x90x30/500



Appendix 5 IDEF0 diagram of TO-BE process



Appendix 6 Manufacturing process of Pole kp T leg H=1792x90x30/500

Activity		
Name	**Number**	**Definition**
Pole kp T leg H=1792x90x30/500 production	A0	
Threaded metal plate manufacturing	1	
Threaded metal plate stamping	11	
Threaded metal plate marking	12	Information is stamped on detail by the worker using dot peen marking system.
Threaded metal plate stamping reporting	13	The scanner on the work center identifies and counts the details automatically. Operation is reported in ERP system.
Threaded metal plate drilling, chamfering, dreading	14	
Threaded metal plate drilling, chamfering, dreading reporting	15	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Pole L1791 90x30 manufacturing	2	
Pole L1791 marking	21	Information is stamped on detail by the worker using dot peen marking system.
Pole L1791 metal sawing	22	
Pole L1791 metal sawing reporting	23	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Pole L1791 Laser tube cutting	24	
Pole L1791 Laser tube cutting reporting	25	The scanner on the work center identifies and counts the details automatically. Operation is reported in ERP system.
Tube 60x30x1,5 L=320 manufacturing	3	
Tube L=320 marking	31	Information is stamped on detail by the worker using dot peen marking system.
Tube L=320 metal sawing	32	
Tube L=320 metal sawing reporting	33	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Pole L=120 manufacturing	4	
Pole L=120 marking	41	Information is stamped on detail by the worker using dot peen marking system.
Pole L=123 metal sawing	42	
Pole L=123 metal sawing reporting	43	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Tube L=120 manufacturing	5	
Tube L=120 marking	51	Information is stamped on detail by the worker using dot peen marking system.
Tube L=120 metal sawing	52	
Tube L=120 metal sawing reporting	53	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.

Activity		
Name	**Number**	**Definition**
Shelf support manufacturing	6	
Shelf support marking	61	Information is stamped on detail by the worker using dot peen marking system.
Shelf support FinnPower	62	
Shelf support FinnPower reporting	63	The scanner on the work center identifies and counts the details automatically. Operation is reported in ERP system.
Shelf support Edging	64	
Shelf support Edging reporting	65	The scanner on the work center identifies and counts the details automatically. Operation is reported in ERP system.
Shelf support rolling/straightening	66	
Shelf support rolling/straightening reporting	67	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Pole kp T leg H=1792x90x30/500 manufacturing	7	
Pole kp T leg assembling	71	
Pole kp T leg marking	72	Information is stamped on detail by the worker using dot peen marking system.
Pole kp T leg assembling reporting	73	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
End-product finishing	8	
Pole kp T leg finishing	81	
Pole kp T leg finishing reporting	82	Worker uses hand-held scanner at his work center for reading the QR code on the detail. The detail is identified and worker inserts the processed quantities on the scanner. Operation is reported in ERP system.
Sending to ERP	9	