Kelvion

Optimization of pre-production processes

Improving processes in an engineer to order environment

UNIVERSITY OF APPLIED SCIENCES

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January 9th 2022

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Preface

In order to finish my bachelor in Industrial Engineering and Management, I conducted a research at Kelvion refrigeration B.V located in Sint Maartensdijk, where I investigated the pre-production processes in order to map out the processes, identify waste and effectively lead to the generation and implementation of improvements. An opportunity worthy of gold in terms of the period in which I secured it, initiated and offered by my in-company supervisors, Paul Plasmans and Martin Quist.

As an Industrial Engineering and Management student, striving for improvements in the midst of struggles and hurdles has been instilled in you to become a natural instinct. Additionally, my passion for learning about methodologies that are in place to effectively overcome trying times in companies further pushed me to grab this opportunity and apply what I have learned in the past.

The following report is a result of thorough and extensive analysis conducted in an engineer-to-order environment, containing comprehensive information about Kelvion's internal processes, and ultimately documenting the research I had conducted at the company.

I would like to use this opportunity to thank some people in particular. First, I would like to express my deepest gratitude to Paul Plasmans who provided unfaltering support as my in-company supervisor, and Martin Quist who provided me with this opportunity. Thank you to Lauren Deckers, my internship supervisor, who took the time to provide me with Feeback and improvements on my work. I would also like to thank Jeroen Van Beers, A professor at the university, for his constant support to graudating students.

Lastly, a special thank you goes out to all of the Kelvion employees who provided me with valuable information when interviews were conducted. Without you all, this would not have been possible.

Executive summary

Kelvion refrigeration B.V is one of the world's leading manufacturers of heat exchangers, who provide solutions for almost every industrial application imaginable, working in an engineer to order fashion to provide the customers with the utmost ability to customize their products.

In theory, 9 weeks are dedicated to receive (an order request), process, manufacture and deliver a product to allow for maximum satisfaction and a better position in the customized heat exchanger manufacturing sector. However, in a vast majority of these projects, the period defined by the company is not met and this is largely caused due to the pre-production processes which take up the majority of these 9 weeks dedicated for the entire process.

Consequently, concerns from the company's representatives had risen, and for this reason, a graduation assignment was initiated to effectively allow for the identification of waste around the company's pre-production processes and ultimately put forward improvements that would lead to process optimization. On this bass, the pre-production processes of the company were thoroughly investigated, mapped out, and improvements proposals were made with the aim to reach process optimization especially in terms of lead time reduction and productivity. The main research question is as follows:

"How to improve the current situation of the pre-production processes in order to achieve process optimization?"

In pursuance of structuring the research report, the main research question is divided into 4 different sub-questions:

1- What is the current situation?
2- What are the tasks conducted in the processes and sub-processes found between AT1 and AT4?
3- What are the wastes and bottlenecks found in the processes?
4- What are the possible improvements to be implemented leading to the optimization of the processes?

These research sub-questions are ultimately answered through multiple different phases, which are indicated in the research roadmap displayed in figure 9 on page 26, designed following the lean six sigma methodology.

A theoretical framework was established focusing on relevant theories used throughout this research such the customer order de-coupling create awareness on the engineer to order processes, Lean management which is used to reduce waste around companies, and process mapping theories as another large objective requested by the company was the mapping of the processes.

Several different data collection methods were applied to gather comprehensive information about the processes. Firstly, interviews took place with multiple different employees around the company which had a function in the pre-production processes, and this allowed for a great understanding of the tasks that are conducted around the company, as well as some of their complaints about the processes. Observations were also applied to add to the range of qualitative data collection methods used in this report, providing the opportunity to identify a vast number of wastes and improvements.

Additionally, an ERP analysis was conducted to help understand the situation in a quantitative form of data, and allow for the recognition of where the issue stands in the company, as well as the number of projects conducted through the span of a year in terms of completed pre-production processes.

Following the execution of the research methods concluded in accordance to the theories used, wastes were identified, and a large list of improvements was established including, but not limited to, Training of staff, Creating additional work form, Utilizing existing and some process re-designs; leading to process optimization and an overall 19% reduction in terms of lead time.

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Abbreviations/Glossary of terms

Webtools: Organizational tool to allow each department to see what steps are available to work on

CAPCALC: A system used by Kelvion to calculate heat exchanger capacity.

SAP: Kelvion ERP system

ERP: Enterprise resource planning

Sofon: A Software used for product configuration and pricing.

SCO: Supply chain operations

VSM: Value stream mapping

ETO: Engineer to order

PAM: Process activity map

VA: Value adding activities

NVA: Non-value adding activities

BVA: Business value adding activities

NNVA: necessary non-value adding activities.

RADAN: CAD drawing program for sheet metal applications

Inventor: 3D drawing program

ABAP: High level programming language created by SAP

CPQ: configure-price-quote.

Duration time: Also known as lead time where the time recording starts from the appearance of a task on your worksheet until its departure

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1-Introduction

This section of the report will include a general overview of Kelvion's various functions, the different types of departments which can be found around the company in the Netherlands' location, and which exact one will the project being conducted fall under. This section will also provide some heavy and salient insight on what the current problem is and what would be the appropriate research question would be.

1.1- Company introduction

The company of Kelvion is one of the world's leading heat exchangers manufacturers, responsible for building heat exchangers and coolers Depending on the customer's want in an engineer to order environment, providing complex and flexible solutions for various types of industries making use of these heat exchangers. Some of the company's major attributes are their amount of experience in this field of works, their highly diverse possibilities in customization, and its vast amount of partnerships with many different industries such as transport, oil, gas as well as food industries and many more.

Formerly known as GEA heat exchangers since its date of establishment back in 1920, the company was later acquired by Triton fund in 2014 enabling the name change to Kelvion which pays homage to Lord kelvin, who formulated the laws of thermodynamics.

Kelvion operates in 67 different locations worldwide and generated a grand total of 915 million euros in year of 2019 throughout all the continents where it operates (Kelvion, 2019).

Of all these locations, a large amount of companies fall under the Kelvion corporate family, to be specific 113, of which is Kelvion Sint Maartensdijk, hereinafter Kelvion SM, situated in the Netherlands. Kelvion SM Currently holds 163 employees and generates $29.3 Million in revenue yearly and where this current project will take place.

Mission statement

The company of Kelvion possesses many years and in-depth expertise in the field of heat exchangers manufacturing which forged them to become specialists in this field of work.

The heat exchangers are designed specifically to meet all needs of the respective machine or equipment system desired by the customers to acquire a heat exchanger, thus ensuring outstanding energy efficiency and reliability in any requested market segment.

Vision statement

Kelvion (2019) established a vision for the company's future which can be described briefly through the following quote:

> *"Heat X-changing the world with sustainable engineered solutions."*

Values

The values which are treasured in the company of Kelvion are the following:

One Kelvion: *"We are one global kelvion"*

Customer Driven: *"We are customer driven"*

Transparent: *"We are open and transparent"*

Committed: *"We keep our commitments"*

Lead by example: "*We lead by example"*

Strategy

The company of Kelvion follows a certain created a strategy which is known as "the high five strategy" where the name is derived from the 5 following actions:

1- Less complex projects- more service
2- Less fossil- more green
3- Grow data center business annually
4- Growth in NAFTA & APAC- become a true global company
5- Two digit EBITDA margin

1.1.1- Finished goods

Kelvion SM is responsible for three different production sites, the first based in the Netherlands, the second based in Poland, and the third one operating in Czech Republic. All ordered are processed in the Sint Maartensdijk, where the production planners decide the location of production depending on the materials needed to be used to manufacture a heat exchanger as well as where the sale has been made.

The 3 different materials coomonly used for manufacturing theheat exchangers are copper tubes and aluminum fins, stainless steel tubes with stainless steel fins, and hot dipped galvanized steel tubes and fins.

The company of Kelvion worldwide consists of manufacturing 4 different business units at different locations, each specializing in a different product, notably machine cooling systems, plate heat exchangers, thermal engineered solutions, and refrigeration technologies under different branches.

Kelvion SM falls under the refrigeration technologies sector, where the main focus is placed on manufacturing customized and commercial air coolers.

Table 1 provides a clear image to allow for gaining an insight on the product lines and markets that fall under each of the 4 listed products.

	Thermal engineered solution	Machine cooling systems	plate heat exchangers	Refrigeration technologies
Product lines	1-Air Fin cooler (AFC) Alu or HdG 2-Air Cooled Condenser (Multi-Row, Single Row) 3-Wet Cooling 4-Air Preheater / Air Dryer 5-Economizer 6-Shell & Tube and 7-Desublimator	1-Shell & Tube Double Safety 2-Shell & Tube Single 3-Transformer Oil Pumps 4-Transformer Oil Air Coolers 5-Transformer Oil Water Coolers 6-Closed Circuit Cooler 7-Aluminium Bloc 8-Engine Air & Gas Coolers 9-Coils 10-Box Cooler	1- Brazed plate heat exchangers 2- Gasketed plate heat exchangers 3- Fully welded heat exchangers	1-Commercial Aircooler 2-Customized Aircooler 3-Condenser & Dry Cooler 4-Radiator & Dry Cooler
Markets	1- Oil & gas 2- Chemical refineries	1-Chemicals 2-Data Center 3-Food Processing 4-Marine 5-Onshore 6-Power 7-Transportation	1- Fine chemicals 2- Food &beverages 3- HVAC 4- Marine	1-Data Center 2-Food Processing 3-HVAC 4-Marine 5-Onshore 6-Power 7-Refrigeration 8-Transportation

Table 1-product lines and markets per product

As indicated in table 1, the company of Kelvion possess a large market share worldwide, with companies ranging from multiple different industries.

This means Kelvion provides its services to a wide range of companies, most notably are these key customers indicated in figure 1

Figure 1- Kelvion key customers (Kelvion, 2019)

1.1.2- Department

At the time of this internship, the project being conducted falls under the supply chain operations department, the roles/sectors which fall under this department are as follows:

- logistics management
- Supply chain operations management
- Purchasing
- Planning
- Work Preparation

Figure 1 found below illustrates the previously mentioned teams and members which fall under this department, as well as the hierarchy setting,

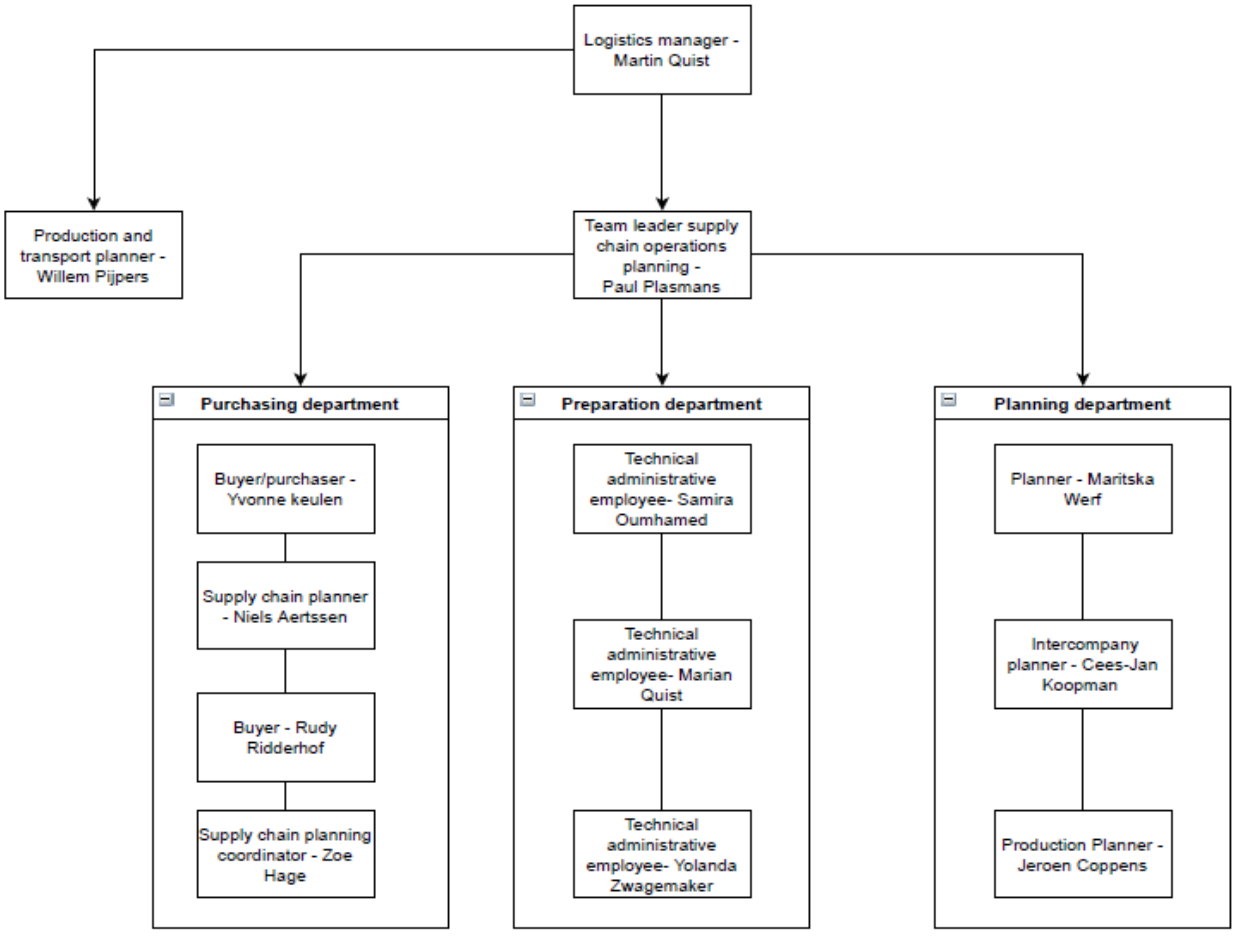

Figure 2-Organizational chart of the supply chain management department

1.1.3- Project team

- Supply chain operations manager – Paul Plasmans: Leader of the supply chain management operations who's function in the company is be the team leader for the planning, work preparations, and purchasing teams as well as holding meetings with other department managers to strive for improvements in the processes. In terms of the internship, he is one of the enablers of this project, and will be responsible for the provision of the resources needed to complete this project such as factory visits and interviews with different departments around the company. He also has the role of being the in-company supervisor as for a function when it comes to in-company meetings regarding university objectives.

- Logistics manager - Martin Quist: Leader of the entire logistics chain and continuous improvement manager. He was also the second enabler for this project to happen, his role in this project is to accommodate the needs for this project to be set in place such as providing resources needed whether be it in the form of interviews to be done with the employees, or surveys.

1.2. Research problem (Problem statement)

Kelvion Refrigeration B.V is responsible for building heat exchangers given that the dimensions, material required, and size have been received through the customer. This total process (appendix 1 shows summary process) in theory should take a maximum of 9 weeks which was defined by taking into account the customer's wants.

The 9 weeks countdown essentially Starts from the moment a sale has been confirmed and given to be handled by the pre-production processes. Once broken down, it consists of the following processes as shown in appendix 1:

- 5 weeks dedicated to the pre-production processes
- 3 weeks dedicated to the production processes
- 1 week dedicated to the delivery process.

However, in a majority 75% of the projects which are held and conducted by the company take quite longer than the specified period mentioned of 9 weeks, this delayed time of completion is highly unacceptable and could cause frustration at times for customers which in turn will cause the company of Kelvion to lose projects to competitors and as a result decreasing their market share.

A large range of possible bottlenecks and wastes could be happening around the companies processes which could be resulting in this delayed time, therefore a brainstorming session took place, and a fish bone diagram was created to help identify the possible causes for this current issue that the company of Kelvion is facing.

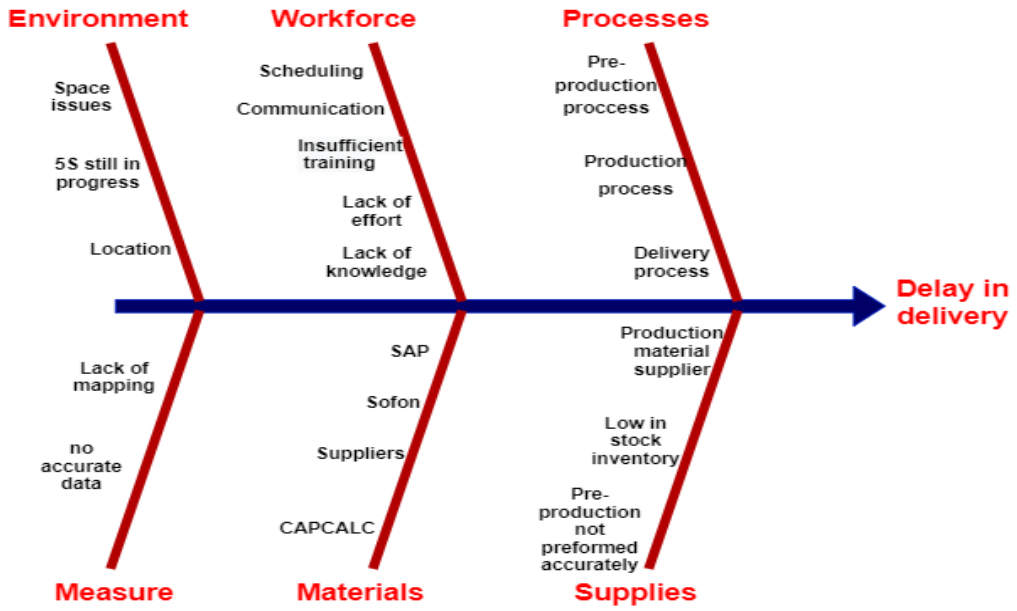

Figure 3- Fishbone diagram

Following the creation of the fishbone diagram, a good outlook on what are the possible causes for this delay in the project completion. However, a further investigation was executed to capture the root cause of this current problem, therefore a 5 why analysis has been conducted to determine the main source of this delay between all processes.

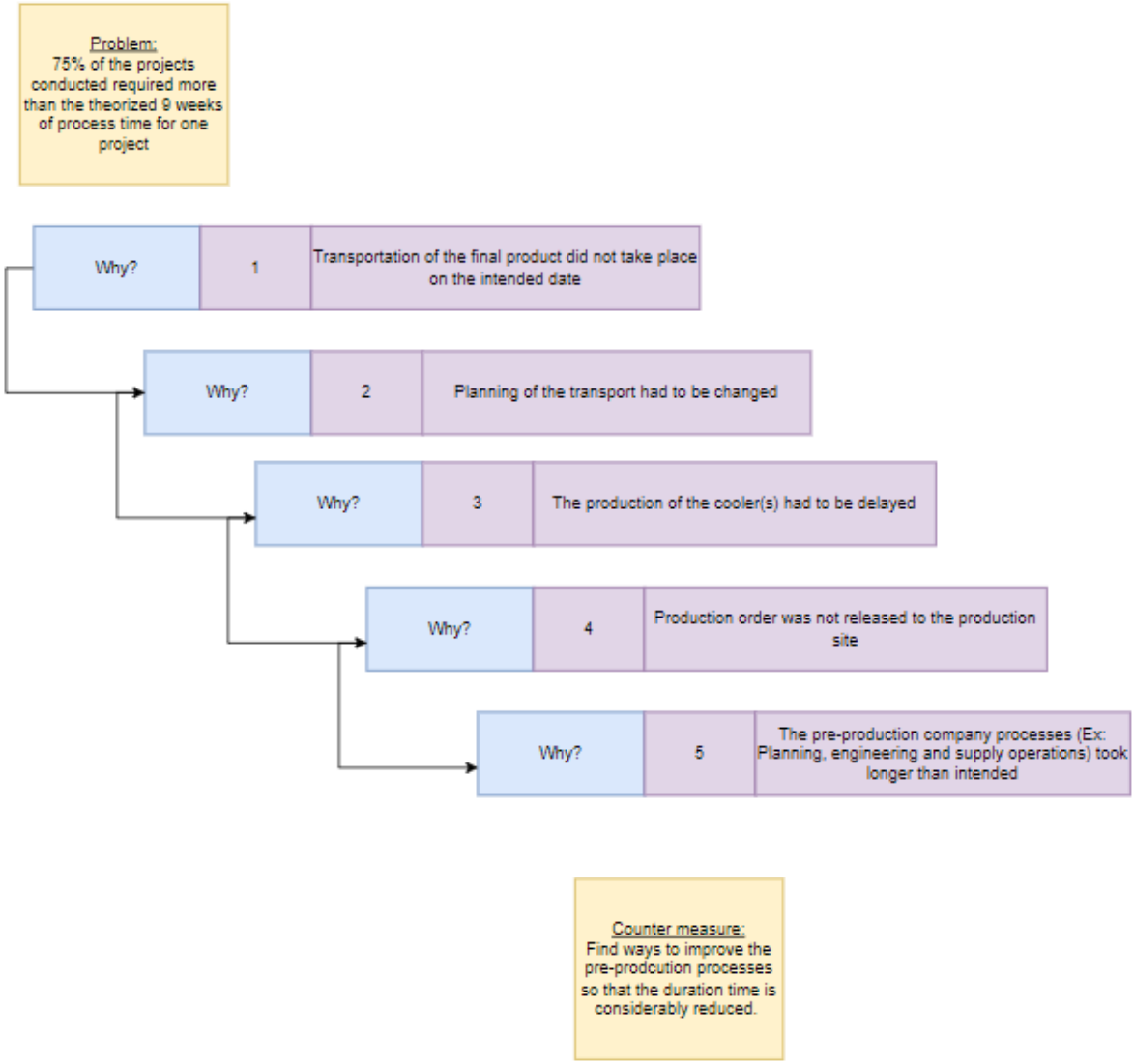

Figure 4- 5 why's root cause analysis

As shown in Figure 4, the root cause analysis lead to the determination of one main reason why the desired total process time of 9 weeks is not being met, and that is due to the pre-production processes, also known as internal processes taking place from AT1 until AT4 which are the activities taking place from the moment the order desk receive a sales order until its release to production as shown in figure 4.

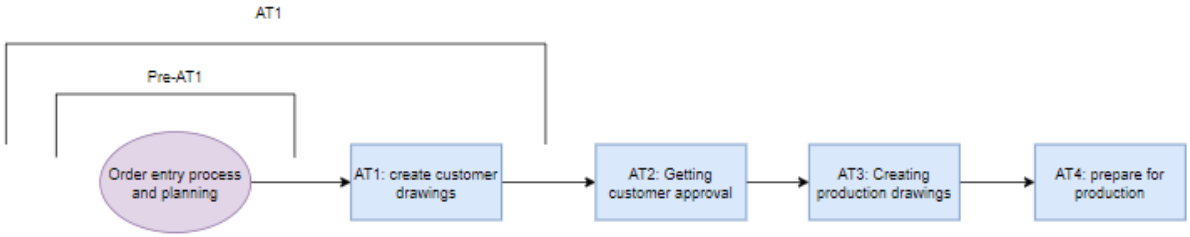

Figure 5- AT1 until AT4 simplified process

1.3 Research objective

In the already formulated problem statement, a thorough description of the current situation's issue has been identified, where more than 75% of the projects planned are not meeting the desired lead time due to the pre-production processes.

Due to this situation, the company of Kelvion have made a demand for going through the processes listed in appendix 1 (AT1- until AT4) with a main focus on AT1 and AT2 due to the bottlenecks occurring in those processes, mapping them out and giving out recommendations on possible fixes and solutions which the company should implement. This could range from small to large changes the company could make once the examination of the company's processes has been executed.

Based on the given information in the problem statement, the following goal has been formulated:

" *Mapping out the pre-production processes which are found between AT1 and AT4 for practicality reasons, followed by the analysis of the processes and identifying the possible wastes and bottlenecks to ultimately provide the company of Kelvion with improvements, thus allowing for process optimization within the period of September 2021 until January 2022"*

And to resolve the problem described in the previous paragraph the following research question and sub-questions were developed:

Research question:

How to improve the current situation of the pre-production processes in order to achieve process optimization?

Sub-questions:

5- What is the current situation?
6- What are the tasks conducted in the processes and sub-processes found between AT1 and AT4?
7- What are the wastes and bottlenecks found in the processes?
8- What are the possible improvements to be implemented leading to the optimization of the processes?

1.4- Scope

1.4-1. In scope

Based on the information given in the problem statement, what falls in the inside the scope of the project are the pre-production processes, meaning Pre AT1 processes starting from the Order desk, until AT4 processes where they will be released into the production phase.

1.4-2. Out of scope

The out of scope will be all other process steps (Process steps outside of AT1 to AT4), the budget, as well as measurement of the cycle times due to this being an engineer to order environment making it not feasible to calculate cycle times as a result of extremely high variations in time between each order and steps in the process.

1.5- Stakeholders

In the Stakeholders section, valuable insight will be given on all of the relevant parties who have a certain amount of interest in the project. The main reason why this research is being conducted is due to the rise of competition in the engineer to order heat exchanger manufacturing market around the Netherlands which could possibly be preforming their processes at a faster rate, leading to the possibility of losing past and potential customers and thus losing market share.

For this reason, it is important to identify all of the stakeholders which have some sort of relevancy to the process described in the problem statement.

This will give a comprehensive view on the list of the key organizational players, thus effectively allowing the receival or provision of substantial information about the processes they conduct.

- Order Desk team: The order desk department is responsible for handling the project information after it arrives from the sales department and placing it into the SAP system which would allow the rest of the departments to work on the project, this information includes the heat exchanger capacity calculations and pricing of the project.

- Planning team: The planning team Is responsible for planning the project that is taking place, they specify which factory the manufacturing of the cooler/heat exchanger will take place, they also fill up the preliminary order time decided on by the ERP system.

- Work Preparation team: The work preparation team's goal is to fill out information about the project which relate to preparing the bill of materials needed as well as pushing material information through to the purchasing department. Therefore, it can be concluded that they are the information suppliers to the purchasing team as well as work checkers when it comes to the drawings from engineering in accordance to the ERP data.

- Engineering department: The engineering department responsible for creating the customer drawings, as well as the production drawings. One of the bottlenecks in the company at the moment falls under their department.

- Supply chain operations leader: SCO leader is responsible for managing the planning, work preparations and purchasing teams. he also holds meetings with the rest of the managers to look for improvements that could be added to the present processes that are in the company.

- Purchasing team: The purchasing team's responsibility is to mainly purchase the project specified materials needed which are determined by the SAP system. The purchasing activity is done through contacting the suppliers and making orders.

- Logistics manager: The logistics manager is the initiator of the project and is responsible in providing aid when it comes to collect the information he needs.

- General manager: One of the major reasons why this project is being conducted, revolves around the dissatisfaction of the general manager as a result of not reaching the desired duration time in the pre-production processes. Therefore, the general manager is considered a stakeholders with a fairly large interest.

- Customers: This entire project is partially being conducted to lead for a higher customer satisfaction and eventually leading to gaining more customers. Stakeholders are defined as "groups without whose support the organization would cease to exist"; Therefore, customers always land a peak position in the hierarchy of stakeholders.

2- Theoretical framework

2.1- CODP

CODP which stands for customer order de-coupling points, refers to the breaking point in a supply chain network and manufacturing, where the product is linked to a specific customer order throughout the entire cycle. (GU, JI, 2007). Many different CODPs are available in the present day, and these could be Make to stock (MTS), make to order (MTO), Assemble to order (ATO) and engineer to order (ETO), where they all relate to different positions of the CODP (Olhager, 2010).

The different CODP's listed are related to the ability of manufacturing operations to provide with product customization or a large product range (Olhager, 2010), Where ETO offers the largest possibilities for product customization though requires the longest lead time, and MTS offers the lowest possibility for product customization but is readily available depending on demand forecast.

Figure 5 found below, illustrates where the different CODP are present in each production/SCO strategy.

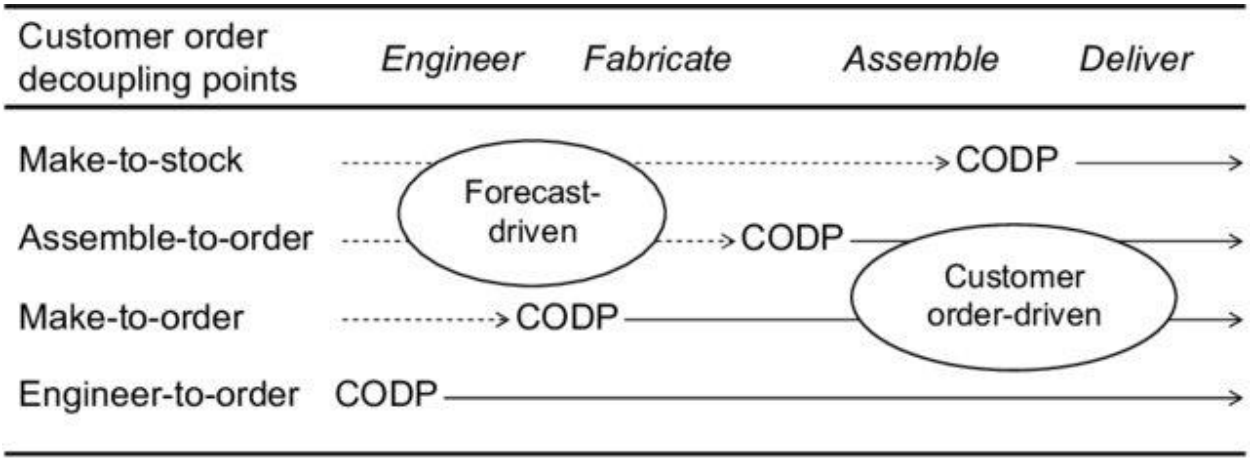

Figure 6 different CODPs depending on SCO strategy (Olhager, 2010)

In the following section a deep dive will take place to thoroughly understand the difference between the ETO manufacturing operation and MTS manufacturing operation:

Engineer to order: ETO is a type of supply chain where the customer gets to make the demands on the product they ordered and offers the largest amount of possibilities for product customization. It is generally regarded as a supply chain where the de-coupling point falls at the design stage, therefore allowing each customer to penetrate and have a voice on the design phase of a product (Naim, Gosling, 2009).

This production strategy will certainly aid an organization in achieving much less inventory and waste, it will also most definitely result in longer and longer lead times, due to the level of involvement of the customer and level of customization it entails. This can be thought of as purchasing a jet, where the

customer adds the different details they desire, and once that has been decided, supplies can be ordered and manufacturing can begin, therefore resulting in months before the product has been built.

Make to stock: MTS is a production/SCO strategy which is used through a vast number of businesses to match the inventory with the anticipated customer demand of goods. Therefore, instead of setting a production level and attempting to sell goods, a company using this strategy would estimate the engagement and number of orders their products could possibly generate, follow by the supplement of enough stock to meet those orders (Segal, 2020).

Make to stock is heavily prevalent in the automotive industry, where vehicles are produced in large amount depending on the expected sales to be generated and then released to the public, and this is due to the long lead times it takes to create those vehicles.

2.2- What is lean?

2.2.1- History

Lean is the concept of efficient manufacturing and operations which was realized by Toyota in the middle of the 20th century (Skhmot, 2017) however there is a backstory which will be explained to give a deeper look into the history on how lean management and manufacturing was invented through the Toyota production system.

The father of the system was Sakishi Toyoda and his sons kichiro Toyoda, Eiji Toyoda as well as Taiichi Ohno who was a manufacturing engineer (Lukasz, 2012, P47). It all started in 1910 when Sakishi Toyoda decided to go for a visit to the United States and realized that “the automation era was just beginning” however it still took 20 years for the family of Toyoda to materialize their plans and start their company (Lukasz, 2012, p47).

1926 was the year of year that the company was established by Sakishi Toyoda, however after several year, the name was later changed to Toyota when it began producing automobiles (Skhmot, 2017).

The next major event which occurred was the travel of Eiji Toyoda to the Ford factory united states back in the 1950’s which led to the realization that Ford was producing 8000 cars a year while Toyota was only managing to manufacturing 2500 cars a year, this pushed him to study Ford’s production system, only leading him to realize that the mass production system employed by Ford cannot be implemented by Toyota due to Japanese market being too small and diverse. (Skhmot, 2017)

This resulted in a collaboration between the Toyoda family and Taiichi Ohno and thus allowing them to come up with new means of production, and this new means of production was the “Toyota production system” which consisted of several novel ideas which allow for a leaner production (Skhmot, 2017).

Finally, in 1991, Lean manufacturing was coined by James P. Womack, Daniel T. Jones and Daniel Roos from The Massachusetts Institute of Technology in their book “The Machine That Changed the World” which was based on studying manufacturing systems and later was based on their observations at Toyota. In fact, it was later regarded as the “successor” of the Toyota production systems (Lukasz, 2012, p48).

2.2.2- Lean

Lean six sigma is a methodology which provides companies with a way of work to achieve a much more efficient and effective process to manufacturing and management. It has been described in the Ajorn journal as the following (Kimsey, 2010):

"*Lean production is a process management philosophy that examines organizational processes from a customer perspective with the goal of limiting the use of resources to those processes that create value for the end customer. Lean manufacturing emphasizes increasing efficiency, decreasing waste, and using methods to decide what matters rather than accepting preexisting practices.*"

One of the pillars of lean six sigma usage is to determine and decrease possible waste. And for this reason, a heavy reliance will be put on the implementation of one of lean six sigma's tools in the analysis phase, namely *"the 8 types of waste"*

2.2.2.1- The 8 types of waste (Muda)

According to the lean methodology waste is something of no value to a process that is identified and is required to be eliminated. Lean waste can come in many different forms such time, material and labor, however is also may be related to the utilization of skill sets and poor planning (Gay, 2016).

The 8 different wastes which are presented by the lean six sigma handbook can be introduced as the following:

- **Defects:** Defects can be classified as products and/or services which are out of specification and require resources to fix. They can impact time, money and most specifically customer satisfaction, some examples of defects within a process could range from wrong documentation of the product through the order form to even wrong dimensions of pipes when fitting it into a frame, and both of those examples could result in the loss of a hefty sum of money, workforce to fix and the loss of customers.
- **Over-production:** overproduction according the six sigma handbook signifies the excess in production of a certain product. This product could range from files in work in terms of order forms to a physical product such fans or coolers. And one of the major issues with over-production is that it could lead to not detecting a defect in time if one was to occur.
- **Extra processing:** Extra processing is defined as preforming any activity that is not vital or necessary to produce a well-functioning product or service. This could be due to multiple different reasons which could be related to management or administrative issues such as the lack of communication and/or duplication of data (Gay, 2016).
  A good way to tackle this issue according to the lean methodology is process mapping, which will be used in this report.
- **Waiting:** One of the most stressed on waste steps in the lean methodology is the waiting time. Waiting can be defined as the form of waiting for the previous process to be executed. It could be the result of many different things such as poor process communication or even unplanned downtime in the factory. This waiting time, if not eliminated from a process, could lead to additional costs, lack of working labor, and importantly an extended length of time to produce a product.
- **Inventory:** Inventory waste relates to waste forms such as any inventory or information that is not being processed, and the reason it is considered waste is due to the fact that it results in

waiting time when looking for different pieces of information or due to the related holding costs. This form of waste could also work as a signal to inform a company that there is poor communication or process design when it happens. A good way to mitigate this excess in inventory is to purchase, plan and schedule with high effectiveness.

- **Transportation:** Transportation waste relates to any transportation happening that is not required to be done. It can also trigger other forms of waste such as waiting and motion. transportation should be kept at a minimum. Transportation wastes triggered due to large batch sizes and storage areas, deficient facility layout and limited understanding of the process flow.
- **Motion:** The six sigma handbook defines motion waste as the people, information and/or equipment making unnecessary movements are the company. Motion extra physical movements such as reaching, lifting and bending. The reasoning for motion waste in an organization could be due to the workspace layout, ergonomic issues and searching for items which were placed where they are not intended to be.
- **Non utilized talent:** This type of waste is the result of not having certain employee(s) effectively engaged in certain processes when they very could be. This type of waste was added to the lean methodology to allow organizations to include the development of staff in their lean implementation. Some of the reasons why this waste could happen in an organization is poor management when giving tasks, whether be it that the employee is not trained for that task or that the employee could handle a larger amount of work variations.

2.2.3- Lean in ETO

Engineer to order is a type of production process which requires the design to be done first according to the costumer's needs, then engineered according to the given specification to after the order has been received, and this is mainly a market targeting customers who may not be available readily in the market, thus leading to those customizations (MBAskoolteam, 2021). This can serve some advantages as customization and product proliferation has been promoted as a source of competitive advantage (Gosling, Naim, 2009).

The scope of the involvement in an engineer to order environment is changing features of a manufactured product and that result in a one of a kind product at each project (Kjersem, Halse, kiekebos & Emblemsvag, 2015).

As stated earlier, Lean six sigma is a methodology which provides companies with a way of work to achieve a much more efficient and effective process to manufacturing and management, however it comes with its challenges when the will for its application is performed in a ETO environment as it was invented for mass production type environments or other repetitive manufacturing industries with high volume production that require mass consumption, therefore making it rather unappealing/unfitting to follow through with lean tools and ideas (Kjersem, Halse, kiekebos & Emblemsvag, 2015).

This also forms an obstacle in the measurement of lead time and cycle time since it is near impossible to collect the data accurately due to the high variations in the process steps and duration times (Matt, 2014). In fact, Matt and Rauch Erwin (2014) who conducted a case study about the implementation of lean into an ETO manufacturing environment in Italy stated that "*The experiences from the case study illustrate that the suitability of certain lean methods, such as value stream mapping or Kanban is limited*". However, this does not eliminate the usage of the Lean methodology, rather it just limits the tools that can be used to implement it into an ETO workspace.

Relevance to research

The relevance of this part of the theoretical framework "2.1.3- Lean in ETO" Is to provide insight on the limitations which will become apparent in the project most specifically the measurement part, this is due to the cycle time not being feasible, therefore the measurement part will partially be carried out through the use of a Process activity map (2.3 Process activity map – VSM tool) which will allow to determine whether an activity is deemed as a "value added" or a "non-value added" activity. Measurement with quantitative data will be made use of in the form of duration time also known as lead time, meaning the amount of time that a certain project has been awaiting to be processed by the relevant departments for the project until its completion.

2.2.4- Solution prioritization matrix

A solution prioritization matrix is a lean six sigma tool which assists in the evaluation of proposed recommendations and solutions which would lead to resolving the identified problems in a process. The way a solution prioritization matrix works is through having a set of rankings and criteria, and the solutions with the highest scores should be considered to be implemented first (University of Illinois, 2015),

Solution	Ease of implementation	Impact of solution	Permanance of solution	Total
Solution A				
Solution B				
Solution C				
Solution D				

Table 2-Example of Solution prioritization matrix

Table 3 provides a good visual representation of what a solution prioritization matrix could look like, and its usability is fairly simple according to the university of Illinois (2015), who proposed the following guideline steps,

Firstly, an establishment will be made on what are the possible solution for a certain process and places them on the X axis,

Next would be placing the different variants that a research team agrees to use for grading their solutions and placing them on the Y axis,

The grading system ranges from 1 being the least favorable grade and 5 being the most optimal grade,

Once all of the variants have been graded according to the proposed solutions, the total grades are then multiplied and a total grade would be determined,

Lastly, once each solution has been graded accordingly, they are compared to other solutions and ranked from the highest to the lowest, the highest taking priority in the implementation and lowest will be implemented last.

2.3- Process mapping

2.3.1- What are processes

A business process is inherently distributed system where each certain activities are performed by a set of specialized employees moving from location to location or department to department using a set of IT systems (Smirnov, Reijers, Weske & Nugteren, 2012). Melan (2002) also provided a very clear definition with the following statement “We define a process as a repeatable, bounded group of purposeful and interrelated activities, characterized by one or more transformations, resulting in a flow of work”. Previously in the past, only manufacturing processes were regarded as processes, however, later on also business operations were starting to be regarded as processes, thus allowing for improvements in productivity, costs and quality (Melan, 2002). Hence, it can be concluded that Processes are complex artifacts which challenge managers to properly govern them (Smirnov, Reijers, Weske & Nugteren, 2012)

2.3.2- What is Process mapping

Process mapping Graphical representation of processes which serves as a management tool, initially developed and implemented by general electrics to significantly improve their business performance (Daniel, 1996). It is used to describe in workflow diagrams and supporting text every vital business process and has been proven to be an outstanding analytical and communications tool with the intent to help an organization to improve their business processes (Hunt, 1996).

It allows the reviewers to get a better understanding of the organizational processes, thus allowing for improvements where it is deemed worthy to be more successful and ensure that optimal value is being provided to the customer (Jacka, Keller, 2009).

It not only allows for the visualization of the activities that are taking place in the total process but also allows for clear understanding of the connection between the departments taking care of the certain mentioned process, hence allowing for the illustration of the mutual influence between the departments.

Detailed process maps can be thought off as “peeling an onion”, where you break down the process into subprocesses, workflow elements, connects and business service processes (Hunt, 1996).

The process taken to mapping out the process could also result in improvements being pinned out following the flow of the process (Jacka, Keller, 2009), it can be visualized as the following in figure 7,

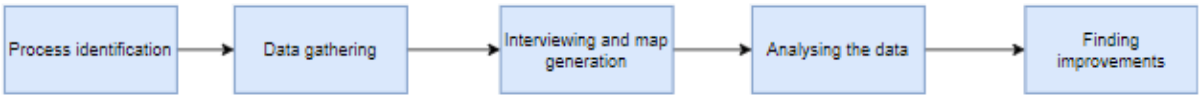

Figure 7-Process mapping flow leading to improvements

2.3.2.1- Flowcharts

A flowchart is one of the process mapping tools which have been created, it serves as a graphic representation of the sequence of the work activities used to create, produce, or provide a unique output (Damelio, 2011). Their main characteristic is their flexibility as it allows for a process to be described in a wide variety of ways (Augular-Saven, 2004) Figure 8 which is found down below depicts what a flowchart could look like,

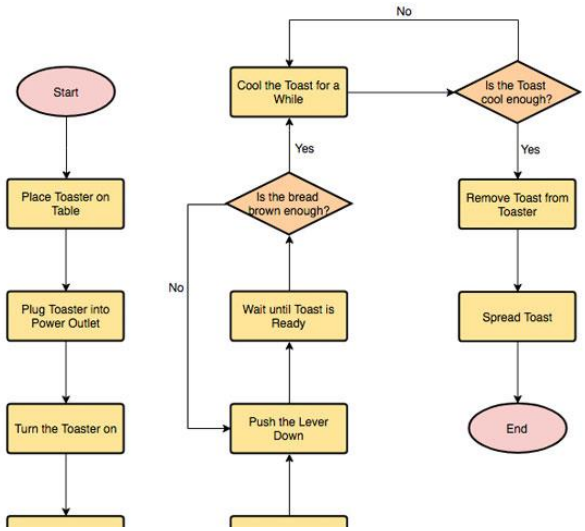

Figure 8-Example of a flowchart (Ambrero, 2018)

A flowchart is a good way of documenting processes and helps to understand the logic behind the given process. Flowcharts are also easy to comprehend and allow for a quick identification of bottlenecks and inefficiencies where the process can be improved (Augular-Saven, 2004).

2.4 – Value stream mapping tools

Value stream mapping is a lean manufacturing tool which helps visualizing the complete production processes, representing both information and material flow, and has been regarded by many as a splendid way to support and implement the lean approach (Singh, Garg, Sharma, 2010). A defined Value stream map provides the identification of all of the value added and non-value added activities as well as the relationship between each process step, to assist the user in identifying which steps could possibly be worked on to be eliminated and which steps are vital to the process (Singh, Garg, Sharma, 2010).

It is important to comprehend that Value adding activities (VA) are any activities which involves the conversion of information/raw materials into something which provide value to the process in order to produce a finished good, While non value adding activities (NVA) are any activities that are considered waste to the process and do not provide any added value in terms of creating a finished product, a good example of NVA is waiting time (Hines, Rich, 1997). Furthermore, NVA can be split up into non-value adding activities and Necessary non value adding activities (NNVA) which are steps necessary to the current process however do not have any added value to the process such as walking time to retrieve a part necessary for a process.

The scheme of a normal value stream map was regarded to be generic which led to its extension to different areas, of which the 7 VSM mapping tools were created, namely: process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis and physical structure mapping (Singh, Garg, Sharma, 2010).

2.4.1- Process activity mapping (PAM)

As stated earlier, Process activity mapping is one the 7 VSM tools and has its origins in Industrial engineering. Process activity mapping provides insight on the process activities identifying whether they are VA or NVA activities, as well as the nature of the process such as options including operation, Transport, inspect, store and delay. And main the reasoning for choosing to go with this value steam mapping tool is due to the VALSAT rating system which has determined that it provides better effectiveness in measurement and analyzing leading to the reduction of waste (Pude, Naik, Naik, 2012)

Wastes / Structure	Mapping Tools						
	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure (a) Volume (b) Value
Overproduction	L	M		L	M	M	
Time Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate Processing	H		M	L		L	
Unnecessary Inventory	M	H	M		H	M	L
Unnecessary Motion	H	L					
Product Defects	L			H			
Overall Structure	**L**	**L**	**M**	**L**	**H**	**M**	**H**
Origin of Tool	Industrial Engineering	Time compression/ Logistics	Operations Management	New Tool	Systems Dynamics	Efficient Consumer Response / Logistics	New Tool
Notes: H = High correlation and usefulness M = Medium correlation and usefulness L = Low correlation and usefulness							

Table 3-VALSAT rating of the 7 Value stream mapping tools (Pude, Naik, Naik, 2012).

3- Research method

Research method essentially provides the final decision on what type of research will be conducted to acquire the data needed to go forward with this project. There exists 3 different types of research, qualitative and quantitative, and throughout this paragraph some insight will be provided on what are the different forms of data collection in which these 3 types of research can exist as, as well as a final part explaining what research method was selected.

3.1- Qualitative research

Qualitative research is a form of research which involves collecting and analyzing non numerical data such as text, video and audio to understand concepts, opinions and experiences (Bhandari, 2020). Making use of this research method could lead to determining the strengths and weaknesses around the departments in the company which would act as an enabler to find solutions and thus making the appropriate changes to achieve a lower duration time. It can exist in the following types of forms:

- **Interviews:** An interview is a structured conversation where one person asks another a series of questions, and the interviewee gives answers for the interviewer so that he can achieve his goal of conducting this conversation.
  Conducting interviews around the company holds a very important role in this project since most of the valuable information that needs to be received to analyze the faults and come up with improvements revolves around the employees perspective of things, the nature of their work, and what they are not satisfied with as a part of this current ERP.
- **Literature review:** This revolves around finding literature pieces relevant to a study a person is conducting and reviewing them to find information which will benefit them in achieving their end point goal.
  Literature review will come in important when looking for past experiments or studies to help in finding a solution to the current problem, as implementation of something highly successful which has been proven to work would likely lead to major success in reducing the total lead time.
- **Observations:** Observations are quite self-explanatory; you observe your surroundings.
  In the case of this project, observations could possibly be used through making observations around the company and seeing if there is any room for improvement.

3.2- Quantitative research

Quantitative research is the process of collecting and analyzing numerical data. It can be used to find patterns and averages, make predictions, test causal relationships, and generalize results to wider populations (Bhandari, 2020). Making use of this information could help out a person a lot when making calculations or predictions when it comes to departments such as the sale department. The different forms that this type of research could exist in are the following:

- **Experiments:** This method of data collection is based on testing the reaction between 2 different variables and to see how they would react.
- **Surveys:** This form of quantitative research revolves around asking a group of people questions about the topic you would like to research and could be conducted online or offline.

This form of research could be of help for this research report that is being conducted as giving surveys would help the project leader to get insight on the current situation

- **Secondary research:** This form of research revolves around collecting already presented data which has been collected in the past, and it could be very helpful when trying to calculate the number of projects conducted throughout a year.

3.3- Mixed method research

Shorten and Smith (2016) Explain that mixed method research is a form of research where you collect and analyze both qualitative and quantitative research within the same study. Mixed method research draws on strengths of both qualitative and quantitative research, thus enabling researchers to build their research on whilst benefiting from both numerical and non-numerical data.

Some of the advantages which a researcher can gain over choosing one research method are:

- It provides strengths that offset the weaknesses of both, the quantitative and qualitative research methods.
- It provides a more complete and comprehensive understanding of the research problem than either quantitative or qualitative approaches.
- It helps to elaborate on findings much better than using one research method alone.
- It also helps when developing a specific instrument.

However, it also has some disadvantages when compared to the mentioned research methods, and these consist of and are not limited to:

- The research design could possibly be immensely complex.
- Takes a longer duration as well as resources to plan and implement this type of research
- It would be rather difficult to resolve discrepancies that might arise in the interpretation of findings.

3.4- Conclusion- Choice of research method

After some thorough and extensive thinking and analyzing, it became apparent that the most optimal method for such a research report is going to be mixed method research form which will mostly be consisting of mostly qualitative research due to this being an engineer to order process, however also contain an element of quantitative research. All methods of data collection have limitations; therefore, the use of multiple methods can neutralize and cancel out some of the disadvantages that one would cause, on top of that the strengths of each of the research methods can complement each other (Byrne, Humble, 2007). This will be implemented through the use of the DMAIC methodology.

Since a motive on the selection of the appropriate research method that is going to be put in use has been given, it is also important to be informed on which elements of mixed methods research that will be used.

3.4.1- Interviews

The first form of the mixed method research which will be conducted is through interviewing the relevant parties which would help in acquiring the needed information to successfully conduct the research.

Interviews are based on collecting data around the method from the professionals working on the process. The struggle is that several individuals must be contacted and met to gain insight on the overview of the entire process as different people could give varying information to some degree on the processes they work on. However, the quality and strength of interviews is that it can pinpoint different perspectives on the total processes and how they operate.

Interviews will be the most critical form of data collection when it comes to mapping out the processes as the employees responsible for their roles in the company will provide guidance throughout the activities they go through to allow for the process to successfully happen.

3.4.2- Observations

The second form of data collection which will be used throughout the research will be observations. This will yield an advantage when it comes to the analysis and the improvement parts of the project as it will allow for the placement of the relevant issues which can be found around the company and thus allowing for the generation of more improvements. It also comes in great use when pin-pointing parts of the process that other data collection methods do not offer, as it allows for a more objective rather than subjective qualitative data collection method.

Observations give a splendid overview on the nature of the processes and how they are conducted, however, they can undoubtedly affect the nature in which the employees preform their tasks on day to day basis, therefore skewing the data at times, due to employees have a resistance to change.

3.4.3- Secondary research

The third form of data collection to be utilized during this research project will be secondary research.

Secondary research revolves around making use of data that has already been published before and is readily available for use to researchers (Forumplus, 2020). This can be collected from books, journals, websites and many different past sources, and it provides a great level of assistance when formulating their theoretical framework.

Throughout this project, secondary data was used to receive an immense amount of guidance when it came to finding ways which aid in improving processes, namely the lean methodology.

3.4.4- ERP Analysis

An ERP system is an integrated set of programs which is used to support businesses with their organizational activities (Colmenares, 2009). The greatness which lands with having an ERP system is that all of the past data is recorded and can be effortlessly found, given the ERP system is well organized.

An engineer to order environment, calculating the cycle is not feasible due to range and shifts in the time that a single task takes to be completed. However, using the ERP system will allow for the illustration of the amount of projects which have been conducted, leading to the possession of some quantitative data to calculate how much benefits the improvements suggested will provide.

Using the ERP system's data will also act as a tool when it comes to the measurement of the duration times that a task takes, meaning the time an order has been placed at a certain department and until its execution.

4- Research roadmap

DMAIC is the continuous improvement of the present system by objective problem-solving. According to Rama (2009), DMAIC methodology takes a problem that has been identified by the organization and utilized a set of tools and technics in a logical fashion to arrive to an appropriate solution. It attempts to improve the performance of goods and services through improving the process resulting in them rather than the final output itself. The letters in the acronym represent the five phases that make up the process which are Define, Measure, Analyze, Improve and Control.

Define: The Define phase focuses on defining the identified problem which has been spotted, it also involves explaining the improvement activity needs, stakeholders, and the project goals, therefore allowing for a clear definition on the project's purpose

The define part of the DMAIC methodology has already been performed through chapters 1, 2 and 3, where all relevant information about the project has been described such as the company introduction, the problem recognized in the company, the purpose of the project, the literature review which will used to back our findings, and the method of research which will be conducted.

Through the realization of the define phase, the first research sub-question "*What is the current situation?*" can be resolved.

Following these steps will set an outstanding foundation for the project to move in the right direction.

Measure: First of all, mapping out the processes will be conducted as an objective for the project to illustrate what are the steps that the total process consists of, followed by a thorough description to provide a better understanding.

Due to the nature of ETO production processes, it is not feasible to record the cycle time of the processes, for this reason the measure step will be conducted through a process activity map where all of the processes and sub-processes will be listed, and a VA or NVA rating will be given to each step, which will allow for the realization of the number of activities that are not required in a total process as well as its efficiency through a percentage rating.

Another measurement form which will take place, will be through the form of retrieving data from the ERP system where valuable information can be found and used to aid in the analysis phase through helping in spotting the bottlenecks found in the process.

Therefore the tools which will be used for the Measure phase are the following:

- Process mapping
- Process activity mapping
- ERP analysis

Once the measure phase has been executed, the second research sub-question *"What are the tasks conducted in the processes and sub-processes found between AT1 and AT4?"* can be successfully answered

Analyze: The analysis phase will be the most detailed and extensive part of the DMAIC phase, where multiple different methods will be used to help in pointing out the bottlenecks and inefficiencies found in the processes which are being examined,

The following are some of the tools which will be used in the analysis phase:

- 8 wastes of lean
- Pain and frequency matrix

Once the 3 mentioned tools have been used, the analysis phase should provide a comprehensive overview and understanding of the current situation and identify the changes required to lay down the blueprint for improvements.

Following these actions, the third research sub-question *"What are the wastes and bottle necks found in the processes? "* can be comprehensively executed.

Improve: Following thorough and extensive analysis, a move is made towards one of the most critical parts of the DMAIC methodology which is improve. In this step, a valuable insight will be gained on what the bottles necks and issues are in the process, and therefore must come up with improvement.

The following are some of the tools which will be made use of in the Improve Phase:

- Solution decision matrix
- Waste X Solution matrix

Once the appropriate improvements have been determined and listed, a solution prioritization matrix will be used, where a list of solutions with a list of factors will be used to determine which solutions have the highest level of urgence for implementation moving all the way down to the least importance improvement, followed by a waste X solution matrix which will determine the improvement per waste and the departments that certain waste and improvement relate to.

In addition, going through these mentioned actions will result in answering the last sub-question *"What are the possible improvements to be implemented leading to the optimization of the processes?"*

Control: Lastly, comes the control part in the DMAIC methodology, a provision of a control plan will be executed, which will enable the company to keep the employees from reverting back to the old ways of working through having tasks to be done in the control plan, a description on how it should be done, who is the person responsible for that certain step, and lastly the status on whether the step has been accomplished or not.

In the following diagram, an illustration of a research roadmap is provided,

Figure 9- Research roadmap

5- Analysis and interpretation

The main outcome of this chapter will be the analysis of the current situation which found at the company of Kelvion and eventually reach to solutions and improvements. Throughout this section, a majority of the research sub-questions are going to be answered as indicated in section “4- Research roadmap”.

The analysis and interpretation section will follow the DMAIC methodology form, where the “Measure”, “analyze” and “improve” will be listed, following the application of both quantitative and qualitative research methods as listed in in chapter 3 of this report.

The measurements will allow to pinpoint where the problems are mainly focused, the analysis section will allow for the determination of what are the wastes and bottlenecks which are causing or contributing to issues grasped around the pre-production processes, and lastly will be the “improvements” part where possible solution will be determined.

5,1- Measure

Since the define phase of the DMAIC methodology has been executed, the next actions in the “measure” section will consist of the following:

- Firstly, map out the processes and indicate the tools used per process,
- measure the efficiency of the drawn-out processes with the use of PAM.
- In addition to that, the ERP system will be examined, and the duration time of the process steps will be provided.
- Lastly the total numbers of projects worked on in the pre-production processes will be determined for the span of one year.

5.1.1- Process mapping

Due to the complexity of the processes that are due to be analyzed and later on given improvements for in the coming stages of the DMAIC methodology, a decision has been made to split each process step separately and further deconstructed them into departments.

Figure 8 below demonstrates what each of the symbols used in the flowcharts signify,

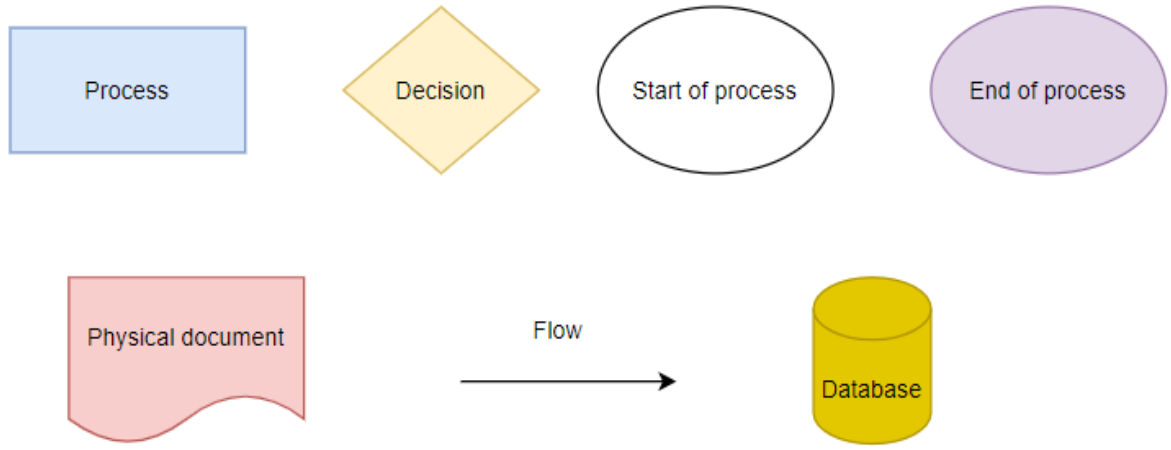

Figure 10- Symbols meaning

Firstly, the processes are going to be thoroughly described to give a better understanding on the mapped-out processes, and as mentioned earlier, a split will occur where AT1, AT2, AT3, and AT4 are all going to be mapped out and described separately.

(Note: it is necessary to observe and heed the mapped-out processes as they are the sole reason for these descriptions)

5.1.1.1- AT1

The AT1 processes have been drawn out and can be found in (appendix 2), in this part of the report an elaboration is made on what has been drawn out to give a better understanding on the processes

The following information will be placed in chronological order in terms of flow of information between departments due to AT1 being a linear process.

Order desk:

To start off the AT1 process, the order desk team receive an order from the sales team through webtools that an order form needs to be created due to having a new sales order,

The first step to create this new order form is to enter a program called CAPCALC which allows the order desk team to calculate the capacity of the newly ordered heat exchanger,

Once that has been performed, the order desk team enter another program called Sofon, where the information required is entered to receive the product configuration as well as the pricing of the heat exchanger/cooler that needs to be manufactured.

The following step that takes place, is the conversion of the order specific information into an HMTL file using Sofon, this is important as it allows the SAP system to process the information into the company's system,

Now that HTML file has been created, it is entered into the SAP system which is the ERP system used by the company, thus allowing us to receive a preliminary order confirmation,

The preliminary order confirmation is then printed and given to the secretary who's function in this part is to send this order confirmation to the customer to notify them about the expected date of delivery.

Now that the previously mentioned steps have been executed, the order desk team enter their specified excel file and fill in the relevant information such as date of completion and who handled that certain order.

Another function that the order desk handles while also creating the order forms is receiving a quotation from suppliers for fans ordered that are needed for that specific project,

These quotations are sent to the sales team to double check them, and once approved they are sent back to the order desk team who will process the date of approval in the planning excel file.

The last task that the order desk have to take care of is filling in the date of completion of creating the order form and then pushing the work through to the technical department through webtools.

Technical team (Order desk):

Once work has been completed from order desk and pushed through webtools, the technical team receives an order from the webtools to start their work on the newly created order form.

The first action to be taken care of by the technical team is to open the Kelvion folder which contains all of the orders and head towards the specified order form which needs to be worked on.

Now that the order form is open, they must Check on specifications of the project (dimensions, materials) to make sure information is placed correctly on order form.

The following step which takes place is requesting the planning team to take the order lines from SAP and place them into the excel planning sheet,

When the planning team has successfully placed the order lines into the excel planning sheet, the technical team will start filling up all the information that is relevant for the cooler that is being planned to be manufactured (Ex: Whether the cooler will have a ceiling placement or ground placement).

Their next and final value adding step also takes place in the planning excel sheet, where they must indicate how many hours does the engineering team have to complete the customer drawings.

Furthermore, the technical team must submit the completion of their task on the webtools platform therefore notifying the next department that they have to start working on the order.

Planning team:

To start off, the planning team receives an order from the technical team through webtools that a new order must be processed,

Once that happens the planning team must go to the Kelvion folder and search for the specific order needed to be worked on through searching for the order line number,

Next up, they must open the planning excel sheet and check whether its status is active or not (If not active then they must wait until it becomes active to continue working on it).

If the status is active, the first action that must be completed is filling in the preliminary delivery time into the excel sheet, as well as planning where the production will take place (Kelvion has 3 different manufacturing locations, Netherlands, Poland, and Czech Republic).

Furthermore, they must check for the drawing approval which determines whether customer drawings need to be created or not, as well as indicating the number of coolers that are planned on being produced.

The planning team's next objective is to head back to the order form and check whether the customer has any payment conditions, therefore allowing the company to know if a customer needs to provide a pre-payment before the start of engineering.

Once all those checks have been made, their following task would be to fill up the final relevant information into the planning excel sheet, such as the date they started working on that specific order, as well as the date where the last change has been implemented into the order form,

Lastly, they must also fill in the number code for the fans required to be purchased (number codes indicate different fans), as well as the number of fans needed to build the coolers.

The order is then pushed to the next department through webtools.

Work preparations:

Following the same sequence as the other departments, the work preparation's team start their work on the order once a request has been received through webtools.

Firstly, the work preparations team start their work by opening the Kelvion folder to retrieve the order form followed by opening the planning excel sheet.

Once the order form is open and present in front of the work preparations team, they must open Sofon and fill up the fin material specifications such as the material to be used and the dimensions.

While also on Sofon, they must determine whether the cooler will come with defrost options based on the customer's request as well as the thickness of the cooler.

In order for other departments to retrieve the information filled up, a word document must be created (automatically) from Sofon and then simultaneously placed into the Kelvion folder relating to the order number that is being worked on.

Once that has been done, another form must be used to fill up a checklist on the fans and tubes listing according to the order form.

The next program which must be used is SAP, and the reason for that is to push the information about what needs to be purchased to the purchasing department, as well as to calculate the number of hours required to build 1 cooler, this is then placed on the planning excel file and automatically multiplied with the number of coolers that need to be produced (Filled in by planning department), to give us a total number on the production hours required to build all of the coolers in that specific order form.

Last of all, the work preparations team must check whether drawing approval has been given (Found on the order form), if yes then the order must be pushed to the engineering department, however if it's a no then they must wait for approval.

Engineering department:

As always, the order is first received through webtools, and this is to notify the engineering team that a customer drawing must be created for a certain order.

The first step that takes place is opening both the planning excel sheet and the engineering excel sheet, and this is to see what are the current drawing that still need to be worked on and when can this certain order's drawing be created.

The next step requires the lead engineer at the beginning of each week to delegate tasks to the rest of the engineers to create the customer drawings.

Once an engineer has been assigned a customer drawing task, they must work on it and then send it to a senior engineer whose function is to check on the work of the engineers, if the drawing is feasible then it is sent to the next step, however if not, then the engineer must work on the errors that were spotted by the senior engineer until they get their approval.

As for the last step, once the approval has been given, then the drawing is placed into the Kelvion folder, followed by pushing the work to the planning team through webtools.

Planning team:

Now coming to the final steps of the AT1 processes, the planning team's job to enter the date completion for the customer drawings, and push the work through to the work preparation's department

Work preparations team:

The last step of AT1 requires the work preparation team to send the customer drawings found inside the specified order folder in the Kelvion folder to the customer through email (drawing approval mailbox).

5.1.1.2- AT2

The AT2 process solely revolves around making changes based on the customer's response to the drawings sent. The following will be a detailed explanation on what appendix 3 contains, since many

departments come in multiple different times intertwining with each other, each department's description will contain a letter to allow for the distinction and comprehension on which exact step is being elaborated on.

1-(A) Technical department

The first step of the entire AT 2 process starts with the technical department waiting for feedback from the customer, there are 3 possible scenarios which could be a possible outcome from here, a decision was formed to give them the following names:

1- **Scenario Delta**: The customer does not give feedback in 3 days, therefore the planning team must send a reminder, until the feedback is given and then is followed by either Scenario Alpha or Sigma depending on the customer's feedback
2- **Scenario Alpha:** Approval is given by the customer, therefore process AT3 starts and AT2 is has been executed.
3- **Scenario Sigma:** Once feedback has been given, he could ask for changes in the drawing therefore not approving the drawing, where an entire change of the order form and engineering drawings will take place.

5.1.1.2.1- Scenario Delta:

1 (A)- Planning department

To start off the first scenario, the customer has not given his feedback in 3 days, therefore a notification will a notification through webtools that the customer has not given feedback yet,

If Approval is needed, then a reminder is sent by the planning team to the customer in the form of an email or a Microsoft teams call depending on how many reminders have been sent,

Following this step would be filling in the date of last reminder in the excel sheet, as the excel sheet notifies the planning team whether an additional reminder needs to be given to the customer through the follow of changing colors of the cells,

Once feedback has been given, Scenario Delta continues in the form of scenario Sigma or scenario Alpha.

5.1.1.2.2- Scenario Alpha:

Technical team

Scenario alpha is the quickest pathway of all 3 different scenarios, where feedback is received through the mailbox by the technical within the span of 3 days after sending the drawings to the customers, in which the customer indicated their approval for the drawings, therefore step AT2 is done and work should continue into AT3.

5.1.1.2.3- Scenario Sigma:

Technical team

Scenario Sigma starts off by the technical team receiving the feedback indicating disapproval of the drawings that have been made and requiring change,

The first step is to request a new order form to be created by the order desk team through the use of webtools,

Order desk

A new notification would appear on webtools informing the order desk team that a new order form must be created for a certain order.

The first would require a team member to make use of CAPCALC and calculate the new heat exchangers capacity.

The following step which will take place is the importation of the CAPCALC document into Sofon, to receive the new product configuration and pricing.

While still on Sofon, the newly retrieved and calculated product configuration is then converted into an HTML file, which is then placed into the SAP system to allow for the creation of the new order form with the specified changes,

This newly created project form is then placed into the Kelvion folder to the specified order line while also adding a letter at the end of the order form sheet moving from A to Z depending on the amount of times the order form had to be changed (This indicates for other departments which order form to refer to), figure 7 down below has been provided to allow for making sense of the situation.

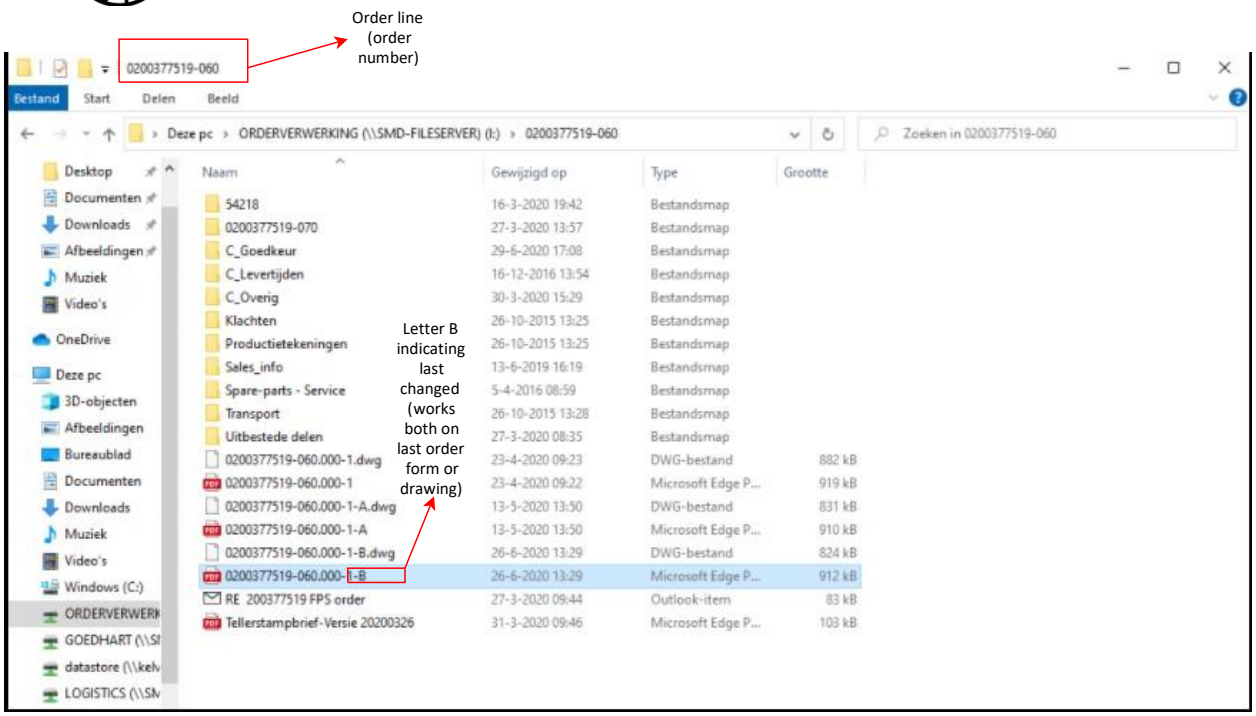

Figure 7, Indication of order line and alphabetical structuring of last document. (Zoom in for better visuals)

Now that the new order form has been placed into the Kelvion folder, the order desk team forwards the tasks of checking the order form to the technical team through webtools.

Technical team

Following the same sequence as every department, a new task appears to be available on webtools which requires the technical team to check the order form.

Once an order form has been checked by the technical team, they can either send it back for further work due to mistakes from the order desk, or approve of it and move on to the next step,

The next would be to determine whether there will be an impact on the current planning, because if the changes that have been implemented into the order form and then the drawings, a task must be sent to the planning department using webtools.

The step which subsequently follows the previously mentioned one also falls under the technical department's tasks, and this is to decide whether the change to be made on the customer drawing is large or small,

If the change is deemed to be small, then the technical team will handle the changes and send the newly changed drawings to the customer and wait for their approval.

However, if the change is deemed to be seemingly large and complex, then the task is pushed to the planning department using webtools.

Planning department

As indicated earlier, if the technical team determine that the change in the order form and the drawing could possibly impact the planning of the project, then an order is sent to the planning department through webtools to check whether some adjustments must be made to current planning or not.

Therefore, the first step to be carried by the planning team, after receiving the order from the technical team, is to head to the Kelvion folder and retrieve the latest order form which has been created.

Once the order form is present in front of the planning team, an analysis is carried out on the changes made which then effectively leads to three different paths, the first one where no changes need to be made to the current planning, however there is an impact on the bill of materials, then an order must be sent to the work preparations.

The second one where changes are required to be implemented, such as the impact on the delivery time, or the number of fans needed, followed by sending an order to the work preparation as they are required to carry out the next task.

The third and final scenario occurs when there is no impact on planning nor the bill of materials, then the work is pushed straight to the engineering team, skipping the work preparations completely.

Work preparations team

The first task which the work preparations is required to handle after retrieving the new order form from the Kelvion shared folder, is to identify the changes made, these changes are already marked in yellow from the order desk team once they have created the new order form.

The following action which takes place is determining whether these newly present changes must be entered into the SAP system such as the change in number of fans and tubes, so that the purchasing department received the updated list of supplies to order.

Following that step, the changes are either entered if necessary or heading straight to webtools and sending an order to the engineering team to work on the customer drawing.

Engineering team

As always, the order is first received through webtools, and this is to notify the engineering team that a customer drawing must be altered to fit the needs of the customer.

The following steps are identical to the AT1 engineering role, however with the goal to change the customer drawings instead of creating a brand new one.

The first step that takes place is opening both the planning excel sheet and the engineering excel sheet, and this is to see when what are the current drawing that still need to be worked on.

The next step requires the lead engineer to delegate tasks to rest of the engineers to change the customer drawings according to the notes given to them as feedback from the customer

Once an engineer has been assigned, changes on the initial customer drawings must be implemented. The action to take place is sending the newly changed drawings to a senior engineer whose function is to check on the work of the engineers, if the drawing is feasible then it is sent to the next step, however if not, then the engineer must work on the errors that were spotted by the senior engineer until they get their approval.

As for the last step, once the approval has been given, then the drawing is placed into the Kelvion folder, followed by pushing the work to the planning team through webtools.

Planning

One of the final steps to take place in AT2 is for the planning to fill in the completion date of when the engineering team implemented the changes in the drawing into the excel planning sheet and push the task to the work preparations team

Work preparations

Last but not least for the AT2 procedure, the work preparations team retrieve the latest customer drawing (last file contains a letter in front of the file name, figure 7), and send the drawings to the customer.

If the customer approves of the drawings, then the technical team will issue an order to the engineering department to start with the AT3 process. However, if the approval is not given, then the AT2 process will restart.

Purchasing team

The purchasing team's role only comes once the customer approval has been given.

Following the approval, the bill of materials which has been processed in AT1 by the works preparations team appears for the purchasing team in SAP.

A list of materials needed for the projects is then automatically created through the SAP and the numbers of materials needed are indicated for the purchasing team.

Following this procedure, the purchasing team then determines which and when to contact the suppliers to provide the materials needed for the certain ordered product.

5.1.1.3- AT3

Process map can be found in Appendix 4

Engineering

The first process to be taken care of in the AT3 process starts at the engineering department. The process itself looks quite identical to the other processes handled by the engineering team, with the key difference of providing production drawings instead of customer drawings.

The process starts with receiving the notification through webtools that a production drawing must be made since the customer gave his approval.

The lead engineer starts by checking the preliminary delivery dates of the orders to determine which production drawings have the priority.

Coming next would be the delegation of the tasks by the lead engineer to the rest of the engineers, referring to who is responsible for creating each project's production drawings.

This is then followed by the engineering team working on their specifically given production drawings and upon completion, the drawings must be sent to a senior engineer where a check-up will take place.

Once the senior engineer checks the drawings, he could either give his approval or make remarks on the drawings where the base engineer will have to correct his drawings.

Upon approval, the production drawings are saved into the project specified Kelvion folder as a pdf file, and Radan export is created which will come to use in the AT4 process.

the drawings are then printed and transported to the planning team's file holder and subsequently pushing the work through webtools to the planning team, indicating that a project needs to be worked on.

Planning team

The last step in AT3 is executed by the production planning team.

The first action to be handled is starting the task through webtools, followed by retrieving the physical documents of the specified projects from the file holder to allow them to continue working.

Once the physical document is in place in front of them, the team member open's the planning excel sheet and fill in the date completion of the production planning.

The next step consists of opening the SAP system and creating an order for AT4, allowing the rest of the teams to utilize it.

5.1.1.4- AT4

Process map can be found in appendix 5

Work preparations

The first actions to be conducted in the AT4 process start at the work preparations team.

The main goal of the work preparations in AT4 is to make changes on all elements going to production.

The process firstly starts when receiving an order to start the AT4 process through webtools indicating that a task must be worked on.

A work preparation team's member then opens the order form from the Kelvion folder then creates a stamp note through the usage of Sofon.

The next step would require them to open a submerge tool and importing the inventor and Radan drawings leading to the extraction of the materials which are going to be needed to build the product. The person responsible for the task would then check materials and detect whether any drawings in the physical document are not found in the list of materials, and then subsequently remove any materials not found on the drawings, as well as correcting any errors detected by the submerge tool.

Once that check has been concluded, the submerge document is processed into SAP and a check on BOM is initiated. In BOM check, any unnecessary assemblies are deleted through the press of a button.

Another important action to take place is ordering pallets if necessary through contacting the suppliers by email. Whether pallets are necessary or not is indicated in the physical drawings.

As for the last step, the work preparation's team member must push the task through to the next department by the usage of webtools.

Purchasing team

Through the purchasing team already purchased the basic materials such as the fins fans and tubes, some projects require more specific materials which have only been specified by the engineering team in AT3.

Therefore, once the work preparations team have processed the information into SAP on whether project specific materials need to be purchased. If the case states the need for those additional materials, the purchasing team will check the stock to determine whether these pieces are available or not.

If the materials are not available, then the purchasing department will contact the suppliers and acquire the needed materials.

Engineering team (Nesting)

Once the Work preparations team have finalized their work, 2 folders are created, one which is transported to the production team, and another which is placed in the file holder.

This is where someone from the engineering team goes to the Work preparations department and retrieves the pile of files that have been processed and printed.

Once the files have been retrieved, an engineer with the specific function to work on nesting starts his work by opening the Kelvion folder from the database and search for the RADAN SYM file for that specific project.

If an order does not contain a RADAN SYM file, then the engineer responsible for nesting will create it.

This RADAN SYM file, once completed, is then imported into Somalink which's function is to be responsible for the nesting tasks.

Upon importing the drawing, the raw materials are checked to be determined if they are available.

Once that has been done, a run on the nester will be conducted, and the pieces to be cut will be illustrated on the program.

Additionally, it provides the user with the option to place more pieces for other projects if space is available for further cutting.

Once that has been done, a run on the tester will be conducted and a file will be created for the machine program manager.

The project is then confirmed through the machine manager program, which will the CNC cutting machine to possess the project specified order.

The files are then printed and subsequently given to the nesting operator.

The nesting operator then searches for the specified project number found on the documents and run the machine.

5.1.2- Process activity mapping

For the second form of measurement, a process activity map is used to determine the waste of the processes' subprocesses through the indication of whether the activities conducted are value adding activities or a non-value adding activities as well as indicating the nature of the activity taking place.

Firstly, it must be made clear that the lean general guidelines provide the 3 following rules for an activity to be determined as a value adding one through the following (Sixsigmadaily, 2019):

- The step must change the form or function of the product or service
- The customer must be willing to pay for the change
- The step must be performed correctly the first time

And anything which does not contribute to one of the three stated points is deemed to be waste and non-value adding to the project.

An important thing to note is that some of the NVAs are Necessary for the processes however still do not contribute to changing the form of the products which are created within the pre-production activities nor adding value to the customer, therefore will also be placed as a part of the NVA category.

Having mentioned that, the pre-production processes which have been mapped out earlier were analyzed and filled out in a process activity map, with the gain of validation from supply chain operations manager.

The process activity map also provides the different types of steps which can be carried out during a process, these different types of actions can be classified into the following:

- Operation
- Transport
- Store
- Inspect
- Delay

Table 4 found down below illustrates a summary of the results which have been achieved throughout completing the process activity mapping per process step.

Appendix 10 illustrates the actions taken to achieve each of the pre-production processes' PAM with all of the VA and the NVA

Process	Number of activities	NVA	VA	Operation	Transport	Store	inspect	delay
AT1	56	32	24	48	3	1	6	1
AT2	42	26	16	36	0	1	4	1
AT3	20	16	4	14	3	1	2	0
AT4	27	16	11	16	4	1	6	0

Table 4- Process activity map for the pre-production processes

AT1

Starting with the first process analyzed, namely the AT1 process, consists of 56 different activities to be carried in order to complete the process. The total number of VA activities amount to a total of 24 different activities, while the NVA add up to 32, leading to the realization that only 43% of the activities carried out provide any sort of value to the process leading to successful Execution of the pre-production tasks.

As illustrated in Table 4, Inspect holds to the top rank when it comes to non-operation activities in the AT1 process. The reason that inspection holds the highest rank is due to the fact that the company of Kelvion would like to establish a high first-time right rate when sending the customer the drawings, this is because once the customer approval has been given, the flow of processes is smooth and the AT2 process is automatically skipped, and the engineering team would start with the AT3 process.

However, the unnecessary delay which can only be found once in the process is resulting in the greatest amount of waste in the AT1.

AT2

The AT2 process is the most complex process of all 4 processes, and this is due the different steps that can take place multiple times, as the goal of this step is to gain customer approve and therefore move forward with creating the production drawings (AT3).

Out of 42 possible activities to take place in the AT2 process, only 18 of them are value adding activities with the rest being non-value adding to the process leading to the creation of the product, meaning that only 38% are necessary for the process to be carried out, while the other 58% do not contribute to the flow of the process.

This is because the AT2 process, in many cases, requires a lot of back and forth and changes are sometimes required to the order form and the customer drawings, therefore adding a lot of repetition and a large amount of delay.

Again, inspection holds the highest rank in the amount of non-operation type activities. This is due to the repetition of the processes which take place, meaning that inspection is going to take place similarly to the AT1 process.

AT3

The AT3 process contains the least number of activities in comparison to all other processes. It consists of 20 different activities where 4 of those activities are considered value adding activities which is exactly 20% of all of the activities.

The AT3 process's main time-consuming activity again must be the inspection, however for quality reasons this is needed for the time being. However, the unnecessary transport which could be done digitally is an issue which should be tackled as soon as possible.

Additionally, inspect is also present in this process step, however inspection in the engineering department is rather done for a quality check, which is the most time-consuming process of all activities happening in AT3, though it is necessary.

AT4

Last of all, the AT4 process consists of 11 value adding activities, with 42% of the total activities being value adding, while the non-value adding activities taking up 58% of the total actions taken.

The main issue which comes with AT4 is the large amount of transport, taking place multiple times between different departments. This type of information flow should be conducted digitally as it ends up costing them time which could be used in more time requiring beneficial activities.

5.1.3- ERP analysis

The third form of data measurement will be done through using the ERP system's past and current calculation of the duration time of a project from its start to finish.

The goal with using these calculated duration times is to allow for the illustration of where the bottlenecks are present throughout the departments and flow within the pre-production processes.

OrderNr	PosNr	Del	CustomerName	OrderlistDescription	pQ	DT Sales	DT Orderdesk	DT P&W	DT Front (Sales/OD/P&W)	DT AT1	DT AT1 Norm	DT AT2	DT AT3	DT AT4	DT ENG
0200418766	000050	1	MONDIAL FRIGO S.A.	Kelvion KB.v 16x3-4200-60x60	16	0	4	1	5	12	18	16	15	43	44
0200418766	000070	1	MONDIAL FRIGO S.A.	Kelvion KB.v 16x3-4200-60x60	16	0	4	1	5	12	18	16	15	46	44
0200418766	000080	1	MONDIAL FRIGO S.A.	Kelvion KB.h 14x2-4350-60x60	32	0	4	1	5	12	18	16	15	43	44
0200446287	000010	1	KELVION FZE	Kelvion PLK.s 32x18-2101-60x60	2				30	14	44	3	3	2	20
0200437097	000010	1	KELVION FZE	Goedhart VRZ- 44637	16	0	14	1	15	14	29	11	12	1	37
0200443759	000010	1	TECNOPOOL S.P.A.	SC800AA42GX+0GAT	1										
0200436737	000030	1	TETRA PAK PROCESSING SYST	HO2171 R3 Packaging	2	0	5								
0200415251	000050	1	GEA REFRIGERATION NETHERL	Goedhart SLK.v 10x12-4000-60x...	2	0	4	5	9	4	14	9	245		259
0200415251	000040	1	GEA REFRIGERATION NETHERL	Goedhart SLK.v 10x12-4000-60x...	2	0	4	1	5	8	14	9	61		79
0200415251	000020	1	GEA REFRIGERATION NETHERL	Goedhart SLK.v 10x12-4000-60x...	2	0	4	0	4	9	14	9	40	205	59
0200415251	000030	1	GEA REFRIGERATION NETHERL	Goedhart SLK.v 10x12-4000-60x...	2	0	4	0	4	9	14	9	56	32	75
0200438574	000030	1	TETRA PAK PROCESSING SYST	210136 R3 Packaging	2	0	7								
0200440390	000010	1	KELVION FZE	Kelvion LLK.p 12x6-1600-50x50-...	4	0	7	1	8	4	12				
0200440390	000020	1	KELVION FZE	Kelvion LLK.p 12x8-1599-50x50-...	4	0	7	1	8	5	14				

Figure 11-ERP duration time calculations

Firstly, it must be explained that duration time refers to the time since which an order has been laying in their department's webtool until the date of completing the task and pushing it forward to the next process or department.

Now as seen in figure 11, a sample has been taken for the month of March 2021 and the reason for taking this sample is to show case the prominent bottlenecks which need to be observed and worked on. A large amount of the duration times contain the color red, which signifies that the process step took longer than the theoretical desired date (Appendix 1).

Some figures are extremely high due to the processes being placed on hold or because the customer wants the product to be delivered by a large number of months or even years from the day of ordering. And as it can be seen, this generally happens in AT3 and AT4, however some of the values are accurate and will be determined in the figure itself.

And as illustrated, an overwhelming majority of the slots are red, and this is due to not meeting the theoretical duration time created by the company.

And the main and first bottleneck that can be identified is found in the order desk department where none of the orders have been processes within the desired duration time of the company which is 2 to 3 days.

The next available bottleneck can be found in the AT1 which only refers to the engineering team creating customer drawings in this case, where a lot of the projects have not met their desired duration time.

AT2 is also another process step which is not meeting the desired duration time, though this could also be caused due to waiting for the customer's approval.

Though AT3 is not meeting the desired duration time, it is not considered a prominent bottleneck, and this is due to consistently creating enough hours in the production site, meaning that the bottlenecks appear from the earlier stages.

Project count

A deep and thorough investigation took place on the ERP system to retrieve the number of projects which have gone through all of the pre-production processes.

Using Little's Law, a final throughput will be calculated which will give a numerical figure to help with calculating the final improvements benefits in terms of projects

$$\text{Throughput} = \frac{\text{WIP}}{\text{Duration time}}$$

Figure 12- Little's Law

A year's worth of project was required; therefore, a decision was made to collect the pre-production orders which have been executed throughout the year of 2020.

This total number amounted to 913 projects. To calculate how many complete pre-production processes took place in a day, the number of weekends and holidays must be subtracted from the year, this will lead to the following calculation, 365-105= 260. There are 260 working days within a year when not taking the weekend into account, however there are also 8 weeks of holidays per employee, therefore leading to the following calculation, 260-40=220.

220 days is the total working days when subtracting the possible and mandatory holidays.

Now to get the total number of the pre-production process complete in a day, the following calculation must take place, 913/220= 4.16 projects a day,

Therefore, according to this ERP data we can conclude that a total of 4 complete pre-production processes. This number will be of great use when implementing the improvements, as it will be used to calculate the number of projects the company could complete in addition to what has been worked on.

5.2- Analyze

Now that the "measure" part of the DMAIC methodology has been executed, the next course of action is to analyze the processes and determine what are possible wastes and bottles which are found in the pre-production processes.

To successfully accomplish the analysis, 2 different ways are going to be used to analyze the wastes and bottlenecks, where one complements the other, these 2 ways are the following:

- 8 wastes of lean: Using this method, the research is going to pinpoint the wastes which are found around the previously mentioned processes.
- Pain/frequency matrix: Using the pain vs frequency matrix, a graph is going to be built, placing the wastes mentioned in the "8 wastes of lean" depending on the severity of the bottleneck and how often does it cause a problem to the total process.

5.2.1- 8 wastes of lean

Lean in itself is a very effective concept used to improve the quality, profitability and reduce duration times in companies' processes. One of the core Lean methodology principles emphasizes heavily on the reduction of wastes which are apparent around the company, these wastes were categorized into 8 different types of waste according to the lean methodology (2.2.2- Lean, P15).

Throughout conducting the interviews and observations, many different types of wastes have been identified throughout the examined processes.

Additionally, all of the wastes which have been determined will be numbered as this will come into use in the next step "5.2.2- Pain vs frequency matrix".

Table 5 found below contains a list of the identified wastes and categorized according to the lean methodology's definition of waste which was defined in chapter 2.2.2.

Category waste	Waste identified in company
Extra processing	-Printing papers when it can be used digitally -Kelvion SM, Kelvion Czech Republic and Kelvion Poland order lines are manually taken from the SAP into excel planning sheet and then filtered -Manually entering information into Sofon
Transportation	Transportation of physical documents carried out by the engineering and work Preparations team
Waiting	- Technical team waiting for the Planning team to place order lines in planning sheet -Order desk team taking too long to process orders -Waiting for project specific supplies due to confirmation on materials is occurring After production drawings are completed. (Header department)
Motion	Searching for files
Inventory	-Having both Physical and digital copies -Having old files in an active project's folder
Defects	-Errors in processing orders -Changed drawings by the technical team contain errors -Faulty order forms are not always changed by the order desk team
Information overflow	Date of completion per task is entered into Excel and is present on webtools
Non utilized talent	-Technical team should help with changing the order form but lack the knowledge -R&D and P&D departments should help with engineering drawings

Table 5- 8 wastes of lean

1-Printing papers while having the same files online

Throughout the interviews, walking around the departments and observing the processes being performed. A very important observation was made when some of the processes required the workforce to print the documents which take up to 15 mins depending on what is being printed and subsequently transported to a different department.

These printed drawings are already available digitally, but due to the work habit of carrying out this process physically, some of the company's departments still do that when it is not really required, such as printing out the production drawings and the Sofon and SAP information, mainly found in AT3 and AT4.

2-Kelvion SM, Kelvion Czech Republic and Kelvion Poland order lines are taken From the SAP into excel planning sheet and then filtered manually

Kelvion SM is responsible for processing Kelvion SM, Kelvion Czech and Kelvion Poland production sites. This results in all of the order lines appearing in the SAP system when it is time to take them out and place them into the excel planning sheet. This results in the planning team of Kelvion SM taking these order lines and placing them into the excel files and then removing the ones which are not to be produced at the SM location.

This waste should be eliminated since it can easily be fixed, and it causes an everyday over processing task for no good reason.

3-Manually entering information into Sofon

Sofon is a CPQ used by the company of Kelvion to receive the production configuration and pricing of the heat exchanger. At the moment, the way the program works requires the users to manually enter all of the relevant data needed in order to receive the pricing and product configuration.

This process on numerous occasions, is time consuming and would lead to completing the tasks with a higher lead time than what it could be.

Atomization is a possibility however manual work on Sofon is still conducted at the company of Kelvion.

4-Transportation of Physical documents

Many of the pre-production processes carried out at Kelvion have turned digital ever since the corona crisis. However, still in some processes, printing out the papers and transporting them is still existing when it really is not needed to.

This issue happens specifically in AT3 and AT4 processes where the department with one of the highest bottlenecks is carrying out the printing and transportation of the documents, namely the engineering

department. This also occurs with the work preparation team in the AT4 process with the work-preparations team when printing out the documents and transporting them to the production site.

In the AT4 process, some physical drawings are transported from the engineering department to the work preparations team, these drawings are utilized as a visual aid to gain a comprehensive idea on what drawings are going to be used and what is not when performing the AT4 step. However, the major issue is that this is done by the department which specializes in creating drawings and time is extremely valuable in that area; therefore, the drawings should be sent digitally, and then printed by the work preparations team, should the drawings even stay as a part of the work preparations teams.

5-Technical team waiting for the Planning team to place order lines in planning sheet

An extremely unnecessary and baffling step which occurs that causes unwanted wait is apparent in AT1 where the technical team must call the Planning team to take the order lines from the excel sheet and place them in the Planning excel file, this process takes about 5 minutes in total.

The reason why this process is extremely unnecessary is due to the fact that the technical team possess the same file that the order lines are taken out from and subsequently placed into the planning excel sheet with a click of a button.

6-Order desk team taking too long to process orders

Another major issue and one of the most substantial bottlenecks which needs to be solved is that the order desk does not process enough projects causing the planning team and work preparations team to have to wait until the orders have been processed in AT1.

This waiting time would eventually lead the rest of the departments to miss their desired lead time for a total project, since it takes up from the total ideal project duration planned to be achieved. And as this is an ETO environment, customer approval is the highest focus, therefore getting it as soon as possible is always the most favorable situation.

7-Waiting for project specific supplies due to confirmation on materials is occurring After the production drawings task have been completed

The engineering team does not specify the project specific materials needed until the production drawings have been finalized in AT3, this is to save time when it comes to sending the customer their drawings in AT1, however, what this does is that it causes the work preparations team and the purchasing team to receive the list of project specific materials needed after the production drawings are ready and can be sent to be worked on by the production team.

This causes a waiting time for those specified supplies to arrive to the company. Therefore, also resulting in waiting time before production could even start.

8-Searching for files

The company of Kelvion makes use of an immense amount of programs and files. Looking for certain types of files when wanting to place a document from the email is very much unnecessary motion. This issue is fairly consistent at the company of Kelvion and since the majority of the employees, have been working there for a large amount of years and therefore are fairly knowledgeable on the system, there was not much of an initiative to make a change when it comes to searching for files to place documents.

9-Having physical and digital copies

Inventory in the pre-production Processes can be less visible, yet it most definitely still has an impact in terms of waste created.

Of the issues which can be classified as excess in inventory issue and has also been discussed in the "Extra-processing "part, is that there is an excess amount of paper when it is not required to. This excess in inventory in terms of printed out papers could very easily be negated by moving more towards digitalization, especially when most of the processes are conducted digitally.

Another major issue is that each project folder contains all new and old documents which are new longer relevant for project. A good example is when a new customer drawing is created and placed in the project file, the older versions are not stored away or deleted, instead the new file would have a letter right next to it indicating the latest version. This could lead to costly mistakes if not handled safely.

10-Having old files in an active project's folder

The current way of working at the company of Kelvion when it comes to placing files into project folders requires them to keep the old files which have been changed after a customer drawing has been changed or an order form was altered due to the customer expressing their disapproval, with the only difference is the placement of a letter ranging from a to z to indicate the latest file.

This causes excess inventory and makes it more prone for employees to make vital mistakes in case they missed the latest letter, leading to the possibility of extortionate mistakes.

11-Errors in processing orders

One of the main complaints coming from the engineering department is that the order form created by the order desk contains mistakes 50% of the time, which sometimes lead to going back in the process to actually receive a corrected order form. This, if not caught in time, could lead to catastrophic mistakes, and a large amount of lost time.

The issue does not just land on the Order desk when creating an order form, but also on the sales team which have a rate 59% when it comes to the first-time right rate, this is almost half of the orders processes containing mistakes which need to be fixed by the order desk team, or even sent back to fixed by the sales team.

Since one of the most recurring bottlenecks is happening in the order desk department, it is important to eliminate every type of waste found there.

12-Changed drawings by the technical team contain errors

Oftentimes, when a customer has expressed his disapproval for the customer drawings and indicates the changes he demands to be made, the technical team sometimes handle those changes granted they are not too big, and then sending them straight away to the customer.

However, this is a major pain point for the engineering team, because a lot of the times the changes on the drawings are performed incorrectly or contain missing information, which would cause the engineer creating the production drawings to have a hard time and therefore potentially leading to longer time to create them the production drawings.

13-Faulty order forms are not always changed by the order desk team

Often, when an error is detected by the engineering team on the order form, which happens in 50% of the instances (Information received from lead engineer), the engineering team make a note of that and provides it to the order desk team expecting that they will create the changes where defects are present.

However, in many times that is not the case, and this could potentially result in issues if a frequent customer asks for the same product again at a later time, and the order form has not been changed, therefore resulting in the engineering team with providing the customer with flawed customer drawings which will not be approved.

14-Placing the completion dates in the planning excel file when they are present on the webtools

Whenever an action is about to be made for any of the process steps, or has been completed, the entire process needs to go through the webtools which gives the orders to start a task and does not move forward to the next step without the completion of the task started. The start and end point of the task on webtools always record the dates.

However, even though that is the case, almost every step which has been completed is also entered manually into the excel file, leading to an overflow in information when it is not necessary. This is a non-value adding nor is it necessary as the dates are already recorded into the webtools system, the only issue would be linking the excel with the webtools, and that can definitely be worked on by the IT team as it is possible to link the 2 together.

15-Technical team should help with changing the order form but lack the knowledge

In numerous occasions, when the customer does not approve the AT1 drawings, a new order form needs to be created with the new specifications to calculate any changes in the prices and to allow for use for the following departments as they need to work with the new order form.
The case that is happening now it that once the customer drawings have been rejected, the technical team gets an email about the rejection and subsequently pushes the task to the order desk team to create a new order form. However, this order form takes a period of 2 days before it is worked on by the order desk team due to the overflow of new orders and past orders which need to be changed.
The technical team essentially is a part of the order desk team; however, they have a different function. Making use of them when it comes to small changes in the order form would cause a substantial reduction in the amount of time needed before new customer drawings are created.

16-R&D and P&D departments should help with engineering drawings

The engineering department almost always misses the target date for creating the customer drawings. And if the company actually wants to achieve their desired goal for providing the customer drawings within 15 days of receiving the order a helping hand is definitely needed in this case.

The R&D and P&D departments consist of a total of 4 people in total, previously having worked in the engineering department, therefore having the knowledge when it comes to creating drawings. This in tough times would immensely help out in meeting the desired date of sending out the customer drawings, however is not put into use

5.2.2- Pain vs Frequency matrix

In the previous chapter, the different possible wastes have been pinpointed according to the lean methodology which has been proven to be effective in many different industries.

In this chapter, each of the wastes which have been determined to occur in the company of Kelvion will be placed in a Pain vs frequency matrix, which allows for the visualization of the frequency of the occurrence of a certain waste, as well as that pain that it is causing or could potentially cause at certain times during the timeline of a year.

The diagram is split into 3 different colors, Light grey signifying low pain and low frequency, grey signifying medium pain and medium frequency, and last dark grey which signifies high pain and high frequency.

Once complete, an overview on the demand for an improvement will be clear on which ones wastes need to be worked on in terms of the level of issues they are contributing to in the pre-production processes of the company of Kelvion.

Figure 13 found below, is an illustration of the results which have been concluded from the construction of the pain vs frequency matrix.

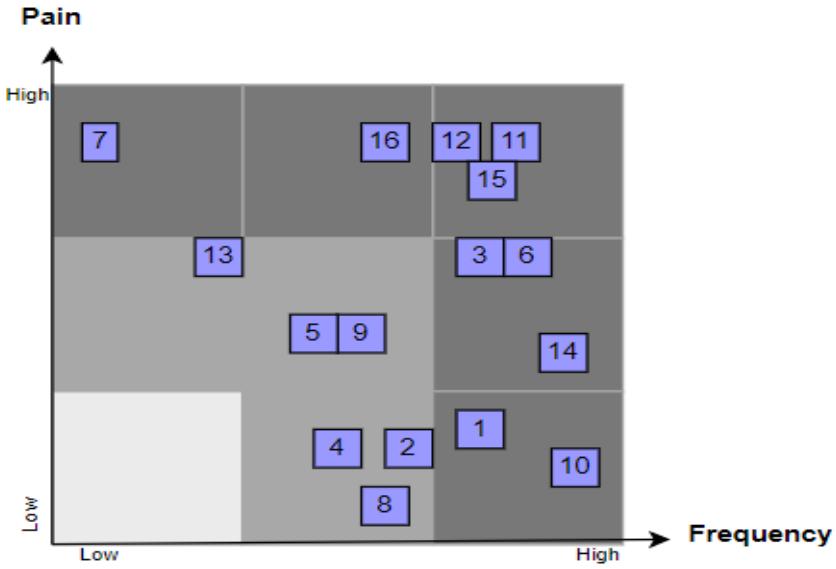

Figure 13- Pain vs frequency matrix

As shown above, a large number of wastes are causing severe pain to company's processes with a large frequency occurrence/possible occurrence, especially waste number 11 and 12.

In the improve part of the DMAIC methodology, improvements will be presented to ultimately eliminate these wastes or at least dimmish them as much as possible.

5.3- Improve

Now that the analysis has been conducted and wastes and bottlenecks have been detected, an improvement plan will be set up to ensure for the process optimization of the pre-production processes.

The improvements are first going to be listed and elaborated on, followed by the use of solution decision matrix as seen in "2.2.4 solution decision matrix" which is a DMAIC tool in the improvement phase which helps in selecting which solution should get the priority when implementing the improvements.

The ranking system will range from 1 to 5, where 1 indicates the lowest priority and 5 indicates the highest priority.

Firstly, the solution will be listed with a letter for identification purposes when creating the solution decision matrix, then followed by a thorough explanation on what each solution listed signifies.

Once the improvements have been listed and placed on the solution prioritization matrix, they will be matched with the waste which has been identified and needed to be eliminated.

5.3.1- Improvements

As explained earlier, first the improvements will be listed with a letter for identification purposes followed by a detailed elaboration on what it signifies.

Improvement A: Move digitally not Physically

One large mistake which can be seen in both AT3 and AT4 is that some activities which are taking place are being performed by the wrong department, and in fact could be performed digitally let alone to be printed and transported which takes about 20 to 25 minutes from the engineering time's department in every single trip taken. This same issue happens in the AT4 process in both the engineering department and the work preparation department when printing and transporting the documents to the production site.

Additionally, since one of the most apparent bottlenecks appears to be present in the engineering department, the printing process could be connected to the receptionist's office, and she would handle the waiting and transporting. Therefore, the most idle improvement for waste number 1 and 2 is to transfer the documents digitally, instead of having wait time.

Improvement B: Process re-design in AT1

One simple and quite apparent improvement which could be easily implementable and highly logical, is having the outlier in AT1 process (Appendix 2), which is the placement of the order lines into the planning excel sheet from the SAP system.

The way this is currently handled is that the technical team would have to call the planning team to inform them that they should place the order lines into the excel file, causing disruption in their work and causing them usually a minimum of 5 minutes, the frequency of this issue is about 2 times per day.

Therefore, the most viable solution is the re-design the process and move the task of the placement of the order lines into the excel sheet to be done by the technical team instead of the planning team since they both can retrieve the order lines from the SAP.

Improvement C: Flexible workforce

An issue which seems to be apparent in almost all of the pre-production process steps is the lack of workforce in some departments, therefore causing a massive delay as shown in" 5.1.3 ERP analysis" and not allowing for the achievement of the ideal dates placed by the company for each department.

Being highly noticeable in the order desk department and the engineering department. This could be combatted by deploying a flexible workforce.

The technical team are a part of the Order desk team however, they do not conduct the same tasks as the order desk team. Using the flexible workforce solution will allow the technical team

to provide support for the order desk when it comes to changing or creating simple order forms.

As for the engineering department, The R&D and the P&D teams were once part of the engineering team in the past and have now changed departments. Each of the 2 teams consist of 2 people, amounting to a total of 4 people being able to help out at times when excessive loads of work are present. The only issue which falls with this improvement is that these 2 mentioned teams contain heavy loads of work, therefore only a limited number of projects should be handed out, such as a single project a week for each of the 4 members.

Lastly, the work preparations team is made up of 3 people, where all of them work with a flexible schedule, where they do not attend the company full team. This at times could cause issues, and for this reason the planning team must also be trained to help out the work preparations team when needed.

Lastly, flexible workforce does not only signify using current employees, but also hiring additional temporary employees when the company is receiving an immense number of orders and the departments cannot execute their tasks in the desired lead time set by the Kelvion SM.

Improvement D: training of staff

As mentioned in improvement C, the technical team should be present to help the order desk with changing order forms. However, one major issue is that they lack the expertise in conducting such a task when this really should not be the case.

For this reason, training of staff is extremely necessary to be able to achieve flexible employment in the order desk department. This will also come a long way in the future as a learned skill that is constantly being put to use will help in conducting the tasks and training future employees.

Improvement E: Quality assurance

Another major issue which is happening in the Order desk department is that the quality of work which is reaching from the sales team is quite low at times leading to a higher lead time when creating a new order form, and additionally leading to the contribution in more mistakes in the order desk department. In fact, the first-time right rate of the sales department is currently at 59%, meaning that 41% of the sales orders coming to the order desk team contained mistakes and at times needs to be returned back for it to be fixed.

The same issue is also currently happening with the technical team when fixing the drawings in the AT2 process, where the drawings are being sent to the customer, but the quality of the drawings is fairly low and contains mistakes, therefore leading the AT3 process to be a more complex process that it should be.

Improvement F: Improvement of CPQ

A largely discussed issue by the order desk, which currently happens at the company of Kelvion relates to the product configuration system which is in use and is deemed to halt their lead time due to the manual work which needs to be put in to receive the information needed.

Though another previously mentioned improvement which was stated indicated that it would be of great help to complete change Sofon, it can take a large amount of training before the users are comfortable and on pace with the orders when using it. Therefore, the most logical and optimal solution to go with from that point, is to implement improvements to Sofon, and one of those improvements which would have a heavy impact on the lead time.

Improvement G: Process re-design in AT3

AT3 is the step that mainly revolves around the creation of the production drawings and specifying what project specific materials are needed for the project to go forth when it is time for manufacturing. However, this causes one major concern which could arise from this way of working, where once the project specific materials are listed in the AT3 process, ordering those materials might take time which could result in a substantial delay in the planned date of manufacturing.

This issue could be negated if the project materials are specified in AT1 or AT2 if the customer does not approve of the drawings, meaning that by the time the company has earned the customer's approval, the work preparations and purchasing team could work in parallel with the engineering team when it comes to AT3, so that ordering the project specific materials happens at a much earlier date than it would have had it been in the past process design.

Additionally, one task conducted by the engineering team in AT3 which can be quite consuming is the creation of exports of Radan file to place them into the Kelvion folder. This could easily take up hours of an engineer's time a week. Therefore, the best decision to go forth with is having the nesting team taking care of creating exports as they are the ones making use of them.

Improvement H: IT services for optimization

Many of the tasks which are conducted throughout the pre-production processes can be seen as repetitive and could easily be shortened through some help from the IT team.

One of the most notable activities carried out throughout these processes is manually entering the dates in the excel files in terms of the date of completion of tasks. This can be seen as unnecessary and resulting in additional time when carrying out the tasks. And the reason for coming to that conclusion is because the IT team could connect the webtools which automatically records the dates of completion, with the excel sheet through project number. One press on the project number in the excel sheet would transfer the user to the webtools folder of that project, where all of the relevant dates can be found.

Another point where the IT team can help, is through creating a shortcut to send emails into folders immediately from the mailbox. Meaning that, through the creation of a certain function in the mailbox, the user will have immediate access to send this file or email as a whole into another file such as the Kelvion folder.

Improvement I: Always change the order form.

As explained in point 10 of the "8 wastes of lean". In many of the cases the order form contains mistakes which are not changed by the order desk team, and this could potentially lead to crucial mistakes, especially if a frequent customer demands the same product and the information in the past order form is inaccurate.

The greatest improvement which could happen here is simple, the order desk must be commanded to always make the changes which have been placed inaccurately in the order form. And this will lead to higher quality and a much smoother flow later down the road, since in many cases, Kelvion customers end up ordering the same products again in the future.

Improvement J: Create an ABAP for Czech, Poland and England order lines

As discussed in waste number 2 in "8 wastes of lean" an over processing waste can be found where all of the order lines from 3 different locations appear in one section.

This can easily be eliminated by creating an ABAP on SAP which would separate all created order lines by providing the SM order lines alone, and vice versa for the Czech Republic and Poland order lines.

Improvement K: Change of CPQ

One of the most recurring issues which the order desk team have reported on, is the frustration and waste time Sofon causes.

Sofon is the current product configurator used at the company of Kelvion, and some of the major issues that the staff which make use of this program have reported is its slow functionality and its ability to log you out in a very small time span if usage is not detected. This could potentially lead the user of the program to lose all of their progress if not saved manually in time. For this reason, a shift towards a different product configurator is highly advisable.

Salesforce CPQ is a product configurator that offers some of top the range features additionally to what Sofon offers, the reviews clearly indicate positive feedback on the program. It can also be deployed in a different range of systems such as apple and android, therefore allowing for a more flexible use. It is also a considerably larger company with a much higher revenue, indicating the difference in the size of the user database and the possibilities for innovations in their systems.

It does come with a downside as it requires a high learning curve, meaning that its integration could possibly take a hefty amount of time.

Improvement L: Senior engineer scheduling

One of the most frustrating issues which the engineering team complaint about is that the technical team fail to apply changes to the customer drawings correctly, therefore causing them trouble when it comes to creating the production drawings.

This issue is planned to be tackled through having a senior engineer check on the work that the technical team in terms of changes in drawings in the AT2 process. However, one major thing that must be thought of is that the senior engineer has to also check the rest of the engineering team's work meaning that if this is implemented, some altered customer drawings must sit for sometimes 2 days before they are checked and given approval to be sent to the customer.

For this reason, a scheduling tactic must be implemented when going forth with this change, where the senior engineer must make use of the first hour and a half of his shift (6:00 am until 7:30 am), to check the technical team's drawings and spend the rest of his shift working with the engineering team. This is because most of the engineering team members do not start their shift until 7:30, while the senior engineer starts his shift at 6.

Additionally, the company of Kelvion SM has only 2 senior engineers which are responsible to check the work of 18 other engineers. Therefore, to achieve the highest level of efficiency, it is best to create a schedule between the two of them where they alternate weekly between each other where one works on creating drawings for the entire week like the rest of the engineers and the other checks the work of the rest of the engineers and vice versa.

Improvement M: Separate new and old files

An important observation which was made is that in the project folders found in the Kelvion database, the old and newly made order forms, drawings and more are only separated through a letter (ranging from A to Z), where the latest letter placed on a file indicates the latest version. This could possibly be a very risky situation if the person responsible to do a certain action makes a mistake and misses the last file due to the overload of files that could be found in the folders.

Therefore, creating an additional folder in the project's folder which contains all of the old files relevant to the order will immensely reduce the inventory as well as diminish the time spent looking for the latest file and mistakes that could be made.

5.3.2- Solution prioritization matrix

Following the generation of solutions for the wastes indicated in the analysis section of the report, a solution prioritization matrix was created to help with the selection of which solutions should be implemented in a ranking order.

The matrix will contain 3 different factors on which a solution can be ranked on, and these are the following:

- **Ease of implementation:** This factor indicates how easily this solution can be implemented into the company, depending on the time and practice that it requires for the company to adopt it into their way of working.
- **Impact of the solution:** This factor indicates the greatness of the impact of the solution that it will have on the company and its processes, whether in terms of quality or lead time reduction.
- **Permanence:** Permanence refers to the length of time that the company can rely on each of the mentioned solutions, indicating if the solution is a quick fix which still needs to be kept an eye on once implemented or whether it is long term solution which will practiced around the company.

Once the evaluation of the factors has been concluded, a rating will be given to each of the solutions per factor ranging from 1 to 5.

In the following image, an elaboration of what each of the ratings signify per factor.

Ease of implementation			Impact of the solution			Permanence	
Rating	Reference		Rating	Reference		Rating	Reference
1	difficult		1	Low impact		1	Fugitive
2	Moderately difficult		2	moderately low		2	temporary
3	Moderate		3	moderately low		3	Moderately durable
4	Easy		4	High		4	Highly durable
5	Very easy		5	very high		5	Permanent

Upon rating the solutions per factor, an addition will take for the ratings given per factor for each solution which will give us a final number, the higher the number, the better the ranking the solution will have.

Subsequently, once the ratings have been given, each factor contains a certain coefficient allocated to it, depending on the importance of the factor, which has been deemed qualitatively through discussion. Each rating will be multiplied by its coefficient respectively, and thus giving out a final rating which will be used to determine the rank of each solution.

Down below is an example of what a calculation would look like, the red numbers indicate the coefficient. It is also important to note that the total of all coefficients adds up to 1, meaning that 5 is the highest number possible to receive.

	Ease of implementation		Impact of the solution		Permanence		Rating
Example	3*0.35	+	2*0.35	+	4*0.3	=	2.95

In the next page, the solution decision matrix will be illustrated and revealed to provide the final outcome of the rankings of the solutions which have been generated.

Solution	Ease of implementation	Rating*Coefficient (0.35)	Impact of solution	Rating*Coefficient (0.35)	Permanence of solution	Rating*Coefficient (0.3)	Total score	Rank
Solution A	4	1.4	2	0.7	4	1.2	3.3	**5**
Solution B	5	1.75	2	0.7	5	1.5	3.95	**2**
Solution C	1	0.35	5	1.75	3	0.9	3	**7**
Solution D	1	0.35	4	1.4	4	1.2	2.95	**8**
Solution E	2	0.7	5	1.75	3	0.9	3.35	**4**
Solution F	1	0.35	4	1.4	5	1.5	3.25	**6**
Solution G	3	1.05	4	1.4	4	1.2	3.65	**3**
Solution H	4	1.4	3	1.05	5	1.5	3.95	**2**
Solution I	3	1.05	5	1.75	5	1.5	4.3	**1**
Solution J	3	1.05	1	0.35	5	1.5	2.9	**9**
Solution K	3	1.05	2	0.7	3	0.9	2.65	**10**
Solution L	3	1.05	3	1.05	2	0.6	2.7	**9**
Solution M	3	1.05	3	0.7	3	0.9	2.65	**10**

Table 5- Solution decision matrix

Following thorough and extensive analysis on the solutions which were generated, appropriate ratings were assigned to each of the solutions per factors which were listed.

This leads to building the following table which enables us to see which solutions should come first in a chronological order.

Rank	Solution Letter
1	I
2	B, H
3	G
4	E
5	A
6	L
7	C
8	D
9	J, L
10	K.M

Table 6- Solution rankings

It is important to note that all solutions are important regardless of their ranking, however the ranking system enables the visualization of which ones are decided on to be implemented first before the others.

Some solutions fall under the same ranking due to achieving the same score following their assessment on all selected factors.

5.3.3- Waste X Solution Matrix

Following the identification of all possible wastes and improvements possible throughout the pre-production processes, a matching process must take place to allow for the connection of which solutions are possible to be applied for each waste.

Additionally, the department which contains any sort of relevancy or is a target for the certain waste indicated will be documented in the matrix.

This is then followed by the calculation of the waste eliminated by the solution in the form of minutes, and all additional relevant factors which are needed to calculate the total waste per “Waste X Factor” will also be included in the matrix. The reason being is that these factors are very important to receive an accurate and reliable calculation. A good example is when the engineering team print papers which take 20 minutes, there are 20 engineers who are available to work therefore, the total waste of 20 minutes must be divided by the total number of employees which are available to work. The same goes for the rest of the mentioned cells relevant for the time calculation.

Another clear observation which can be made from examining the matrix is that in many slots the term “NA” is mentioned. This is because the factor mentioned on the X axis must not apply to that certain Waste X solution

Meaning it has no relevance to it when it comes to the calculation of the time saved, or it indicates that it is a quality improvement or a preventative measure not resulting in possible additional waste time instead of saving time directly. A good example to explain this is the solution “process re-design in AT3” where the engineers used to then specify what project specific materials need to be purchased. Re-designing the process, where the provision of what project specific materials need to be ordered for the project happens in AT1 instead of AT3 could sometimes potentially save weeks of waiting time in case the suppliers need to take time to manufacture the materials needed.

It is important to note that some “frequency of waste” indicate the number 4.15, and this is because the use of the ERP data (5.1.3-ERP analysis) is applicable in this section is the waste happens after each process has been performed; therefore not needing to rely on qualitative data.

At last, the table found right below is the final Waste X solution matrix containing all wastes and solutions as well as the total time which could potentially be saved by deploying all of these improvements, validated by the internship supervisor

Waste number	Waste	Solution letter	Solution	Department/ team	Time saved with solution	number of workers in department	Time saved When number of workers into account	Frequency of waste	Frequency X (Time saved/Number of workers)	Total time saved (Minutes per day)
1	Printing papers while having the same files online	A	Move digitally not physically	Engineering	20	20	1	4.16	4.16	**4.16**
				Work preparations	15	3	5	4.16	20	**20.8**
2	Kelvion SM, Kelvion Czech republic and Kelvion Poland order lines are taken From the SAP into excel planning sheet and then filtered manually	J	Create ABAP on SAP	Planning team	2	2	1	3	3	**3**
3	Manually entering information into Sofon	K	Change of CPQ	Order desk	NA	NA	NA	NA	NA	**NA**
		L	Improvement of CPQ		120	4	30	NA	NA	**30**
4	Transport of physical documents	A	Move digitally not physically	Engineering	5	20	0.25	4	1	**1**
				Work preparations	5	3	1.6	4	6.6	**6.6**

5	Technical team waiting for planning team to place orderline on Excel sheet	B	Process re-design	Technical team	5	2	2.5	2	5	**5**
6	Order desk team taking too long to process orders	C	Flexible workforce	Order desk	30	2	60	NA	60	**60**
		D	Training of staff		NA	4	NA	NA	NA	**NA**
		K	Change of CPQ		NA	NA	NA	NA	NA	**NA**
		E	Quality assurance		NA	4	NA	NA	NA	**NA**
7	Waiting for project specific supplies due to confirmation on materials is occurring After the production drawings task have been completed	G	Process re-design	Engineering	NA	NA	NA	NA	NA	**NA**
8	Unnecessary motion searching for files	H	IT services for optimization	Planning team	180	3	60	NA	NA	**60**
				Work preparations	180	3	60	NA	NA	**60**
9	Having physical and digital copies	A	Move digitally not physically	Engineering	NA	NA	NA	NA	NA	**NA**
				Work preparations	NA	NA	NA	NA	NA	**NA**
10	Having old files in an active project's folder	M	Separate new and old files	All departments	NA	NA	NA	NA	NA	**NA**
11	Errors in processing orders	D	Training of staff	Order desk	NA	NA	NA	NA	NA	**NA**
12	AT2 changes in drawing done by technical team contain mistakes	D	Training of staff	Technical team	NA	NA	NA	NA	NA	**NA**
13	Faulty order forms are not always fixed in AT2	I	Always change the order form	Order desk	NA	NA	NA	NA	NA	**NA**
14	Date of completion per task is entered into Excel and is present on webtools	H	IT services for optimization	Technical team	60	2	20	NA	NA	**30**
				Planning team	80	3	10	NA	NA	**26.6**
				Order desk	60	3	10	NA	NA	**20**
15	Technical team could help with creating/changing order forms but lack knowledge	D	Training of staff	Technical team	30	2	60	NA	60	**60**
16	R&D and P&D department provide support to engineering	C	Flexible workforce	P&D	20	2	40	NA	40	**40**
				R&D	20	2	40	NA	40	**40**
total time										**466.2**

Table 7- Waste X Solution matrix

After gaining heavy insight using quantitative and qualitative research, the “Waste X Solution matrix” has finally been built, including the additional time which could be used to work on projects, had the wastes not been in the picture.

The total time amounts to 466.2 minutes a day, the following will be calculated to turn the number from minutes into days as a unit of time.

(466.2/60)/24= 0.32 days.

This number is the total time that could be saved when taking into account all 5 different departments/teams, Engineering, Planning, Work preparations, technical and order desk. This means that 0.33 days must be divided by 5 to achieve the most accurate calculation for the entirety of the pre-production process, as it allows for the calculation of the total time saved when split by each department and worker.

0.32/5= 0.064 days = 1.53 hours = 92 minutes

1.53 hours would have been saved for all departments from an 8 hours shift per employee,

To figure out the additional output rate in the pre-production processes that would be provided from applying these improvements, the following calculation must take place:

1.58/8 = 19.13%

Meaning that the project count would increase by a minimum of 19.13% since there many other improvements which are listed who provide additional production perks but cannot be quantified. Therefore to find out the possible number of project which would have been additionally completed for the pre-production processes, the following calculation will take place:

19.13%*913= 175 projects.

And in-case the concern is the lead time reduction, the following calculation will take place,

0.1913*220= 42.1 days of reduced lead time per working year, which could be used to work on additional projects.

6- Control

Since the improvements have been recognized and proposed with a solution prioritization matrix, indicating which improvements should be implemented first, a control plan has been built to allow for understanding on what different factors are going to be taken into consideration, in order to control the improvements as well as who are the people responsible to ensure there that these set procedures/controls are put in place.

Firstly comes the errors indicator factor which elaborates on the possible failures which could come up when having the improvements set in place and already being used.

The next part is the KPI factor which provides a quantitative perspective on the current performance per critical variable, and the target performance that the improvements should ultimately provide, setting also the anticipated trend, whether be it an increase or a decrease in the KPI mentioned per critical variable (Waste).

Additionally the owner of the process is also mentioned, indicating the person who is responsible for making these checks on the KPI performance. The owner section also indicates the person responsible I conducting the reaction plan if errors are found to be occurring in a frequent manner; the reaction plan will be further elaborated on shortly.

Some slots contain the symbol X, which indicate that control measures are not required for that certain step, this is mostly due to the lack of feasibility for a control action to be done in that certain slot/ step.

Lastly, comes the reaction plan and control period, whether the reaction pan indicates what the owner of the process must do when errors are found and the control period indicates how long will these set procedures will be in place before the improvements are deemed to be flowing correctly around the departments and do not need to be checked on depending on the frequency of checks indicated in the control plan.

In the following page, table 8 illustrates the control plan which has been created for the improvements mentioned.

Critical variable		Improvement		Improvement description	Department Involved	Error indicator	frequency of checks	KPI				Owner	Reaction plan	Control duration
								KPI description	KPI baseline	anticipated KPI trend	Optimal target			
1	Printing papers while having the same files online	A	Move digitally not physically	Instead of printing the papers, make use of the ones found online	Engineering	Employees find it difficult to change to full digital work style, therefore revert to old work style with papers	Weekly	Number of times papers are printed per week	25 per week per department	Decrease	0 per week	Lead engineer	Supply chain operations and Engineering, monitor and guide employees until comfort is gained on working digitally	21 days
					Work preparation				25 per week per department	Decrease	0 per week	Supply chain operations manager		
2	Kelvion SM, Kelvion Czech republic and Kelvion Poland order lines are taken From the SAP into excel planning sheet and then filtered manually	J	Create ABAP on SAP	Create an ABAP on SAP which would separate the order lines per location	Planning	ABAP does not function in the desired way	Weekly	number of times order lines had to be separated depending on location	15 times per week	Decrease	3 minutes per week	Order desk manager	Contact IT team. IT team will review the ABAP, until the desired stated function is achieved	30 days
3	Manually entering information into Sofon	K	Change of CPQ	Getting a new CPQ and replacing the current one	Order desk	Employees find it difficult to use a new CPQ, therefore produce errors	Daily	Time spent to enter information manually	30 minutes per day per person	Decrease	10 minutes per day per person	Order desk manager	Order desk manager monitor returned order forms, if the amount is high, then provide further training	60 days
		L	Improvement of CPQ	Purchasing extensions of the current CPQ , and making work much less manual		Constant errors due to CPQ program functionality	Daily						Report to Order desk manager to collect complaints, and follow up with CPQ supplier. If the issue is of high frequency, then revert to manual work in the mean time	30 days

4	Transport of physical documents	A	Move digitally not physically	Instead of having to transport physical papers, send them digitally through an email or by placing them into the project folder	Engineering	Employees find it difficult to change to full digital work style, therefore revert to old work style with papers	Weekly	Number of times transportation takes place per week	20	Decrease	0	Lead engineer	Supply chain operations and Engineering, monitor and guide employees until comfort is gained on working digitally	21 days
					Work preparation				20	Decrease	0	Supply chain operations manager		21 days
5	Technical team waiting for planning team to place order line on Excel sheet	B	Process re-design	Re-designing a part of the process so that the technical team take care of placing the order lines into the excel sheet	Technical team	X	X	X	X	X	X	X	X	X
6	Order desk team taking too long to process orders	C	Flexible workforce	Creating additional workforce to help in processing orders	Order desk	Order forms are not filled correctly by the newly added workforce	Weekly	Number of projects processed per day	4.16 projects	Increase	5 projects	Order desk manager	Order desk manager assigns easier orders to fill, while also demanding further training	90 days
		D	Training of staff	Training current employees to help in processing orders		X	X						X	X
		E	Quality assurance	Focus on quality of work from the sales team before sending out orders to be processed		First time right of sales orders are still considerably low	Weekly						Order desk team record instances, and inform sales team and other managers	30 days
7	Waiting for project specific supplies due to confirmation on materials is occurring After the production drawings task have been completed	G	Process re-design	Engineering team to create project specific material list in AT1 instead of AT3	Engineering	Engineering team miss listing some components	Weekly	X	X	X	X	X	Engineer adds list of forgotten materials in AT3, with the goal of the mistake not happening again	90 days

8	Unnecessary motion searching for files	H	IT services for optimization	IT team to create functions which allow for transfer of information in a click of a button	Work preparation Planning	Newly created functions are not working properly, meaning that some options are not meeting their designed role	Weekly	Time spent to manually transferring information per day per person	60 minutes	Decrease	5 minutes	Supply chain operations manager	Record which function is not meeting its function and report to the IT team	18 days
9	Having physical and digital copies	A	Move digitally not physically	Use only the digital files instead of creating also physical ones, thus reducing inventory	Engineering Work preparation	Employees find it difficult to change to full digital work style, therefore revert to old work style with papers	Weekly	Number of times papers are printed per week	25 per week per department 25 per week per department	Decrease Decrease	0 per week 0 per week	Lead engineer Supply chain operations manager	Supply chain operations and Engineering, monitor and guide employees until comfort is gained on working digitally	21 days
10	Having old files in an active project's folder	M	Separate new and old files	Create sub-folders in project folders where old files can be placed	All departments	Wrong files are placed in the subfolders	Weekly	X	X	Decrease	X	X	Double check the sub-folder	28 days
11	Errors in processing orders (Order entry)	D	Training of staff	Training of staff handling the order processing steps so that less mistakes are made	Order desk	Errors are still prevalent in the order forms	Weekly	Percentage of order forms containing mistakes	50%	Decrease	20%	Lead engineer	Engineering team send order form back to Order desk and demand better first time right rates	30 days
12	AT2 changes in drawing done by technical team contain mistakes	D	Training of staff	Training of staff that are changing the drawings in AT2	Technical team	Mistakes are still occurring in the changed customer drawings	Daily	Percentage of changed drawings containing mistakes per week	53%	Decrease	0%	Senior engineer	Senior engineer to check drawings before they are sent to the customer.	30 days
13	Faulty order forms are not always fixed in AT2	I	Always change the order form	Changing every order form when a change has been requested by the customer	Order desk	High rate of unchanged order forms is still apparent	Weekly	Percentage of changed order forms	20%	Increase	100%	Lead engineer	Inform Order desk manager and demand improvement	30 days
14	Date of completion per	H	IT services for optimization	Creating a link between excel file and webtools	Technical team	Newly created functions are not working	Weekly	Time spent entering dates manually per day per department	60 minutes	Decrease	0 minutes	Order desk manager	Record which function is not meeting	18 days

	task is entered into Excel and is present on webtools			in terms of order lines	Planning	properly, meaning that some options are not meeting their designed role			80 minutes	Decrease	0 minutes	Supply chain operations manager	its function and report to the IT team	
					Order desk				60 minutes	Decrease	0 minutes	Order desk manager		
15	Technical team could help with creating/changing order forms but lack knowledge	D	Training of staff	Training of staff to help in creating/changing order form	Technical team	Created/changed order forms contain mistakes	Daily	Time spent creating/changing order forms	0 minutes	Increase	60 minutes	Order desk manager	Have an Order desk team member check their work before processing it	30 days
16	R&D and P&D department provide support to engineering	C	Flexible workforce	Make use of R&D and P&D employees to create drawings in times of need	P&D	Both departments could possibly fall back on their work	X	Time spent creating customer/production drawings per week	0 minutes	Increase	40 minutes	Lead engineer	lead engineer must give less time consuming projects	X
					R&D					Increase	40 minutes			

Table 8- Control plan

7- Discussions

The primary reason behind the initiation of this research was the examination of the pre-production processes found at the company of Kelvion, Mapping them out and eventually finding improvements which would contribute to lead time reductions and increase in quality. As the research progressed, multiple issues became apparent and different approaches had to be considered to achieve the goal of this research report. As discussed throughout this report, engineer to order companies contain restriction when calculating accurate average lead and cycles times due to the high variations which can be apparent in “5.1.3- ERP analysis”.

First, an overall look was provided through discussions with the company representatives, to allow for gaining knowledge about the connections between departments and process steps. Subsequently, a large and recurring amount of interviews were conducted to gain heavy insight on the processes which were taking place per department and process step. This ultimately, allowed for the mapping of the processes found around the pre-production section of the company, as well as the value added analysis. Additionally, a number of wastes were discovered thanks to these interviews, as well as certain pain points pin-pointed by the company employees which needed to be improved.

Observations came into large use when examining the way of work in the company, as it allows for the identification of waste, and the generation of ideas on what possible improvements could be produced to eliminate the discovered waste.

Next, an ERP analysis took place, where the duration time of the departments per process steps was figured out, as well as the number of projects conducted throughout the pre-production processes in the span of a year. This allowed for gaining significant amounts of information about the project execution rate and lead times per department, contributing to the use of quantitative information in the project.

The results of the present research act as the blue print to understanding the pre-production processes in depth. The processes, were thoroughly and extensively described, and subsequently mapped out with all possible scenarios, and this will allow for the company to lay out information about the processes to all different departments. Additionally, a process activity map was provided to supply the company with a value added analysis.

Finally, this led to identification of wastes and generation of improvements which could significantly help the company with their output rate, quality and lead time reduction, as per the lean six sigma methodology has explained.

7.1 Research validity and reliability

According to Middelton (2019) Reliability and validity are concepts used to evaluate the quality of research. They indicate how well a method, technique or test measures something. Reliability is about the consistency of a measure, and validity is about the accuracy of a measure. A research has to be reliable for it to be valid in the first place, however reliability when considered alone does not ensure validity as it may possibly does not accurately reflect a real situation.

When implying validity and reliability into this report's qualitative research methods. A cause for concern could be built as it is hard to hold neutrality when using research tools such as interviews and observations, and this because the presence of an interviewer could easily impact the results, as humans are naturally resistant to change and enjoy comfort. This can be thought of in this project's when analyzing waste, and blame is placed on a certain department for waste. For this reason it was important to keep an objective view and hold multiple meetings with different stakeholders in a waste generated, to get as much reliability as possibly, thus allowing for the generation of neutrality in research. However, following the application of these research methods in the company lead to the determination of the link between the theory introduced in chapter 2, such as "2.2- what is lean " and "2.4- Value stream mapping ". Therefore ensuring the validity of the research.

A different result can be concluded when analyzing the validity and reliability of the quantitative research tools which have been used. This is because the ERP system accurately records the duration times taken for a process to be conducted, however certain issues arise such as unreasonable duration times occur due to certain issues such as the customer asking for their products to be produced and delivered over a year later. Therefore causing discrepancies when calculating the duration times. However, this issue has been tackled by taking into account multiple different days into account when going forth with the calculations. Additionally, an exemplary solution relating to the validity came into play in terms of quantitative research method tools where the project count for the period of a year was retrieved from the ERP, leading to accurate information being available when it comes to measurements.

8- Conclusion

Kelvion refrigeration B.V focuses on the execution of multiple complex processes before the production phase even starts, mainly due to the level of involvement the customer has in the product they ultimately want. Complexity sometimes breeds waste, and whenever waste is present, improvements are also possible. This study was able to identify wastes happening around the company as well as the provision of substantial improvements throughout the pre-production processes.

The sole purpose of this research was to analyze the company's pre-production processes, map them out and provide improvements where possible to achieve process optimization.

The main research question was answered gradually, through answering each of the sub-questions which have been determined to be fit for this task. Each of the DMAIC steps have some sort of involvement in answering this question therefore a further elaboration will be given to provide better understanding.

Firstly, the define phase answers the first sub-question "What is the current situation", achieved through the multiple previously held meeting, allowing for a better understanding on why the research needed to be executed, and what was the problem the company of Kelvion was struggling with, prior to this investigation.

Second, the research sub-question "What are the tasks conducted in the processes and sub-processes found between AT1 and AT4?" was answered thoroughly in the measure phase, where the processes and sub-processes were extensively analyzed and drawn out, allowing for the illustration of a general picture for the employees working within the pre-production processes, as well as providing rigorous aid when measuring the extent of waste happening around the company.

Third of all, the research sub-question "What are the wastes and bottlenecks found in the processes?" was comprehensively answered throughout the analyze phase, where the application of lean was vital and wastes around the pre-production processes were concluded, ranging from small wastes which can be fixed quickly to large wastes which could cause serious issues if not eliminated rapidly.

Lastly, the final research sub-question which ultimately contributes to answering the main research question is "What are the possible improvements to be implemented leading to the optimization of the processes?", and this was comprehensively broken down in the Improve phase of the DMAIC methodology, where improvements were provided for each of the wastes as well as a quantitative study on how much lead time reduction these improvements could provide the company with.

Multiple meetings were held with the stakeholders, and all inputs were taken into consideration to allow for fairness and reliability in the research. Validation of data came from multiple sources, most notably the internship supervisors due to the high level of communication and their involvement in this research.

Finally, as a result of the actions which were conducted throughout this research, it can be concluded that the goal of this project was achieved, leading to process optimization around the pre-production processes, through eliminating waste and finding improvements according to the lean methodology.

9- Recommendations

As a result of this study, the numerous improvements which were listed throughout this research report must ultimately be implemented to reap all of the benefits indicated in the “improve” part of the project.

It is highly recommended to have a large focus on training staff, having a flexible workforce since the lack of these 2 proposed improvements seem to be generating a large amount of waste for the company.

Implementation should take place as stated in the solution prioritization matrix, and the use of the control plan is a must, to ensure that the improvements implemented are actually resulting in change for the better.

Digitalization and IT solutions are also other recommendations which could provide the company with faster and simpler ways of working, therefore also contributing to reducing waste around the company.

Additionally, some research extensions came to light following this study, and these are the following:

- Sales department investigation: One of the reasons why the order desk team is causing some errors when creating order forms is due to the sales team’s mistakes. A desire to investigate the sales team’s processes was apparent; however, due to time constraints this was not possible. Therefore, a recommendation for future research could be to investigate the sales team’s processes, analyze them and come up with improvements.
- Process optimization of the production processes: This research solely focuses on improving the pre-production processes as it was determined through the 5 why’s they are causing the main issues around the company. However, the production processes should also be investigated, mapped out, and improved. Being that the company of Kelvion works with three different material lines, this project suggestion could be a complete project for a bachelor’s student looking for a graduation internship.
- IT solutions: Throughout this internship period, another intern was present pursuing their IT studies, where solid improvements were provided and implemented for the company’s systems. Therefore, a good recommendation would be to keep pursuing IT students, where both parties could massively benefit each other.

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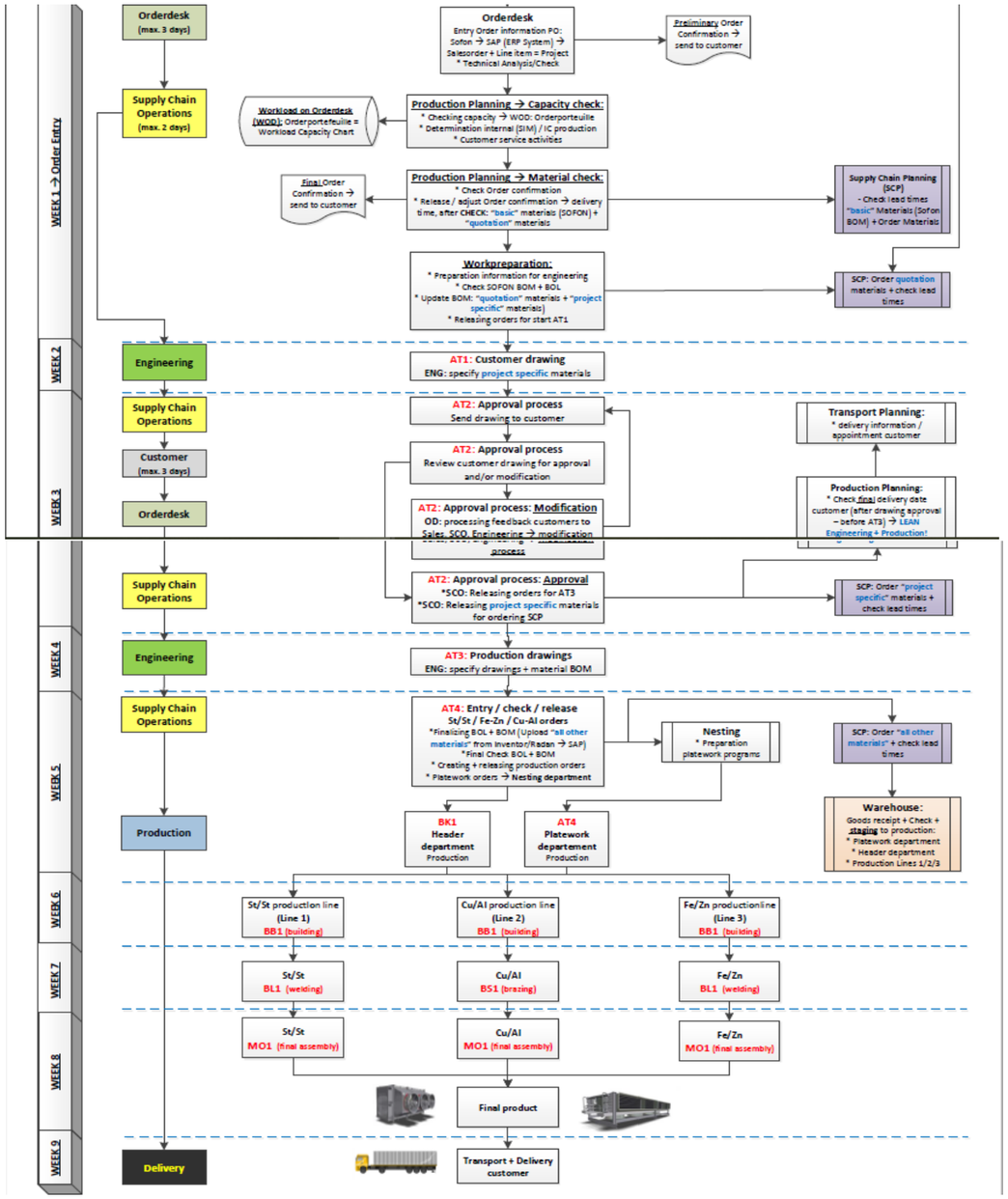
11- Appendices

Appendix 1- Total order process – Kelvion refrigeration B.V



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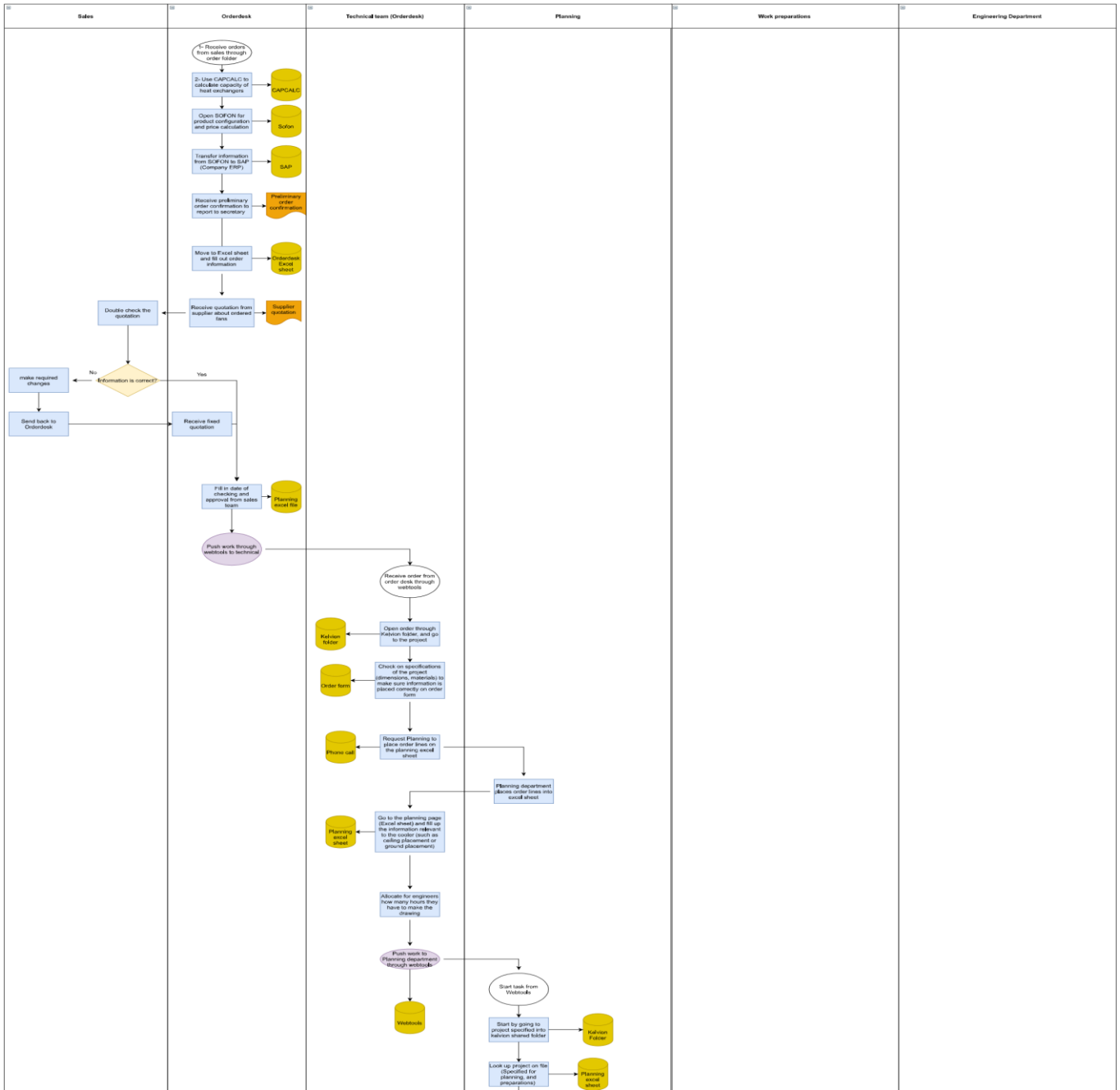
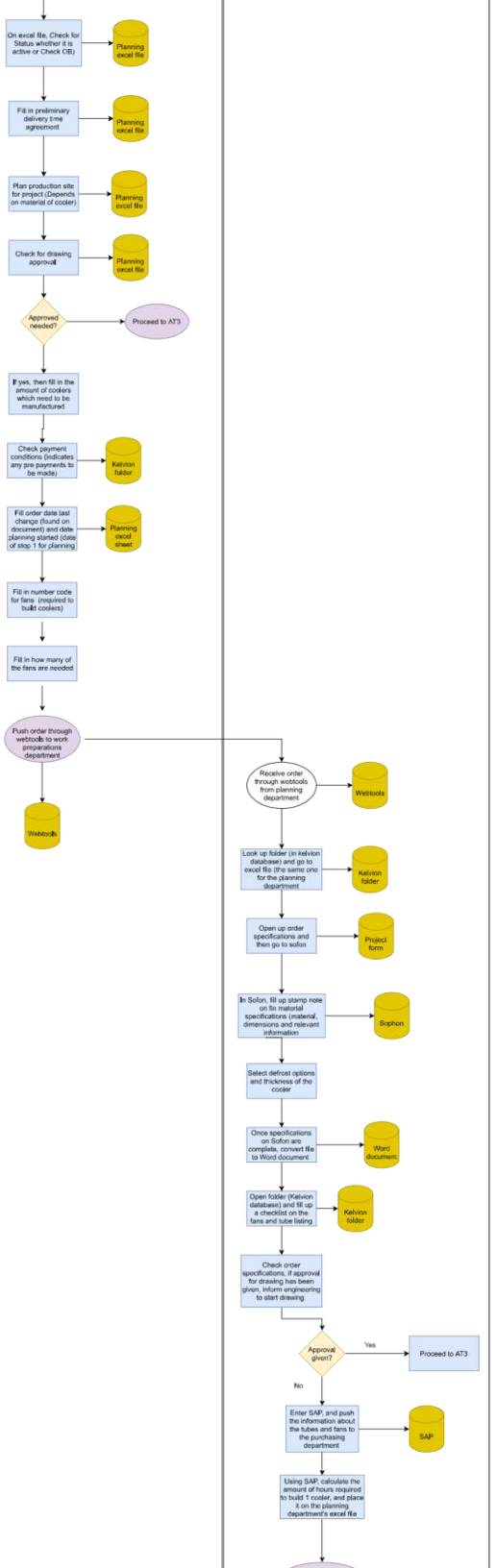
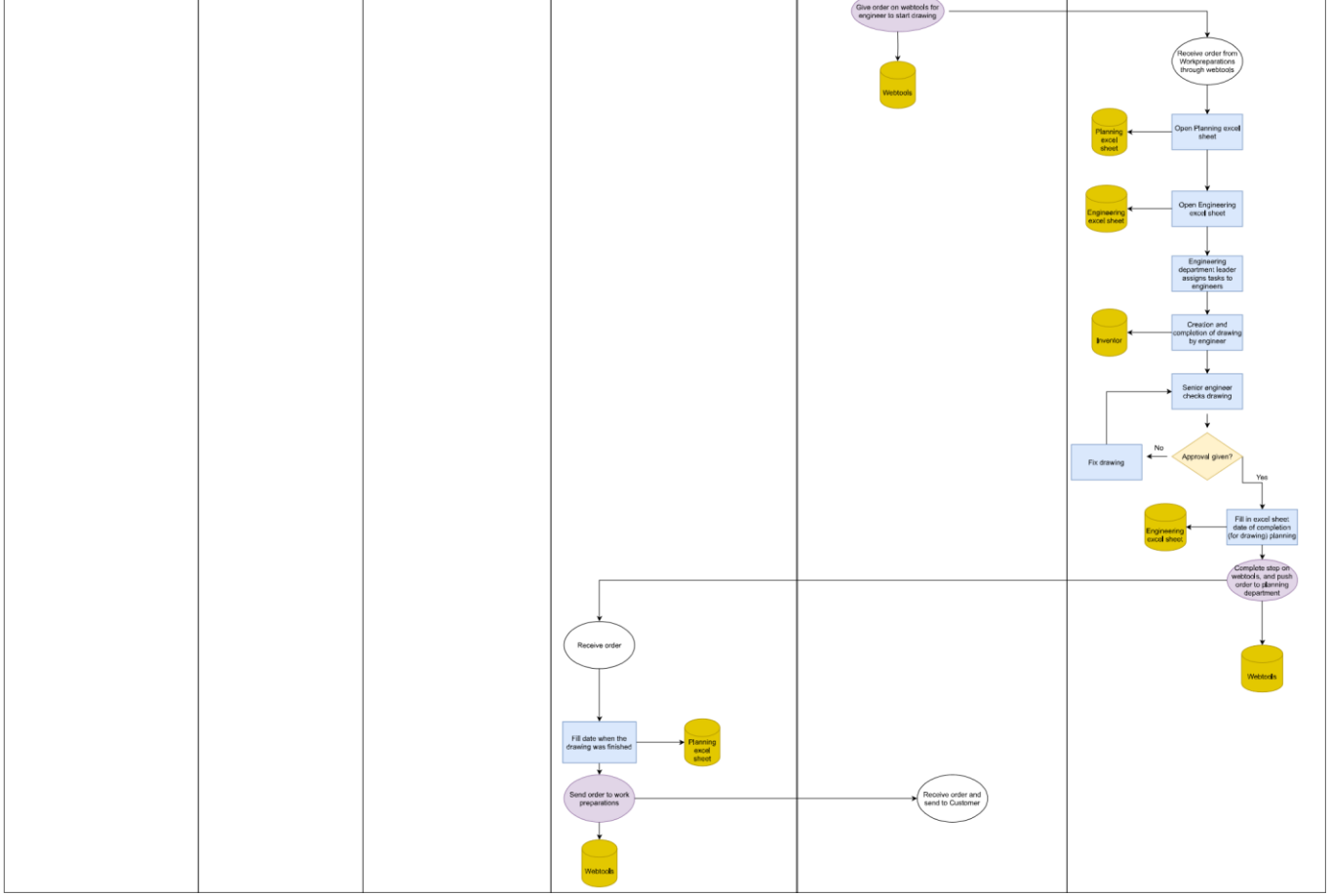
Appendix 2- AT1 process map

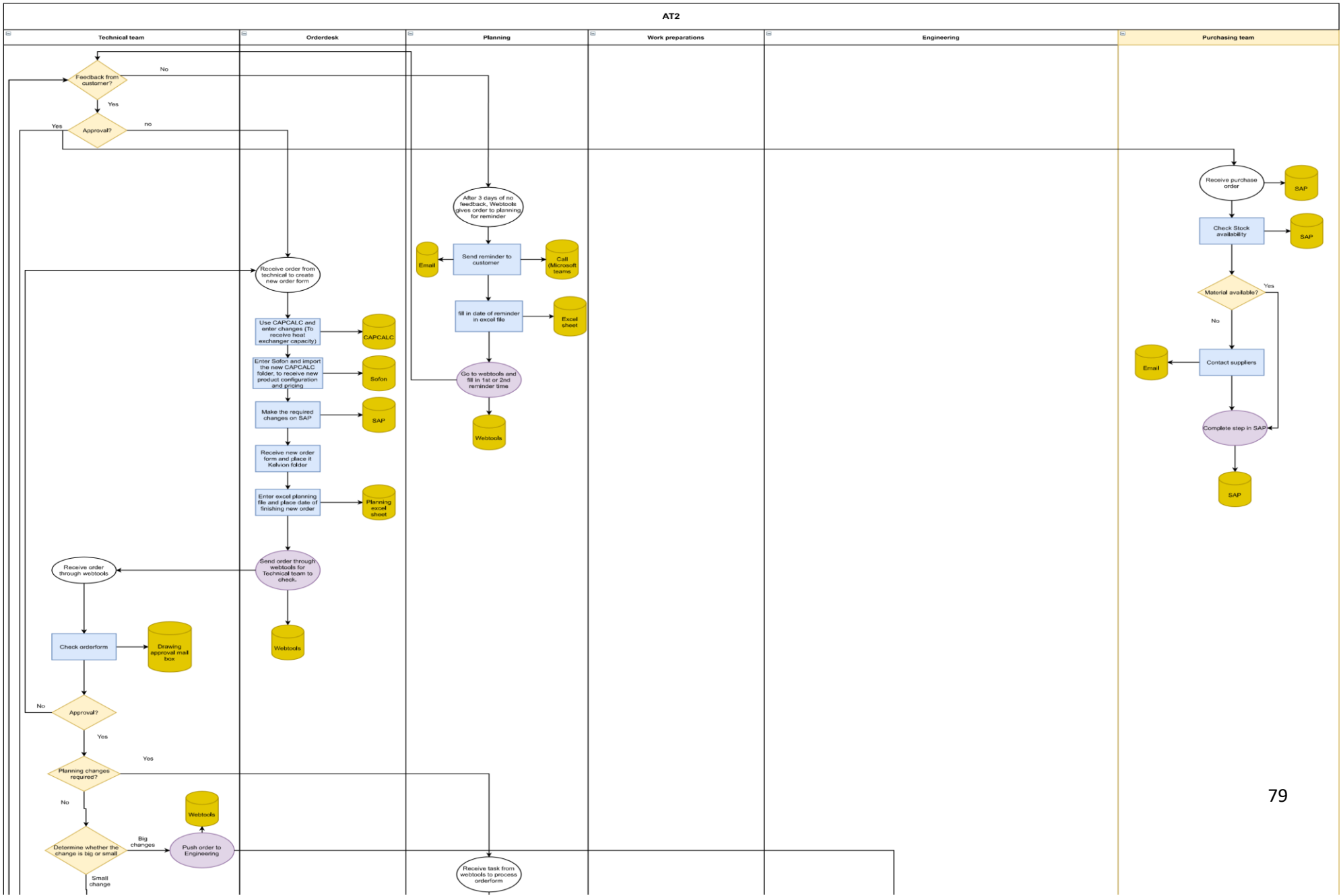
Zoom in for clarity

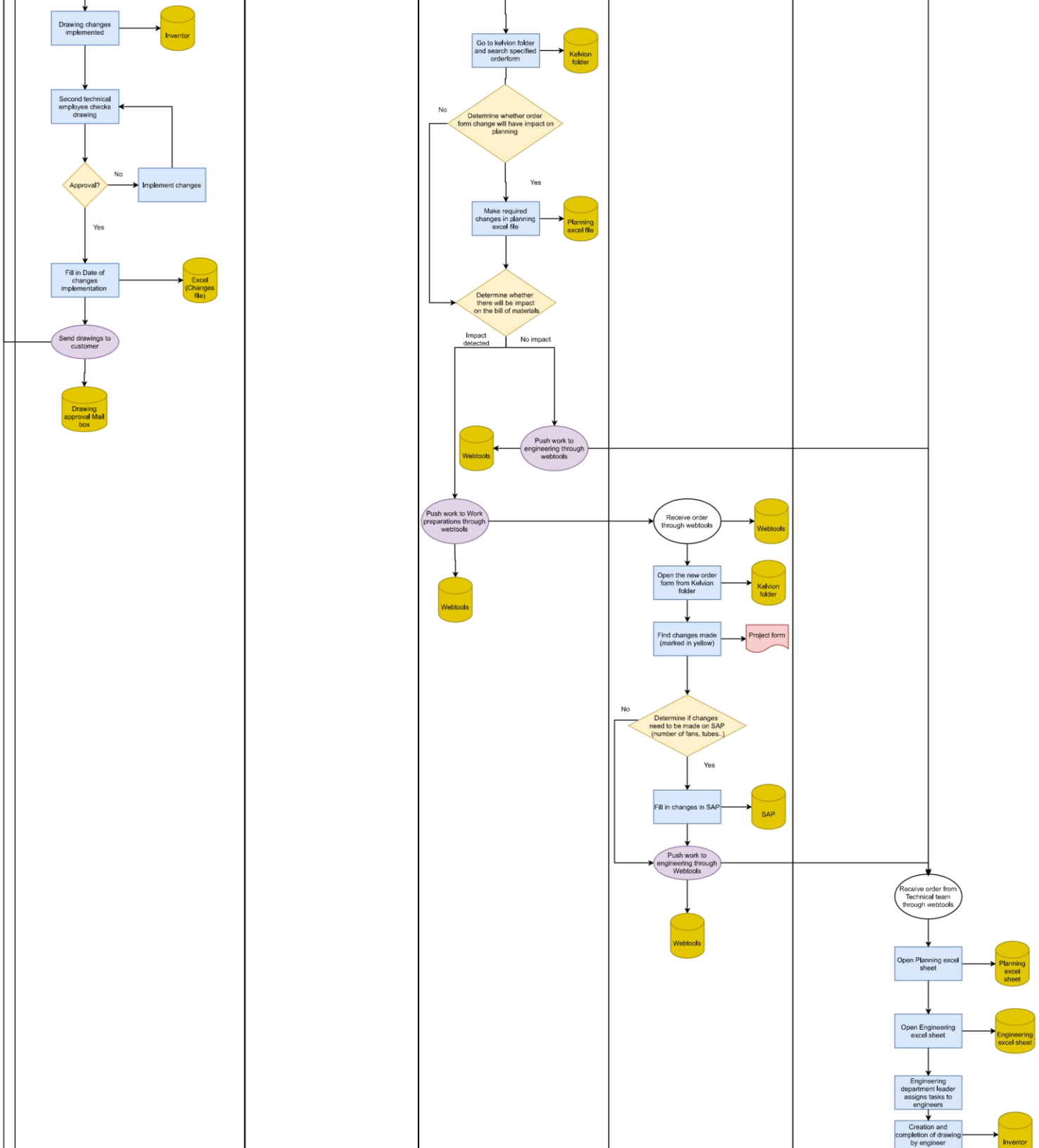


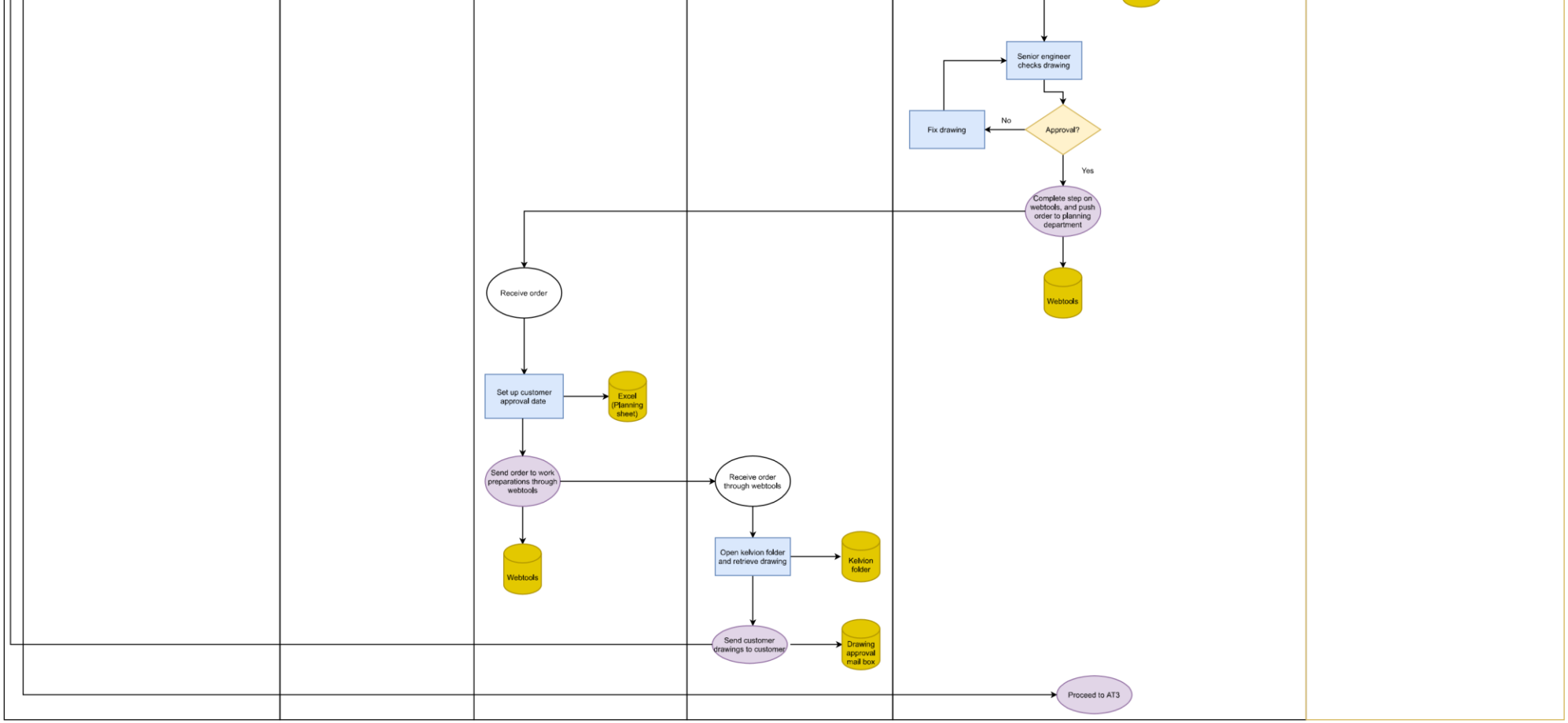

On excel file, Check for Status whether it is active or Check OB)
Planning excel file
Fill in preliminary delivery time agreement
Planning excel file
Plan production site for project (Depends on material of cooler)
Planning excel file
Check for drawing approval
Planning excel file
Approved needed?
Proceed to AT3
If yes, then fill in the amount of coolers which need to be manufactured
Check payment conditions (indicates any pre payments to be made)
Kelvion folder
Fill order date last change (found on document) and date planning started (date of step 1 for planning)
Planning excel sheet
Fill in number code for fans (required to build coolers)
Fill in how many of the fans are needed
Push order through webtools to work preparations department
Webtools
Receive order through webtools from planning department
Webtools
Look up folder (in Kelvion database) and go to excel file (the same one for the planning department
Kelvion folder
Open up order specifications and then go to sofon
Project form
In Sofon, fill up stamp note on fin material specifications (material, dimensions and relevant information
Sophon
Select defrost options and thickness of the cooler
Once specifications on Sofon are complete, convert file to Word document
Word document
Open folder (Kelvion database) and fill up a checklist on the fans and tube listing
Kelvion folder
Check order specifications, if approval for drawing has been given, inform engineering to start drawing
Approval given?
Yes
Proceed to AT3
No
Enter SAP, and push the information about the tubes and fans to the purchasing department
SAP
Using SAP, calculate the amount of hours required to build 1 cooler, and place it on the planning department's excel file


Give order on webtools for engineer to start drawing
Webtools
Receive order from Workpreparations through webtools
Planning excel sheet
Open Planning excel sheet
Engineering excel sheet
Open Engineering excel sheet
Engineering department leader assigns tasks to engineers
Inventor
Creation and completion of drawing by engineer
Senior engineer checks drawing
Fix drawing
No
Approval given?
Yes
Engineering excel sheet
Fill in excel sheet: date of completion (for drawing) planning
Complete step on webtools, and push order to planning department
Webtools
Receive order
Fill date when the drawing was finished
Planning excel sheet
Send order to work preparations
Receive order and send to Customer
Webtools

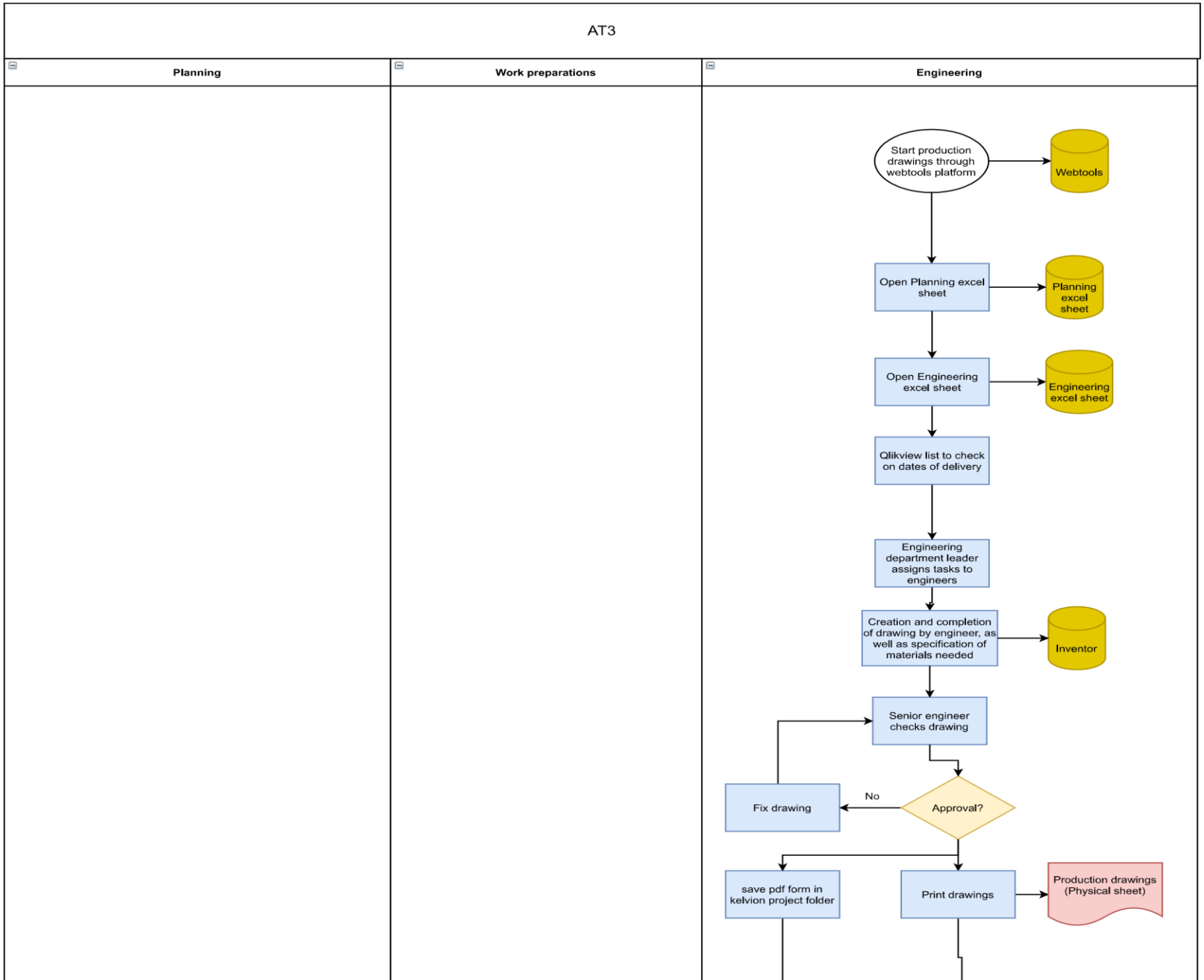
Appendix 3- AT2 process Map

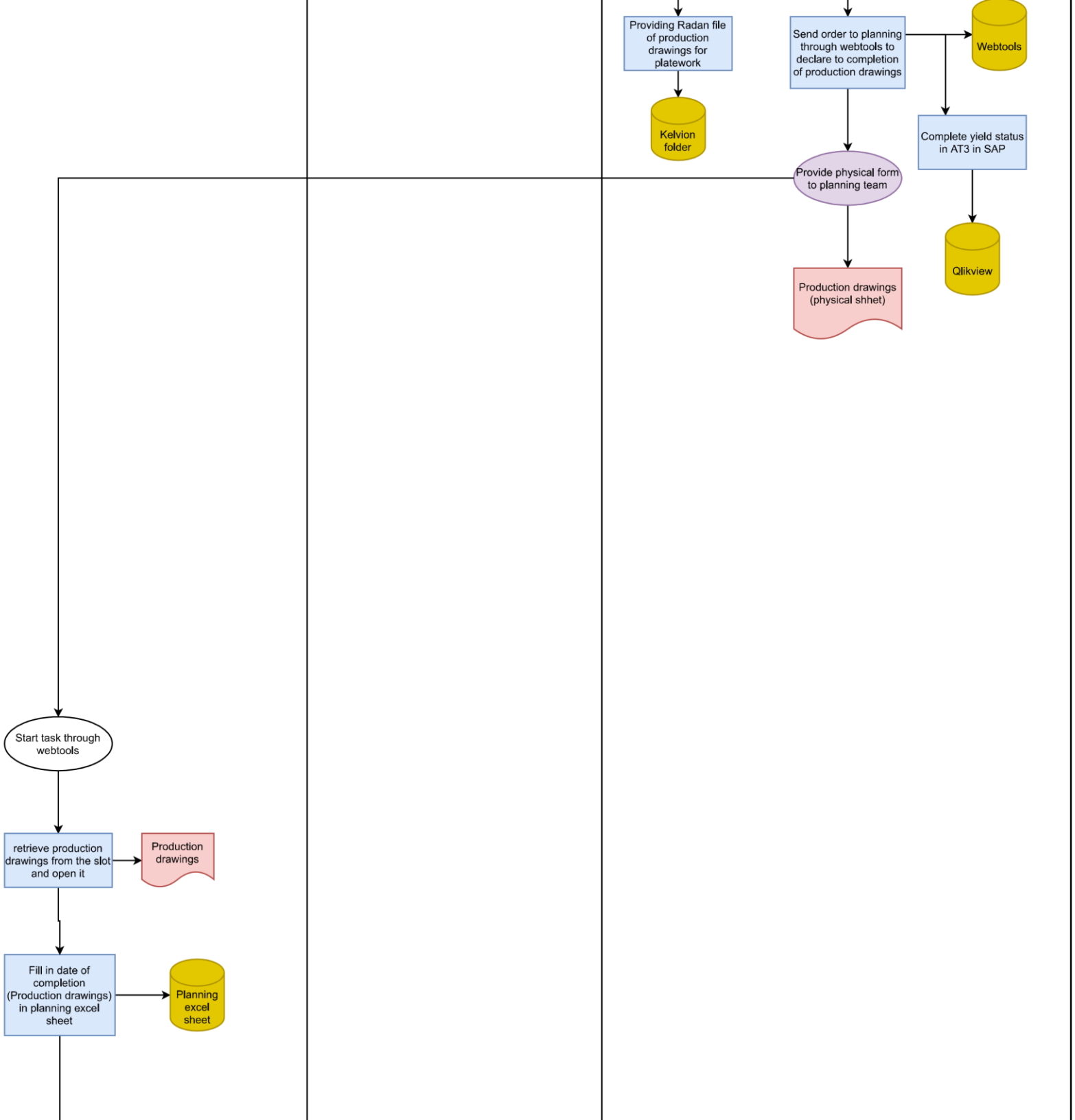


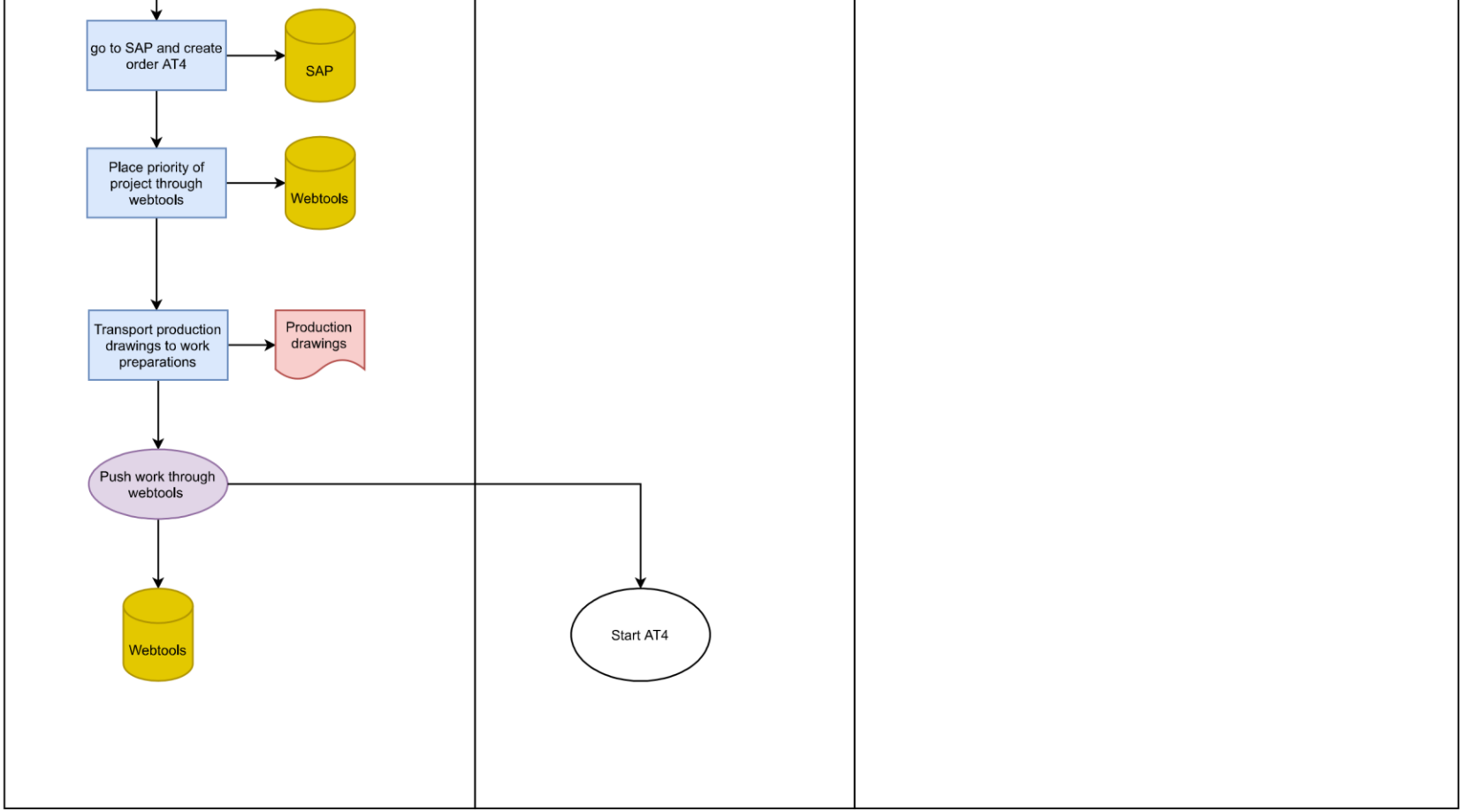

Drawing changes implemented
Inventor
Second technical employee checks drawing
Approval?
No
Implement changes
Yes
Fill in Date of changes implementation
Excel (Changes file)
Send drawings to customer
Drawing approval Mail box
Go to kelvion folder and search specified orderform
Kelvion folder
No
Determine whether order form change will have impact on planning
Yes
Make required changes in planning excel file
Planning excel file
Determine whether there will be impact on the bill of materials
Impact detected
No impact
Webtools
Push work to engineering through webtools
Push work to Work preparations through webtools
Webtools
Receive order through webtools
Webtools
Open the new order form from Kelvion folder
Kelvion folder
Find changes made (marked in yellow)
Project form
No
Determine if changes need to be made on SAP (number of fans, tubes..)
Yes
Fill in changes in SAP
SAP
Push work to engineering through Webtools
Webtools
Receive order from Technical team through webtools
Open Planning excel sheet
Planning excel sheet
Open Engineering excel sheet
Engineering excel sheet
Engineering department leader assigns tasks to engineers
Creation and completion of drawing by engineer
Inventor


Senior engineer checks drawing
Fix drawing
No
Approval?
Yes
Complete step on webtools, and push order to planning department
Webtools
Receive order
Set up customer approval date
Excel (Planning sheet)
Send order to work preparations through webtools
Webtools
Receive order through webtools
Open kelvion folder and retrieve drawing
Kelvion folder
Send customer drawings to customer
Drawing approval mail box
Proceed to AT3

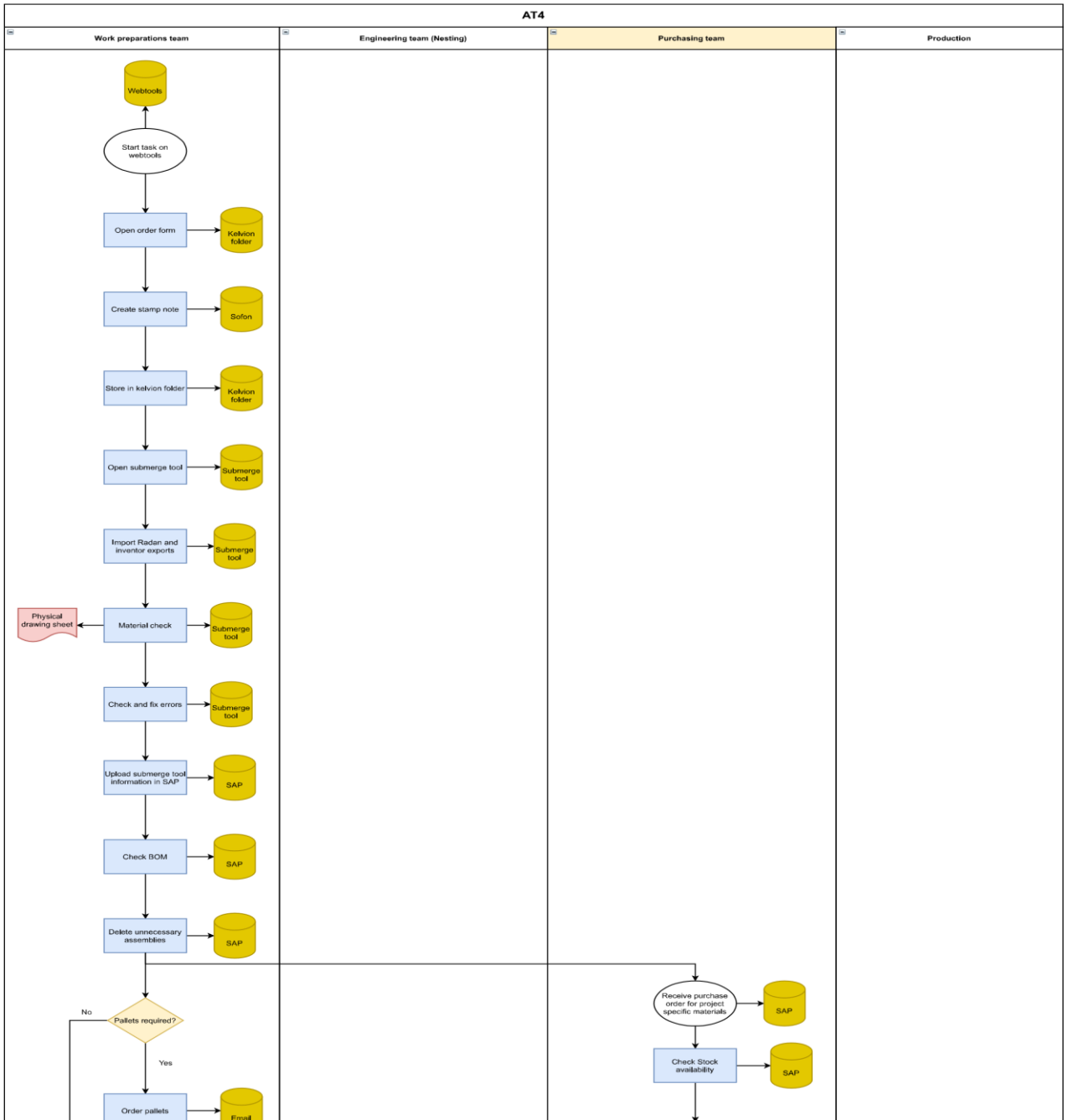
Appendix 4- AT3 Process map

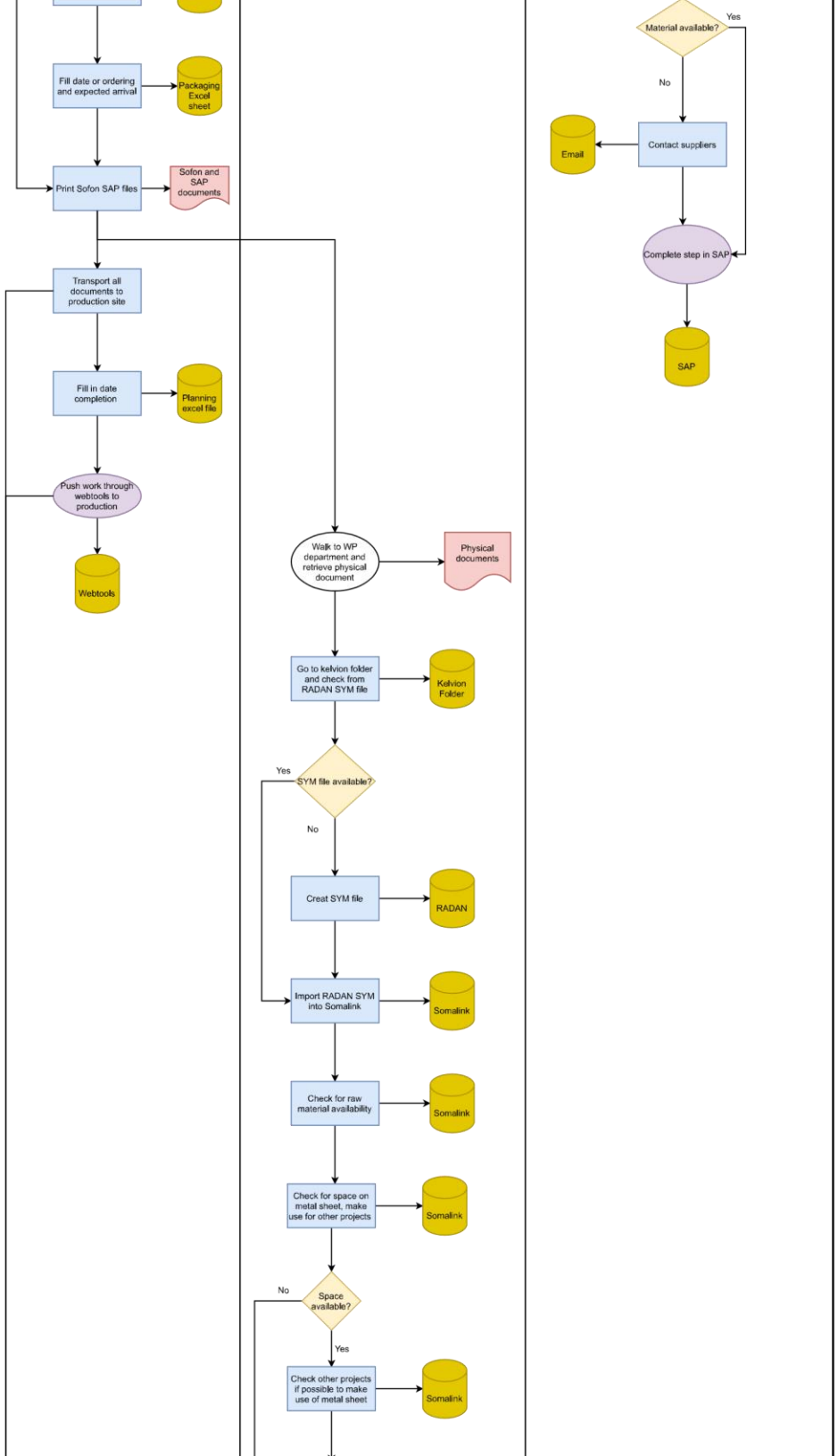


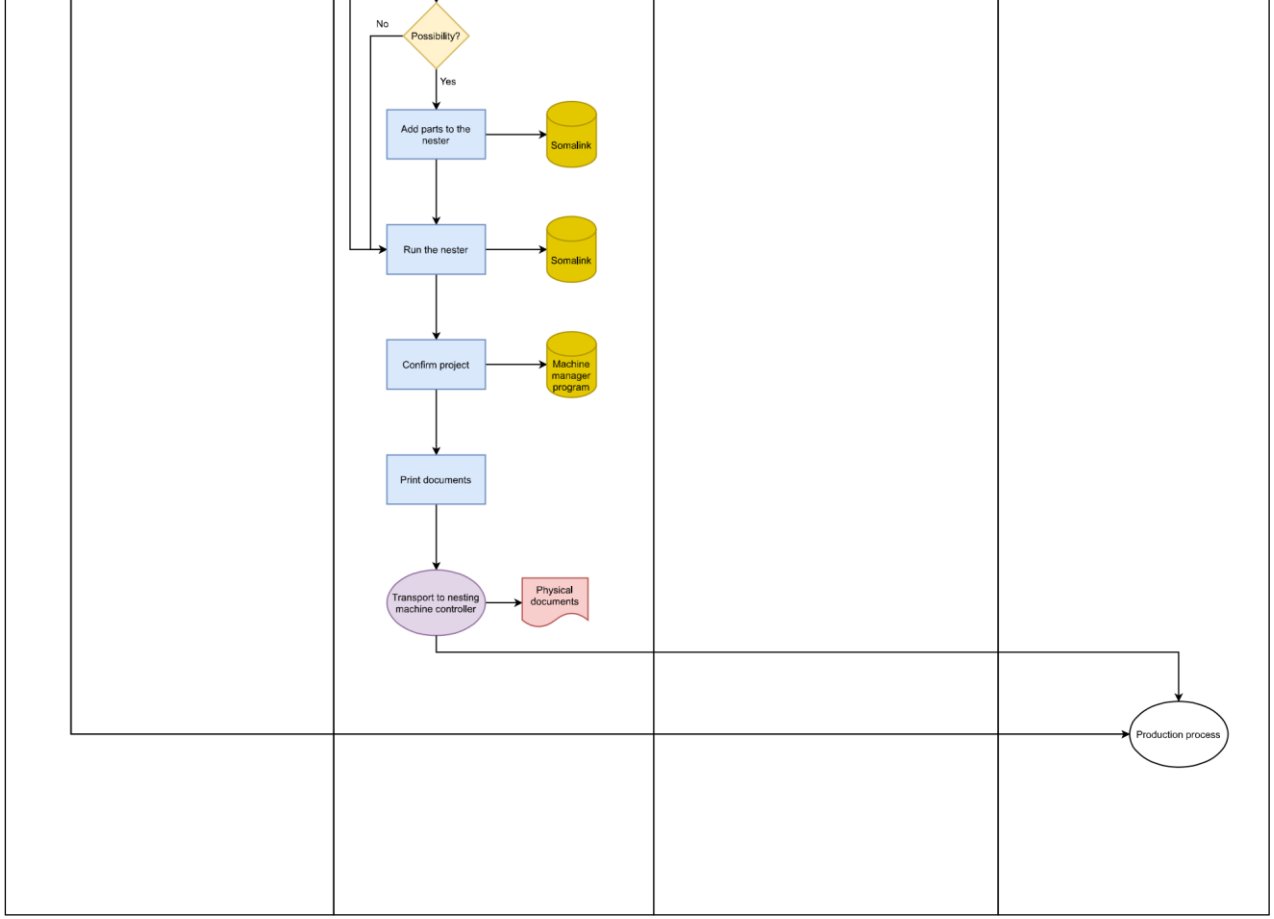

Providing Radan file of production drawings for platework
Kelvion folder
Send order to planning through webtools to declare to completion of production drawings
Webtools
Complete yield status in AT3 in SAP
Qlikview
Provide physical form to planning team
Production drawings (physical shhet)
Start task through webtools
retrieve production drawings from the slot and open it
Production drawings
Fill in date of completion (Production drawings) in planning excel sheet
Planning excel sheet


go to SAP and create order AT4
SAP
Place priority of project through webtools
Webtools
Transport production drawings to work preparations
Production drawings
Push work through webtools
Webtools
Start AT4

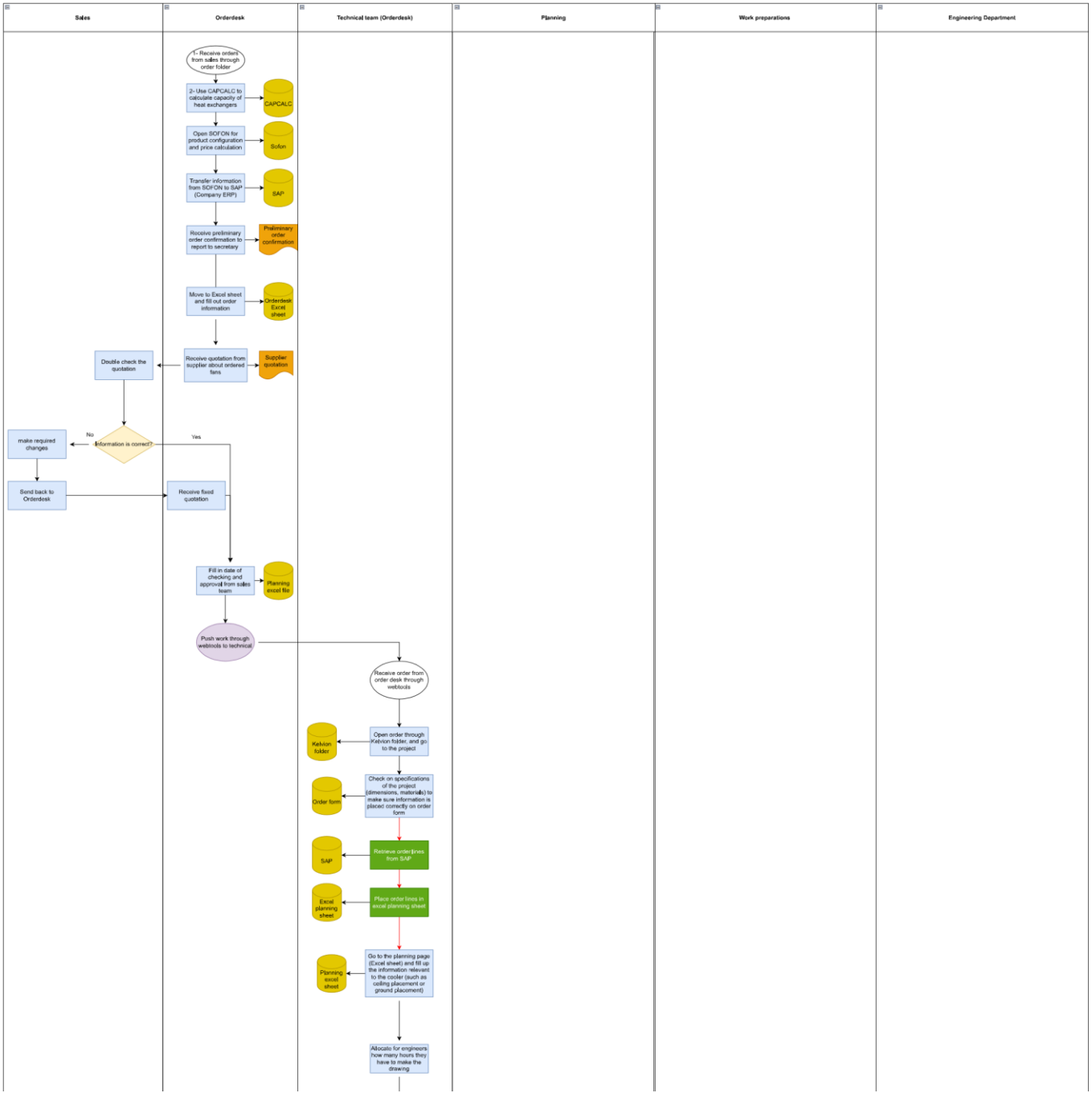
Appendix 5- AT4 process map

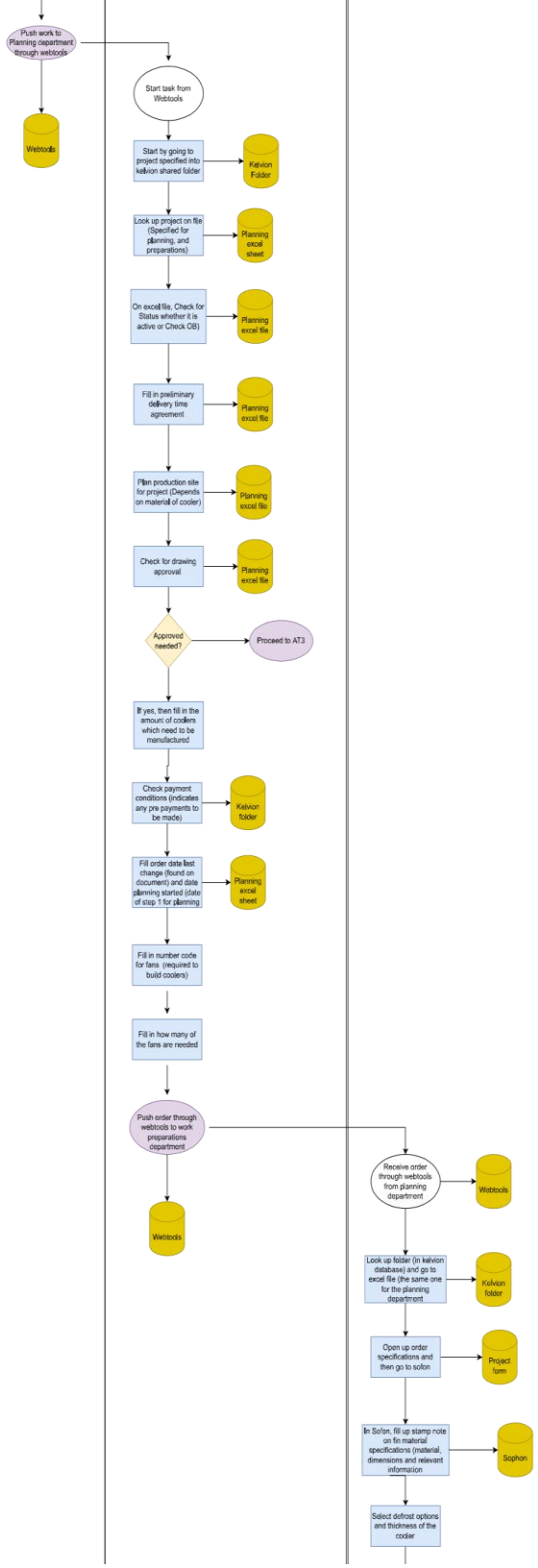


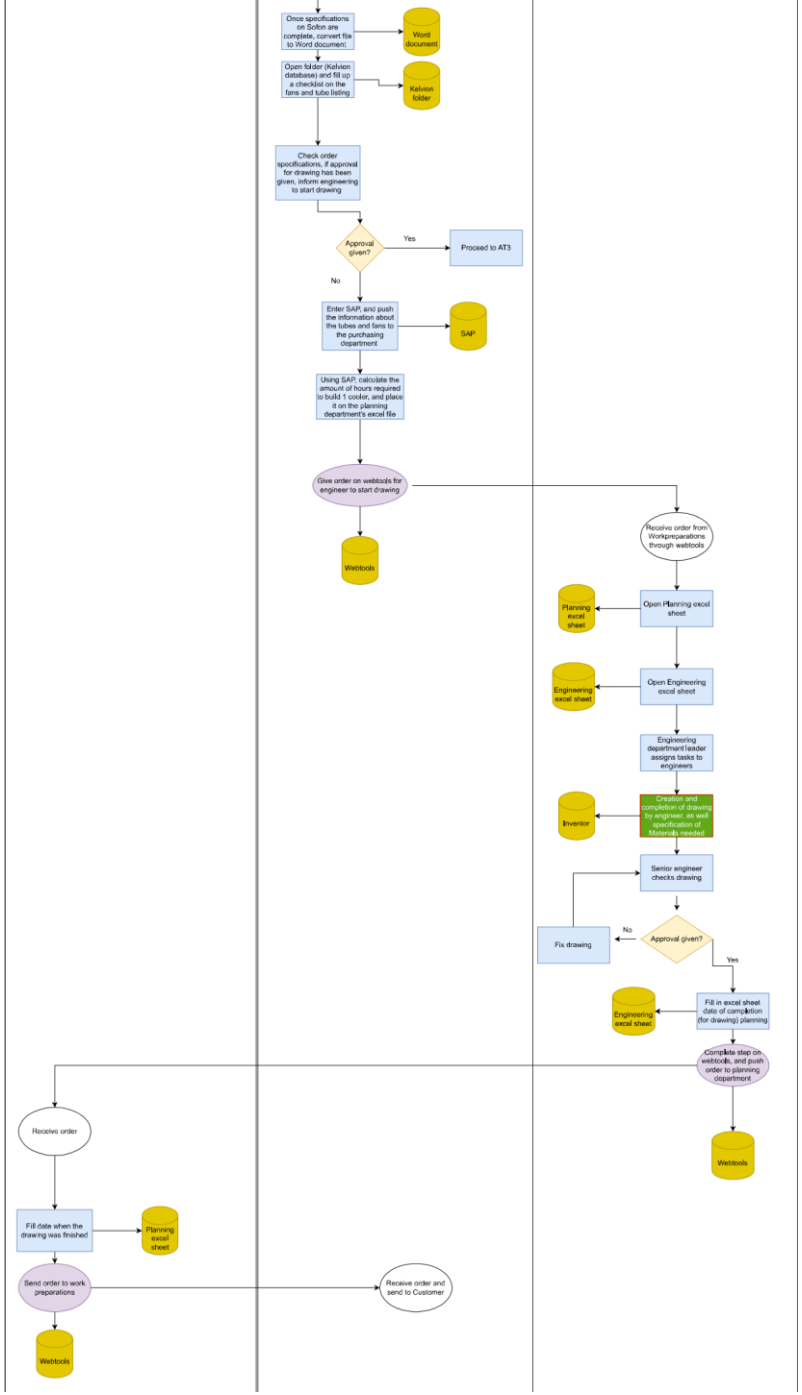

Fill date or ordering and expected arrival
Packaging Excel sheet
Print Sofon SAP files
Sofon and SAP documents
Transport all documents to production site
Fill in date completion
Planning excel file
Push work through webtools to production
Webtools
Material available?
Yes
No
Email
Contact suppliers
Complete step in SAP
SAP
Walk to WP department and retrieve physical document
Physical documents
Go to kelvion folder and check from RADAN SYM file
Kelvion Folder
Yes
SYM file available?
No
Creat SYM file
RADAN
Import RADAN SYM into Somalink
Somalink
Check for raw material availability
Somalink
Check for space on metal sheet, make use for other projects
Somalink
No
Space available?
Yes
Check other projects if possible to make use of metal sheet
Somalink


No
Possibility?
Yes
Add parts to the nester
Somalink
Run the nester
Somalink
Confirm project
Machine manager program
Print documents
Transport to nesting machine controller
Physical documents
Production process

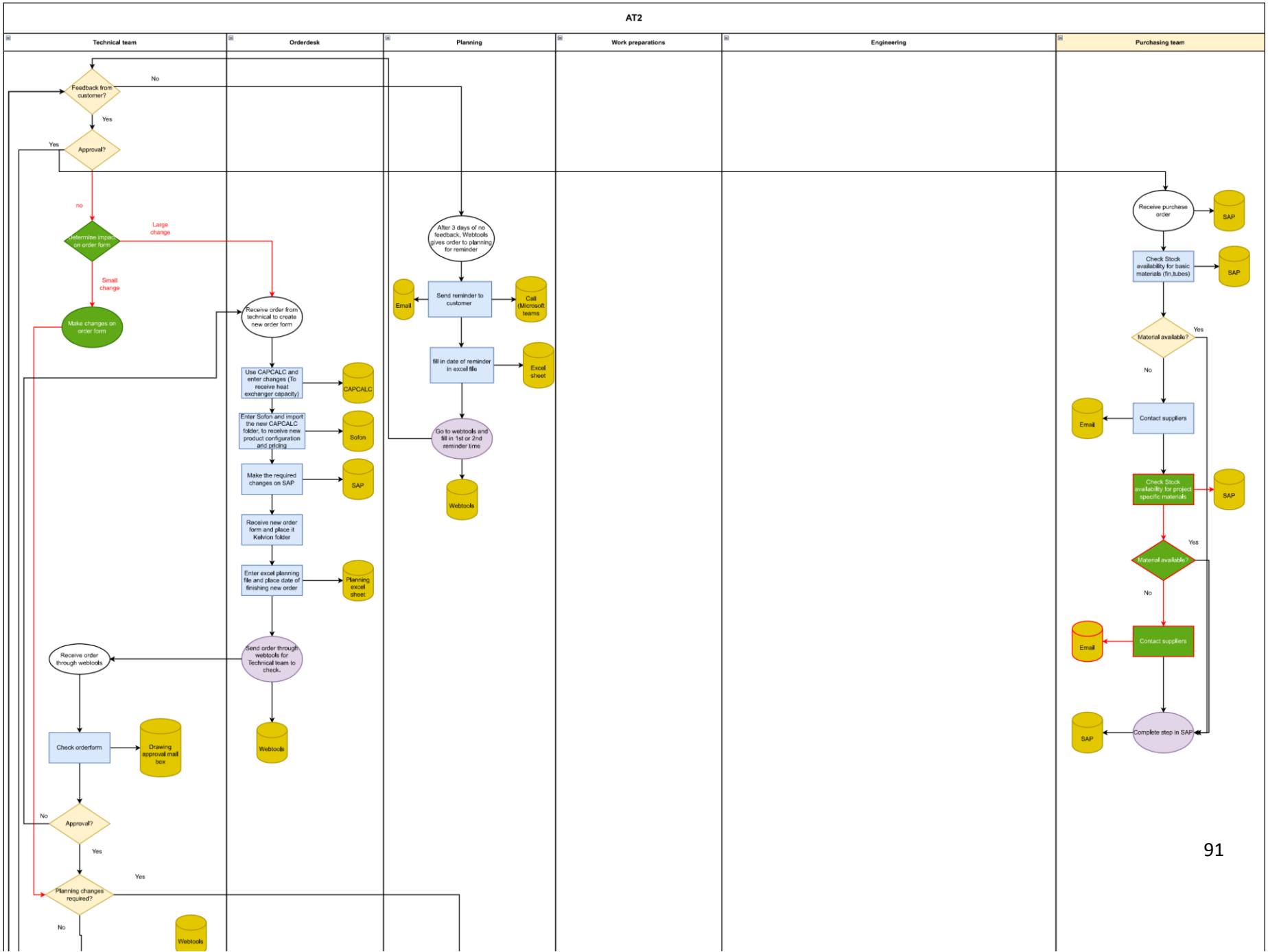
Appendix 6 – Process re-design AT1

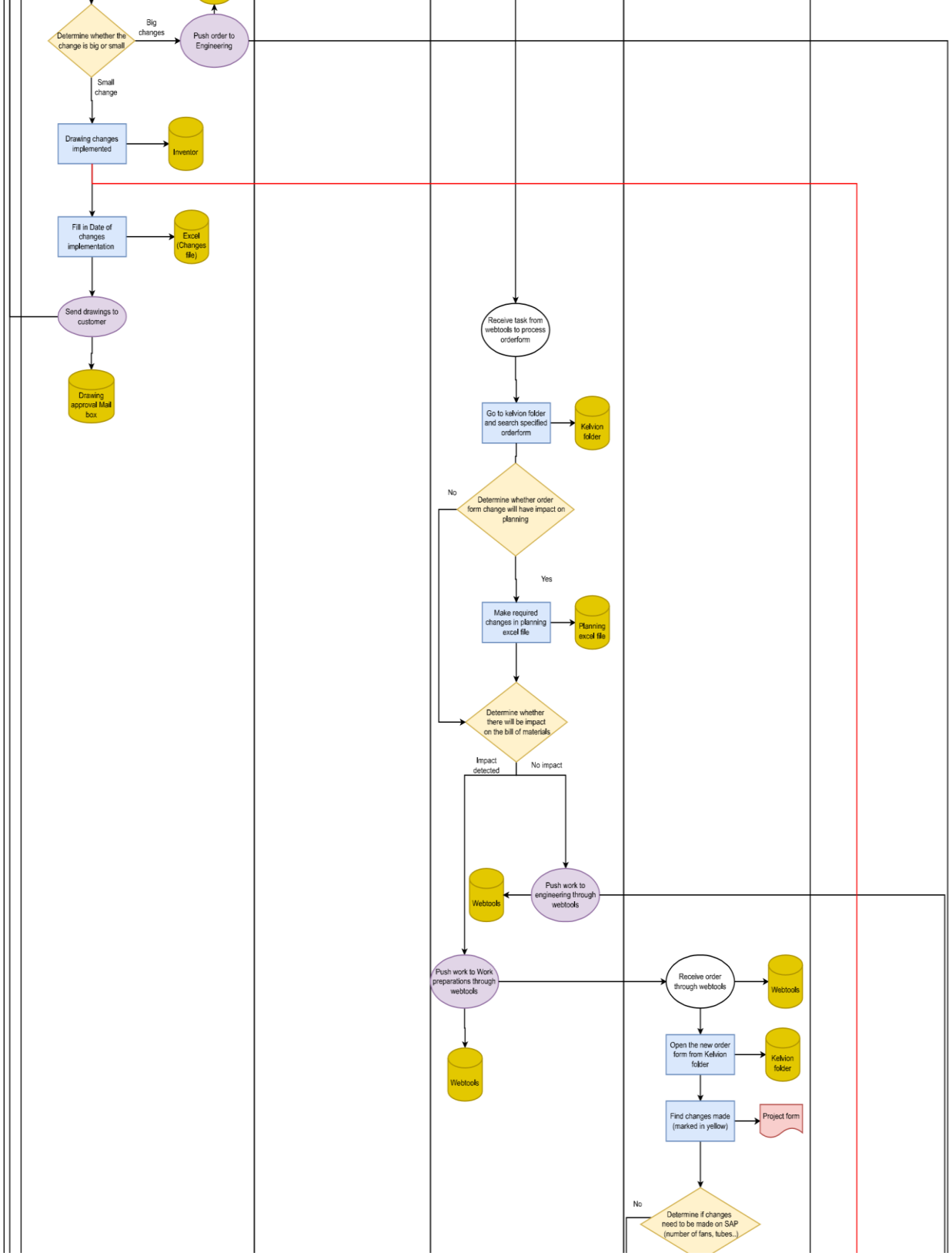


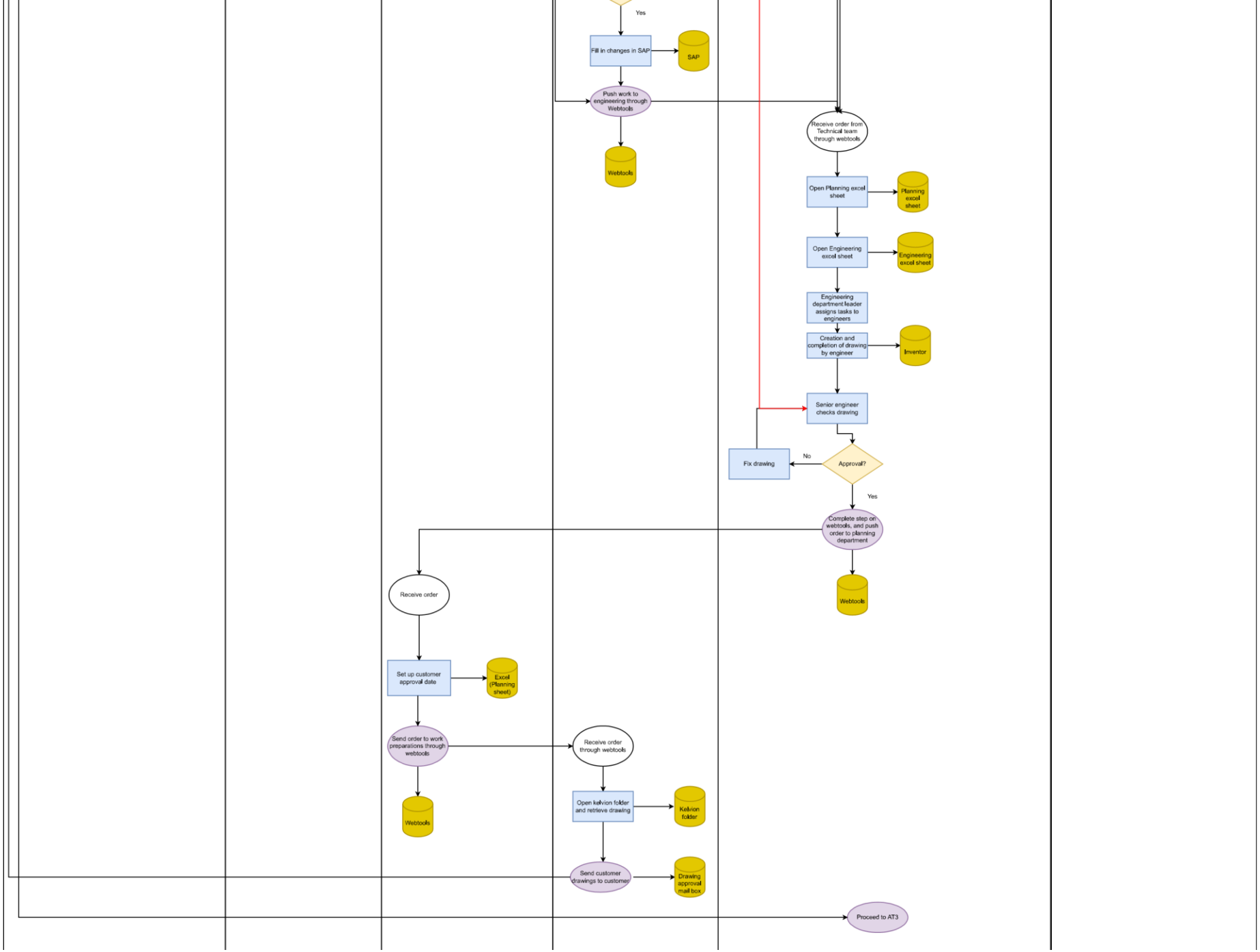

Push work to Planning department through webtools
Webtools
Start task from Webtools
Start by going to project specified into kelvion shared folder
Kelvion Folder
Look up project on file (Specified for planning, and preparations)
Planning excel sheet
On excell file, Check for Status whether it is active or Check OB)
Planning excel file
Fill in preliminary delivery time agreement
Planning excel file
Plan production site for project (Depends on material of cooler)
Planning excel file
Check for drawing approval
Planning excel file
Approved needed?
Proceed to AT3
If yes, then fill in the amount of coolers which need to be manufactured
Check payment conditions (indicates any pre payments to be made)
Kelvion folder
Fill order date last change (found on document) and date planning started (date of step 1 for planning
Planning excel sheet
Fill in number code for fans (required to build coolers)
Fill in how many of the fans are needed
Push order through webtools to work preparations department
Webtools
Receive order through webtools from planning department
Webtools
Look up folder (in kelvion database) and go to excel file (the same one for the planning department
Kelvion folder
Open up order specifications and then go to sofon
Project form
In Sofon, fill up stamp note on fin material specifications (material, dimensions and relevant information
Sophon
Select defrost options and thickness of the cooler


Once specifications on Solton are complete, convert file to Word document
Word document
Open folder (Kelvion database) and fill up a checklist on the fans and tube listing
Kelvion folder
Check order specifications. If approval for drawing has been given, inform engineering to start drawing
Approval given?
Yes
Proceed to AT3
No
Enter SAP, and push the information about the tubes and fans to the purchasing department
SAP
Using SAP, calculate the amount of hours required to build 1 cooler, and place it on the planning department's excel file
Give order on webtools for engineer to start drawing
Webtools
Receive order from Workpreparations through webtools
Planning excel sheet
Open Planning excel sheet
Engineering excel sheet
Open Engineering excel sheet
Engineering department leader assigns tasks to engineers
Inventor
Creation and completion of drawing by engineer, as well specification of Materials needed
Senior engineer checks drawing
Fix drawing
No
Approval given?
Yes
Engineering excel sheet
Fill in excel sheet date of completion (for drawing) planning
Complete step on webtools, and push order to planning department
Webtools
Receive order
Fill date when the drawing was finished
Planning excel sheet
Send order to work preparations
Receive order and send to Customer
Webtools

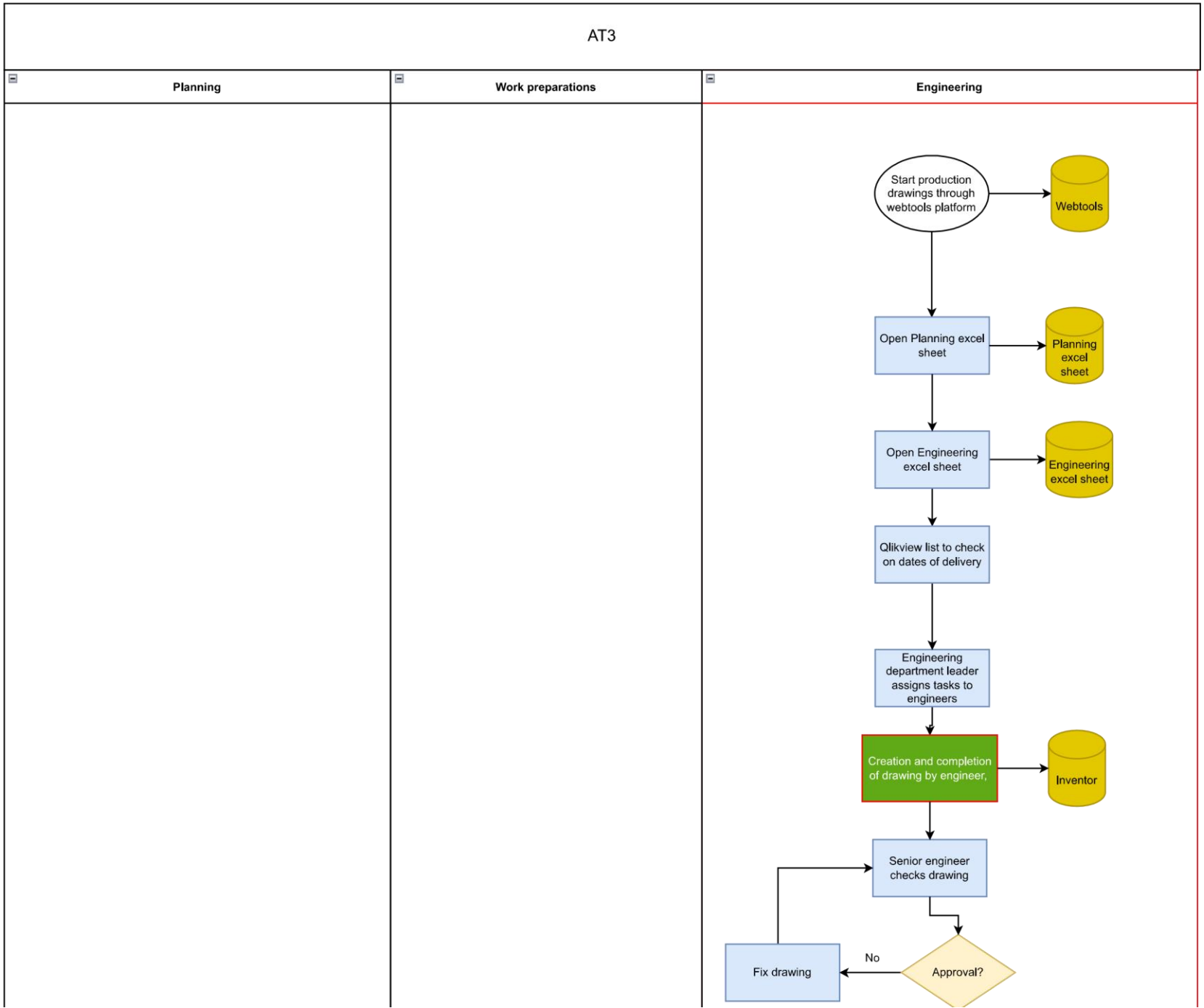
Appendix 7 – Process re-design AT2

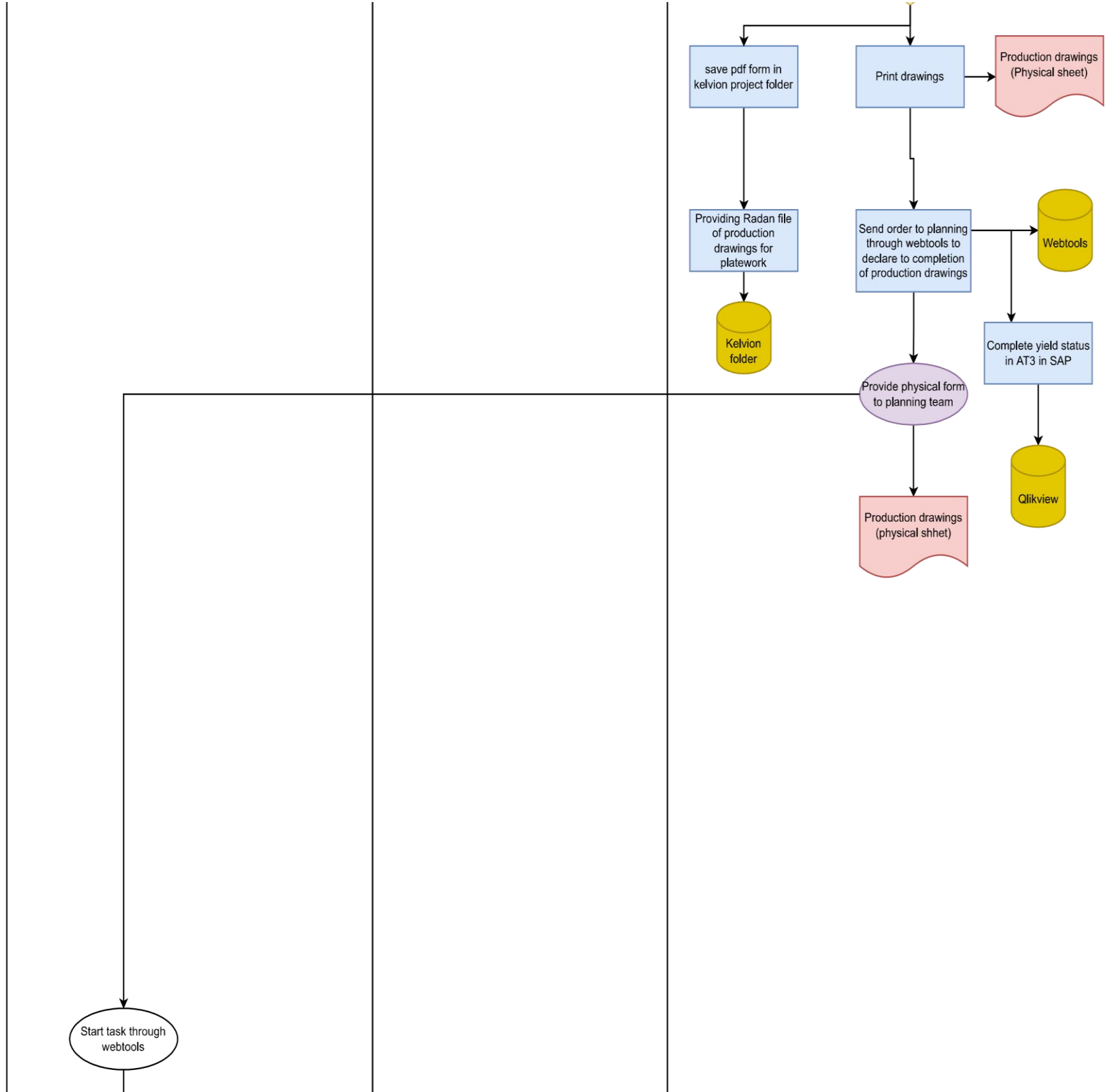


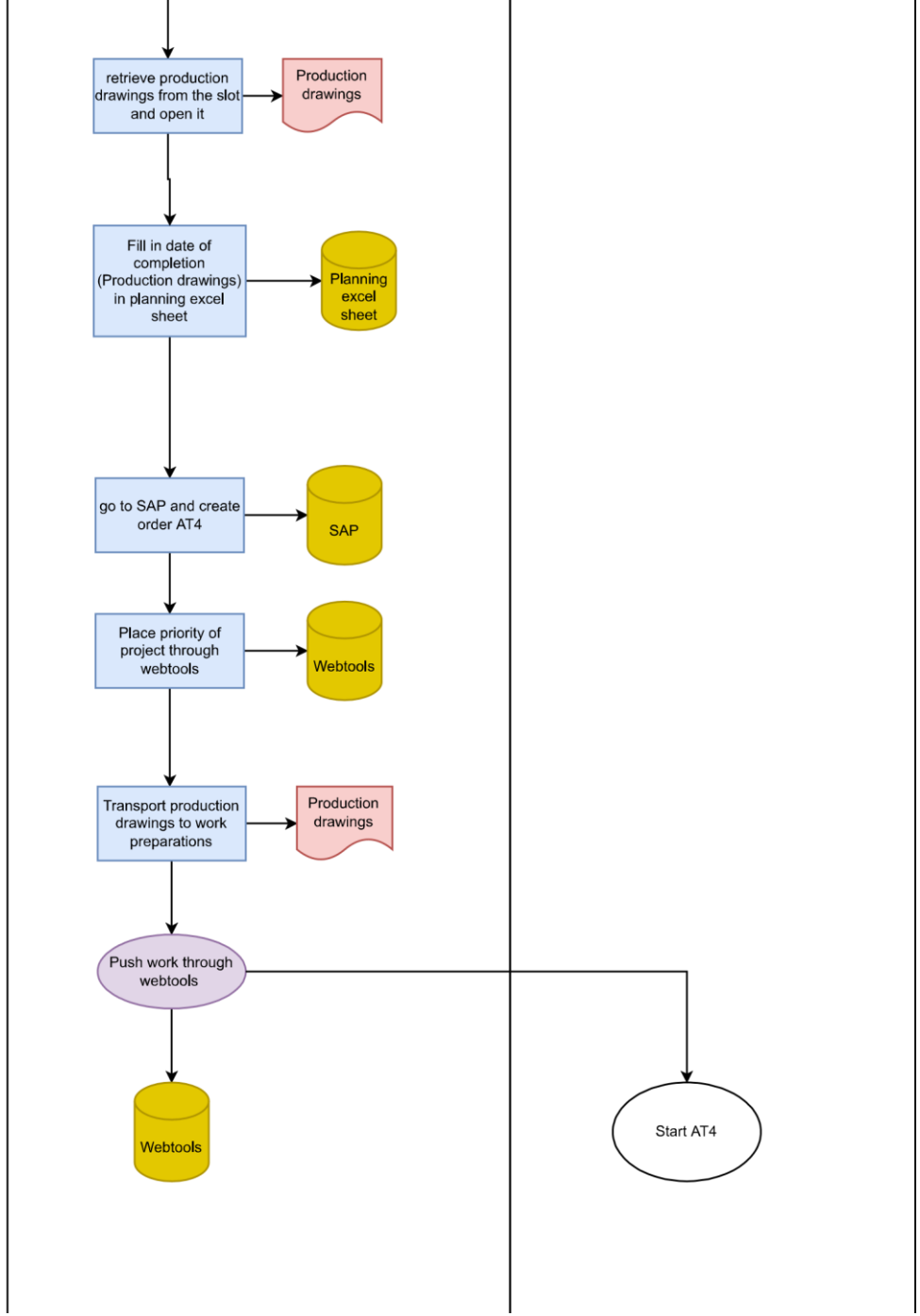

Determine whether the change is big or small
Big changes
Push order to Engineering
Small change
Drawing changes implemented
Inventor
Fill in Date of changes implementation
Excel (Changes file)
Send drawings to customer
Drawing approval Mail box
Receive task from webtools to process orderform
Go to kelvion folder and search specified orderform
Kelvion folder
No
Determine whether order form change will have impact on planning
Yes
Make required changes in planning excel file
Planning excel file
Determine whether there will be impact on the bill of materials
Impact detected
No impact
Webtools
Push work to engineering through webtools
Push work to Work preparations through webtools
Webtools
Receive order through webtools
Webtools
Open the new order form from Kelvion folder
Kelvion folder
Find changes made (marked in yellow)
Project form
No
Determine if changes need to be made on SAP (number of fans, tubes...)


Yes
Fill in changes in SAP
SAP
Push work to engineering through Webtools
Webtools
Receive order from Technical team through webtools
Open Planning excel sheet
Planning excel sheet
Open Engineering excel sheet
Engineering excel sheet
Engineering department leader assigns tasks to engineers
Creation and completion of drawing by engineer
Inventor
Senior engineer checks drawing
Fix drawing
No
Approval?
Yes
Complete step on webtools, and push order to planning department
Webtools
Receive order
Set up customer approval date
Excel (Planning sheet)
Send order to work preparations through webtools
Webtools
Receive order through webtools
Open kelvion folder and retrieve drawing
Kelvion folder
Send customer drawings to customer
Drawing approval mail box
Proceed to AT3

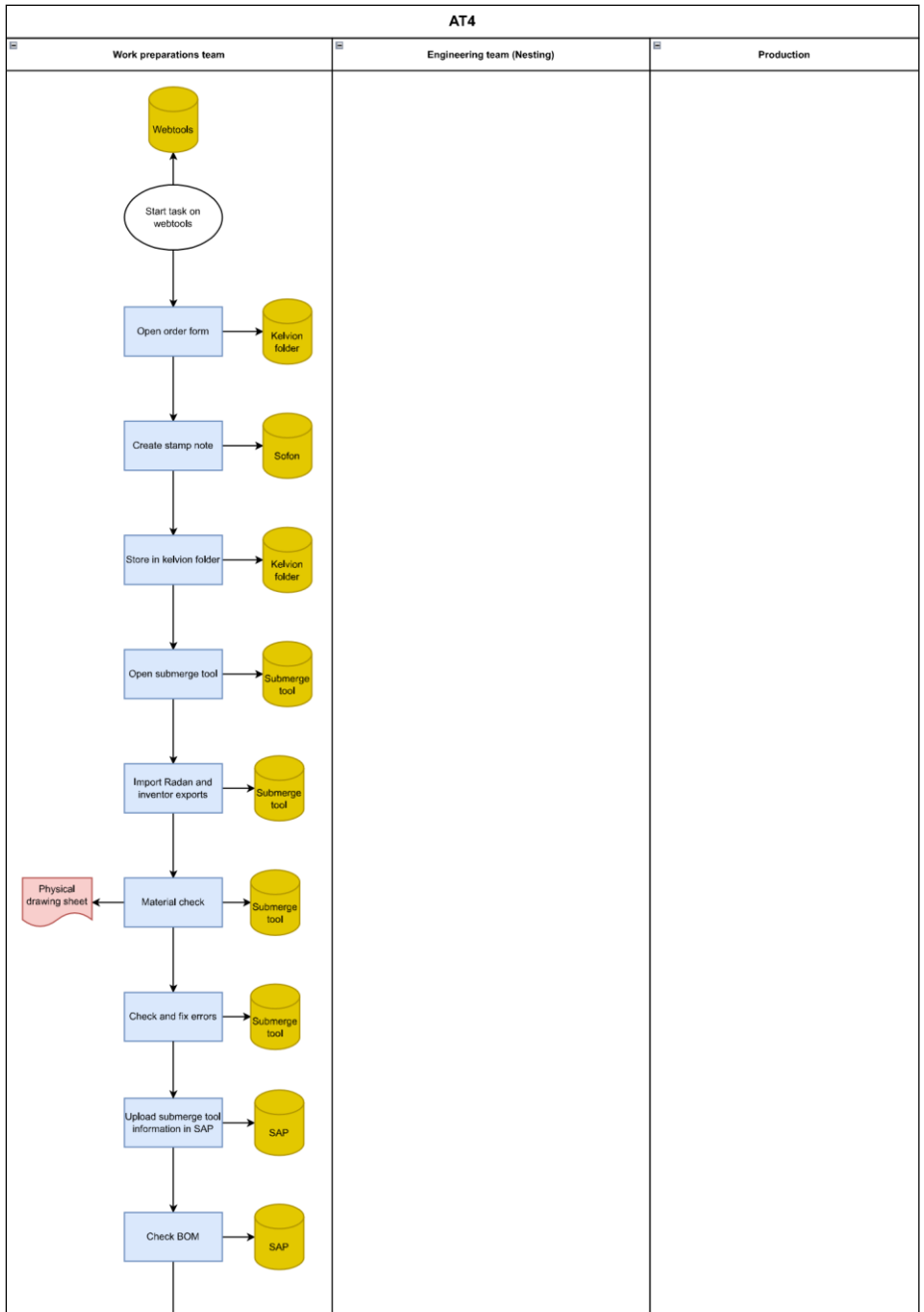
Appendix 8 – Process re-design AT3

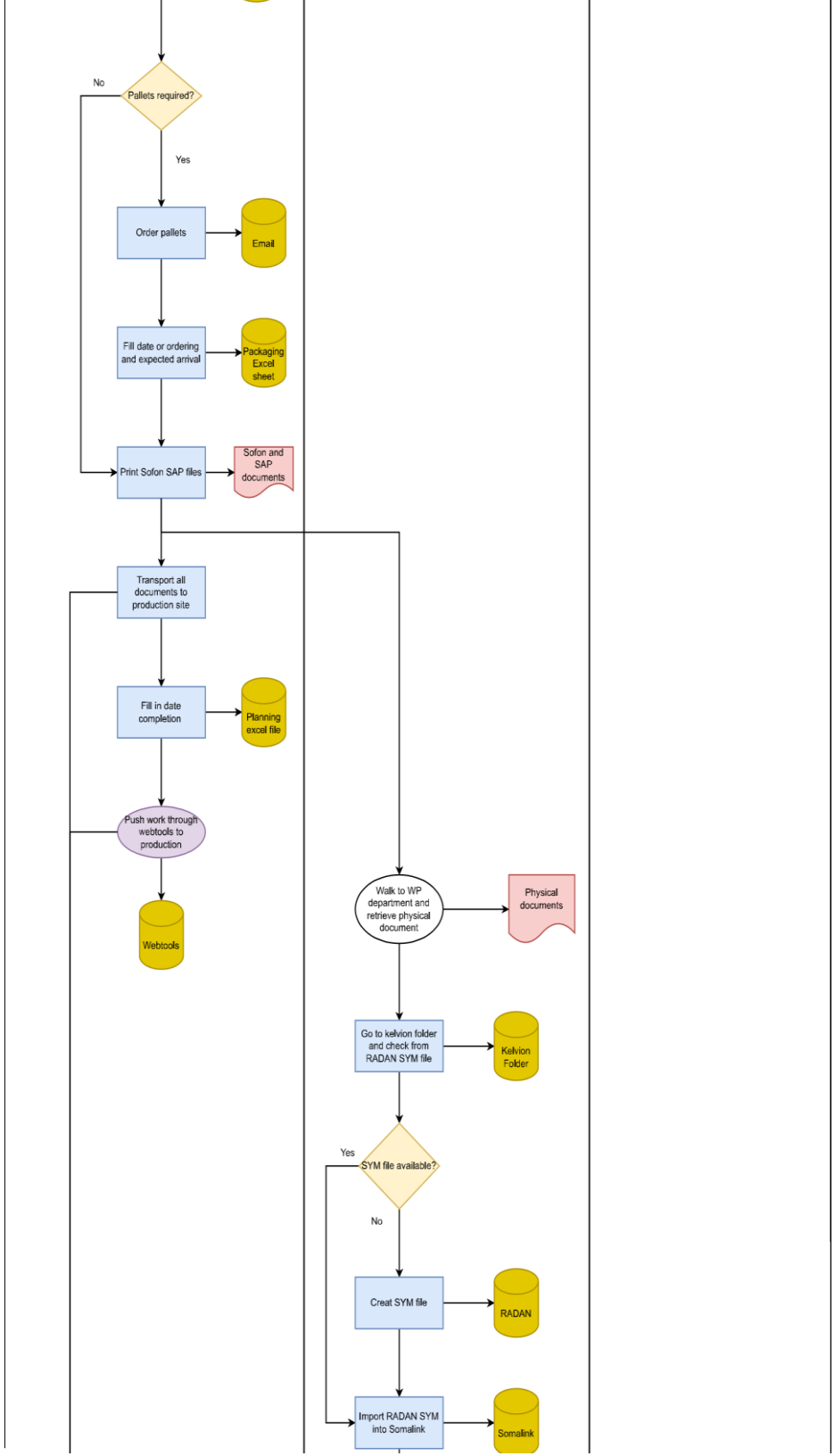


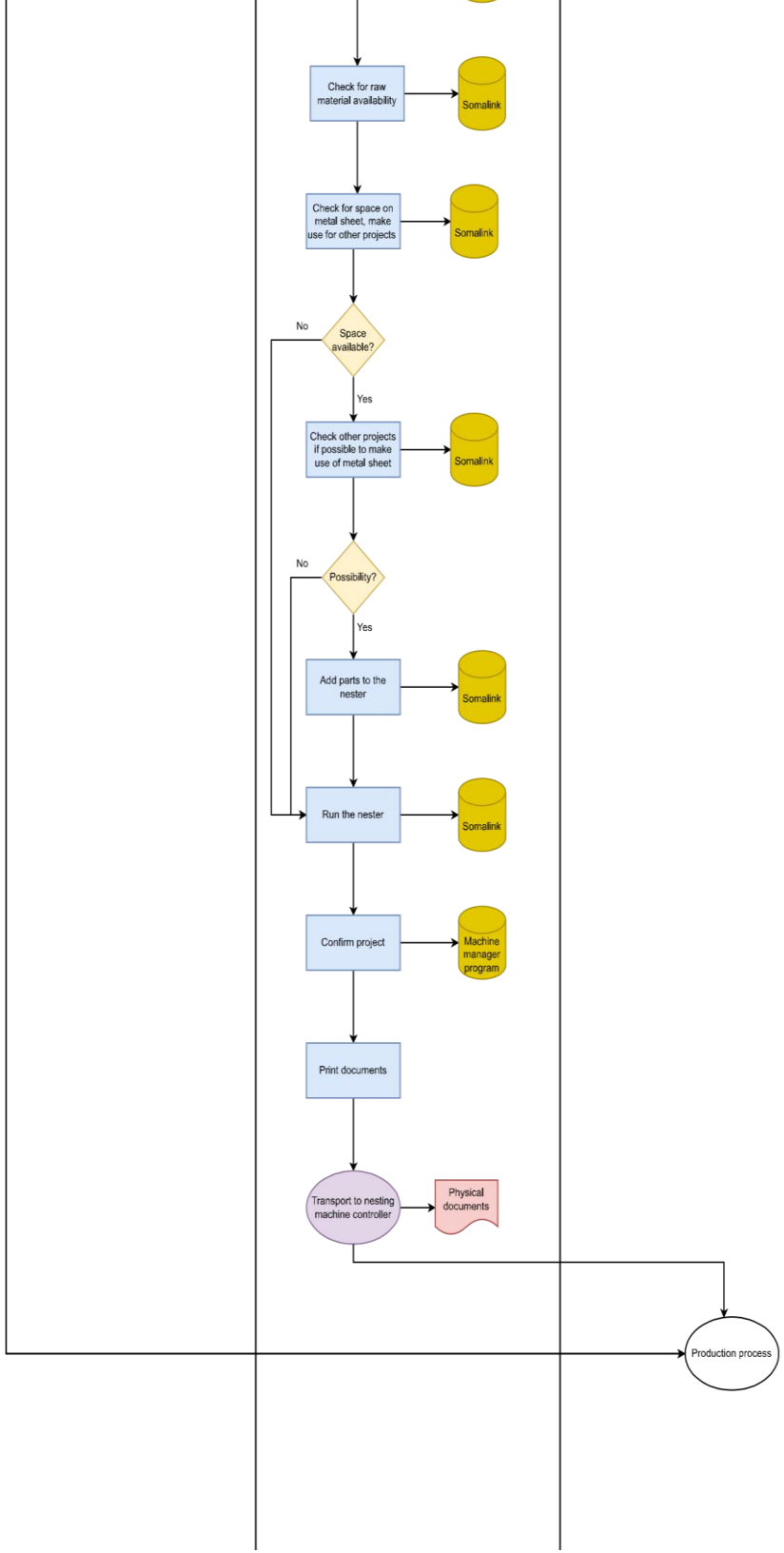

save pdf form in kelvion project folder
Print drawings
Production drawings (Physical sheet)
Providing Radan file of production drawings for platework
Send order to planning through webtools to declare to completion of production drawings
Webtools
Kelvion folder
Complete yield status in AT3 in SAP
Provide physical form to planning team
Qlikview
Production drawings (physical shhet)
Start task through webtools


retrieve production drawings from the slot and open it
Production drawings
Fill in date of completion (Production drawings) in planning excel sheet
Planning excel sheet
go to SAP and create order AT4
SAP
Place priority of project through webtools
Webtools
Transport production drawings to work preparations
Production drawings
Push work through webtools
Webtools
Start AT4

Appendix 9 – Process re-design AT4




No
Pallets required?
Yes
Order pallets
Email
Fill date or ordering and expected arrival
Packaging Excel sheet
Print Sofon SAP files
Sofon and SAP documents
Transport all documents to production site
Fill in date completion
Planning excel file
Push work through webtools to production
Webtools
Walk to WP department and retrieve physical document
Physical documents
Go to kelvion folder and check from RADAN SYM file
Kelvion Folder
Yes
SYM file available?
No
Creat SYM file
RADAN
Import RADAN SYM into Somalink
Somalink


Check for raw material availability
Somalink
Check for space on metal sheet, make use for other projects
Somalink
No
Space available?
Yes
Check other projects if possible to make use of metal sheet
Somalink
No
Possibility?
Yes
Add parts to the nester
Somalink
Run the nester
Somalink
Confirm project
Machine manager program
Print documents
Transport to nesting machine controller
Physical documents
Production process

Appendix 10 – Process activity mapping AT1 until AT4

Document too large to be placed here. It can found separately as an appendix upon submittal through Onstage.

Appendix 11 – Project count year 2020

Document too large to be placed here. It can be found separately as an appendix upon submittal through Onstage.