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Improving the Inbound Supply Processes in the Example of a Manufacturing Company

Master´s thesis

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MSc

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Magistritöö

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Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature, and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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19.05.2022

Abstract

The author considered the difficulties of getting a good overview of material capability for production as the main problem in this master's thesis. The current situation makes it very complicated to calculate commitments for the production quantities.

As a solution to the problem, the author proposed simplifying the material capability analysis and supply improvement processes to remove duplicating process steps and added a vision of automating the end process to improve its efficiency. The solution was carefully analyzed to meet the business requirements.

The analysis was conducted based on the processes of a production company that for confidentiality requirements is hereby renamed as The Company. This thesis is written in English and is 50 pages long, including 8 chapters, 15 figures, 11 tables.

Annotatsioon

Autor pidas magistritöö peamiseks probleemiks seda, et materjaliga seotud tootmisvõimekusest oli keeruline ülevaadet saada. Sellises olukorras on keeruline välja arvutada, millised kogused on vaja klientide jaoks tootmiseks plaanida.

Olukorra lahendusena pakkus töö autor töökorduste ja ajakulu vähendamiseks välja kahe olulise sisseostuprotsessi – materjali võimekuse analüüsi ja sisseostu parandamise protsessi – lihtsustamise. Lisaks lõi autor visiooni lõpp-protsessi automatiseerimiseks, et selle ajaefektiivsust veelgi tõsta. Lahendusega kaasnes põhjalik analüüs, et täita sellega kaasnevad ärivajadused. Töö põhineb tööprotsessidel, mis on kasutusel ühes reaalses ettevõttes, mida konfidentsiaalsuskokkulepetest lähtuvalt nimetatakse töös läbivalt “*The Company*”.

Töö teoreetilises osas kirjeldas autor mitmeid raamistikke ja metoodikaid, millest lähtuvalt töös analüüsi tehti.

Ärianalüüsi osas kirjeldas autor ettevõtte strateegilisi eesmärke ja nende seoseid ettevõtte peamise väärtusahelaga ning selgitas, milliseid ärivõimekusi on vaja ettevõttes parandada. Eelnevast lähtudes tegi autor protsessianalüüsi ja pakkus välja parandatud protsessi.

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Magistritöö peamised tulemid on toodud 7. peatükis.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 50 leheküljel, 8 peatükki, 15 joonist ja 11 tabelit.

List of abbreviations and terms

BOM	A recipe for products or subproducts shows the components and their quantities in a product
Buffer	Surplus of inventory for that is stored in a warehouse to protect against supply chain issues or in case of fluctuating demand
Business capability	The ability of a business to reach a goal
Critical component	Any component that has a prognosed shortage during an agreed-on nearby period
ERP	Enterprise Resource Planning system
Fulfillment rate	A percentage, that shows how much of the overall demand for a time period can be covered by the amount of existing or prognosed component quantities
Lead time	The time it takes a vendor to supply the goods starting from when the order has been released.
Material capability	A limitation on how much of the demand can be covered using existing components
Material capability analysis	A process that has a goal of having an overview of material capability and possibly communicating about it to other shareholders.
MES	Manufacturing Execution System
MRP	Material Resource Planning
Product commitment	Information about how many products are planned to be produced is usually communicated to customers.
Production capacity	A limited amount of time that can be used for producing products
SME	Subject Matter Expert – a stakeholder who knows the processes very well
Supply improvement	A process that has a goal of improving supply and removing prognosed shortages by finding inbound options.
TTM	Time to market – the time it takes for a new product to reach from idea conception to the market
TTV	Time to volume - time that it takes for a product to move from a prototype phase to the volume production phase

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1 Introduction

The main goal of this master's thesis is to analyze and improve two of the inbound supply processes in The Company by suggesting process improvements and designing a tool to support that improved process. This allows The Company to make the necessary changes and/or add the necessary solutions into their current IT architecture to maximize the benefits.

This master's thesis tries to answer the following research questions:

1) How to improve the material capability analysis and supply improvement processes?
2) Is a software solution needed for making the processes more effective and if yes, what requirements should that solution fulfill?
3) How does the business process need to change?

The author of this master's thesis analyzes how the existing business capabilities play a role in realizing the main value stream and which of them need improvement to fulfill the enterprise's strategic goals. The current business capabilities are assessed to highlight the capabilities that need to be added or improved.

1.1 Problem description

In the highly competitive environment that companies are facing today, supply chain performance has become vital for their success. Customers often judge the performance of a company based on its supply chain performance, so the competition has moved from the company level to the supply-chain level [2].

The inbound supply-related processes have gained importance after The Company made a change from a mass-production enterprise to one that is oriented toward introducing new products a few years ago. Demand for products comes now from two flows:

1) previously agreed-on production quantities for end products;

2) production quantities for products that allow for testing out new designs and workflows.

While the first type of demand comes far in advance, allowing The Company to send out component demand forecasts to the component suppliers, the second type is much more unpredictable, creating a need to constantly plan and replan production based on what the material capability will be when the products need to be produced.

The supply chain has buffers kept in every step. This does not cover the volatile demand for The Company. It means that other solutions for managing unpredictable demand need to be found.

The Supply improvement and Material capability analysis processes have been brought into the spotlight with the added pressure that COVID-19-related supply difficulties have been putting onto the global supply chain. The number of material shortages has been rising while the processes can be improved.

The processes on hand have two main goals - improving the supply for critical materials and retrieving information about usable component stock levels.

There are two main issues arising from the status quo:

1) information usability;
2) time usage.

Information usability - currently there is a system that retrieves information from multiple sources and puts it together for easier finding of critical materials. This system does not include all the data sources and when there is communication with suppliers, the results are marked in the system as comments. Comments do not satisfy the need of having all usable component stocks available for calculation in a usable format.

Time usage – the current process has a lot of duplicate work, which is a waste as far as the business is concerned. There is a lot of time spent communicating about the supply improvements which cannot currently be added to the system in a usable form (agreements made on a call or via email), information needed for material capability analysis and product commitment calculation.

As the workload is highly variable between different employees and time periods, the author decided to create a questionnaire where employees could share the estimated number of hours spent in a day for improvable activities. The questionnaire is shown in Appendix 2 and the results were used to calculate the cost in Table 1 and Table 2.

As the data for employees' salaries in a competitive field is highly confidential, the author decided to analyze the current cost using the average wages and labor costs in Estonia. The average monthly labor cost in Estonia per month for one employee is EUR 2179 (Q4 2021) [3] and the average number of work hours in a month is 169,25 [4].

As seen in Table 1 and Table 2, the current state of processes results in a relatively high cost per employee. For a supply chain planner, the average yearly cost is EUR 15897,98, for a purchaser it is EUR 6249.

Table 1. Cost of current processes per one supply chain planner calculated based on average cost per employee in Estonia

Activity	**Average % of time spent on that activity**	**Working hours spent per month**	**Monthly cost per employee (EUR)**	**Yearly cost per employee**
Finding when and on which components the important shortages are	14,8%	25,05	322,49	3869,90
Inner communication about material shortages and solving them	24,3%	41,13	529,50	6353,96
Performing material capability analysis to calculate product commitments	36,5%	61,78	795,34	9544,02
SUM	75,6%	102,90	1324,83	15897,98

Table 2. Cost of current processes per one purchaser calculated based on average cost per employee in Estonia

Activity	**Average % of time spent on that activity**	**Working hours spent per month**	**Monthly cost per employee (EUR)**	**Yearly cost per employee**
Finding when and on which components the important shortages are	8,30%	14,05	180,86	2170,28
Inner communication about material shortages and solving them	15,60%	26,40	339,92	4079,09
SUM	23,90%	40,45	520,78	6249,37

The number of employees is considered confidential information for The Company and the full cost will not be calculated.

As estimated by the author, the time spent on the activities of finding shortages and communication could be reduced by about 90% if the data was brought into one system and unnecessary steps were removed. Calculating product commitments could partly be-automatedsed and this would further reduce another step by around 70%.

1.2 The scope of this Master's thesis

The scope of the thesis includes business analysis, business process analysis and improvement, and system analysis and design for the architectural solution. While the company under analysis is part of a bigger group, the analysis scope will cover processes and tools inside The Company and considers solutions that can be implemented inside The Company.

Things that are not part of the scope:

- writing acceptance criteria for user stories;
- writing and performing user tests;

- development time estimates;
- risk analysis;
- development, testing, and deployment of this system;
- maintenance and new releases for this system;
- possible solutions that include stakeholders outside The Company.

1.3 The role of the Author

The author of this thesis works in The Company as a Business Analyst. The everyday tasks of the author are connected to organizing the development of the supply chain management infosystem. This includes conducting interviews and workshops with stakeholders, gathering and analyzing requirements, proposing possible solutions, prototyping, managing the backlog, and testing the software. Currently, the development team consists of the author as a usiness nalyst and one full stack developer as a developer and architect.

As far as the master's thesis is concerned, the author took the following role:

- analyzing the processes;
- describing and assessing the business problem;
- suggesting process changes for improvement;
- collecting and organizing requirements for a technical solution;
- describing the functionalities of that technical solution;
- creating an architectural view;
- mapping the main business information into a context diagram;
- prototyping the views.

The development of the solution is ongoing but it needs more development resources to get fully developed.

Although the analysis in this master's thesis might seem to be lacking some details, this is a conscious choice by the author to comply with the confidentiality requirements in The Company. The author hereby assures the reader that they have access to all the necessary detailed information to analyze the business requirements on the needed level.

2 Methodology

Companies use different process frameworks and methodologies as a basis for their business analysis. Organizations need process frameworks to help save time and raise efficiency in their projects. Process frameworks include a list of common business process elements and a standardized language that helps talk about these concepts with different stakeholders inside the company [5].

2.1 Six Sigma and Lean

Six Sigma is a team-based [2] project-driven management approach [6], [7], that can be viewed as a metric, methodology, or business initiative [7]. It uses a problem-solving methodology to optimize processes and create cultural change [8].

Six Sigma projects are chosen based on how they can contribute to better meet strategic objectives of the organization such as business growth or customer satisfaction[7].

Six Sigma is customer-centric and revolves around the DMAIC method – define measure, analyze, improve, and control. This is done to find the root cause of any problem that the company is facing [8], [9]. The results from implementing Six Sigma include the following: improved processes, increased revenue, lowered costs, increased efficiency, and improved workplace synergy [10].

Lean and Six Sigma are often implemented together. Lean is a set of techniques that were developed by Toyota [8], [11] and a Lean Production is now a global approach that intends to remove waste and manufacture products in a customer-centric process, whether the value created for the customer is under main focus [9].

Lean thinking considers seven types of waste which are defined by Taiichi Ohno who came up with the Toyota Production System. These can be equated to analogous issues in the software development field. Overproduction can be seen in extra features, which are unnecessary for the end-user. Requirements and requirement handling can be equated to inventory in Lean. Extra steps equal to extra processing steps and finding information to motion in these systems. Defects are built-in into the development process but defects in the Lean sense can be defects that were not caught by tests. Waiting corresponds to waiting for a development to be done, including for customers and transportation can be equated to application handoffs [12].

Today, Lean has changed from dealing only with the elimination of waste and now includes architectural techniques such as value streams, or management techniques like A3 [11]. Value stream analysis in Lean Production allows the removal of waste to raise efficiency [9]. A value stream represents a process from the customer's order to delivery [13].

When Lean is applied in process redesign, the used models mainly focus on the activities and workflows in a process [13].

2.2 TOGAF and ArchiMate

TOGAF (The Open Group Architecture Framework) is a business architecture framework that was created to address the enterprise architecture discipline. It consists of two parts, a detailed method on how to build up an Enterprise Architecture in a company and a set of supporting tools [14].

One tool under the TOGAF framework is the ArchiMate modeling language [14]. ArchiMate, an Open Group standard [1], was developed to allow a standardized representation of architecture domains, their relations, and dependencies to one another [1], [14], [15], to design, access and communicate the results of decisions and changes within and between these architecture domains [15].

While implementing TOGAF - a very flexible and universal toolset - can take a long time and a lot of effort, then Archimate is a supported solution in growing organizations where the following issues are present: developed systems increase in complexity over tiand me, it is hard to integrate new systems with the old ones, developed systems are not well-aligned to business [15]

2.3 Design thinking

Design thinking is an iterative process, where the goal is to understand users, challenge assumptions, redefine problems and create innovative solutions. The process has five phases: Empathize, Define, Ideate, Prototype, and Test. The phases are not always sequential while working iteratively [16].

The prototyping stage is for finding the best practical solutions. Inexpensive ways of prototyping are used to investigate the ideas that were generated and the testing stage allows to tof est the prototypes to find the best solution and further evolve it [16].

2.4 UML

The unified modeling language (UML), owned by the object management group (OMG) is a graphical language that is used for visualizing, specifying, constructing ,and documenting a software-intensive system and its artifacts [17].

UML is standardized and represents the culmination of best practices in the area. It allows for modeling business processes and system functions as well as database schemas and reusable software components [17].

2.5 Rational Unified Process

Rational Unified Process (RUP) is a tailorable software engineering process and framework that tries to ensure that the end-user needs are met within a predictable schedule and budget while capturing the best practices of many successful companies. Along with many others, RUP covers iterative software development and requirement management topics [18]. RUP provides guidelines, templates and examples for different stages of software development [18], [19].

3 Enterprise description

The Company is dedicated to producing a wide portfolio of products. It procures components from its vendors to make this possible. The suppliers are in different countries and lead times for components can vary.

Process improvement is one of the more important drivers of digital transformation in manufacturing companies and this leads to movements like Industry 4.0 [20]. Industry 4.0 describes different IT-driven changes in manufacturing systems that bring both technological and organizational changes [21].

Because of the confidentiality requirements. The ways of working in The Company and its organizational structure will not be widely discussed here in this master’s thesis. The overall description is considered sufficient.

4 Business analysis

4.1 ArchiMate motivation layer

The motivation extension in ArchiMate was created to connect enterprise architecture to the organization strategy. Motivation layer allows visualizing the goals and requirements that precede the enterprise architecture [15], [22].

The motivation extension has added following motivational concepts to the ArchiMate Core such as stakeholder, driver, assessment, goal, requirement, constraint and principle [22].

The author visualized the motivational view for The Company on Figure 1. As per the confidentiality requirements of The Company, no structural information can be published, and the author decided to rename the inner stakeholders with the format “Inner stakeholder n”. Stakeholder represents a person or team that has interests or concerns about the outcome of the architecture [15], [22].

In the motivational layer, driver represents both inner and outer concepts that motivate change in an organization [15], [22]. Main drivers for the stakeholders in The Company are very typical for any manufacturing or production-related company: employee engagement, cost optimization, product quality, TTM (time to market), TTV (time to volume), customer satisfaction. As a company with a high focus on corporate social responsibility, environmental sustainability is also part of that list. Moving towards Industry 4.0, another driver has been raising – process automation.

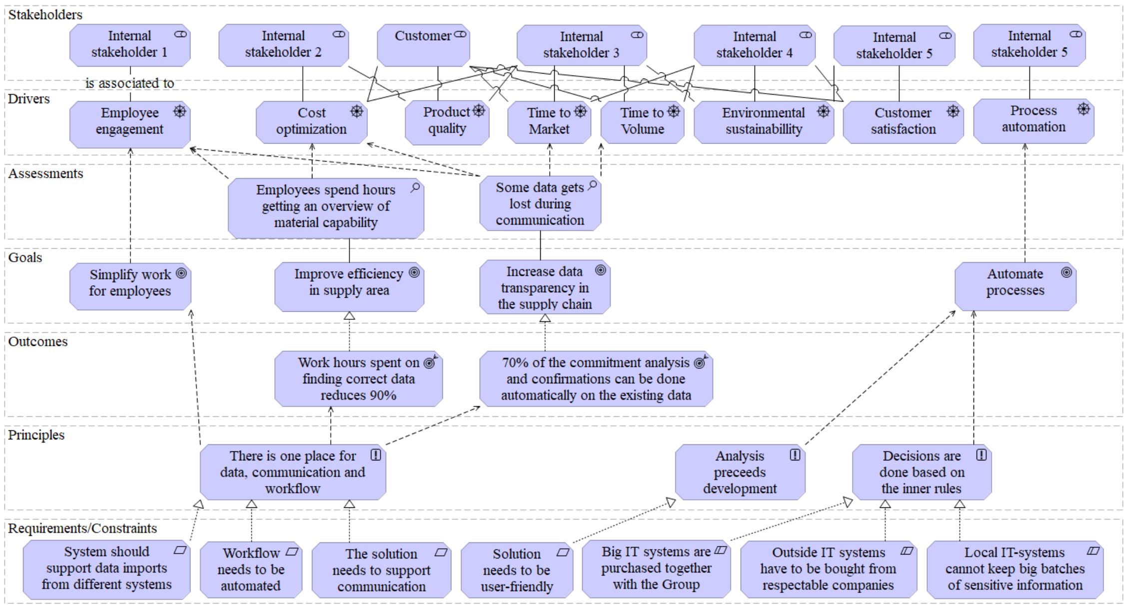


Figure 1. ArchiMate motivation layer of The Company

Assessment is the analyzed outcome on a driver [15]. On Figure 1, the author brought out the assessments that relate to the project at hand. Cost optimization allows investments for improvements and revenue. The fact (assessment) that employees spend hours for just getting an overview of data is illustrated in Table 1 and Table 2. This is a problem that needs to be solved. The answers from the survey shown in Appendix 2 also illustrate the fact that some data is missing when employees are using the current communication method of commenting. This relates to cost optimization in two possible ways:

1) if supply chain planners misjudge the number of components and plan for assembling less products, then less products will be planned and produced and less revenue is earned by The Company for the same cost;
2) if supply chain planners misjudge the number of components and plan for assembling more products, then more products will be planned and the same number of products are produced but there can be a loss of production capacity (cost).

There are four main goals as illustrated on Figure 1. A goal in the ArchiMate standard represents the result that a stakeholder wants to achieve [15], [22]. These goals are work simplification, supply area efficiency improvement, increasing data transparency in the supply chain and process automation. There are also three main outcomes: efficiency can be measured in work hours that are used by employees doing the same tasks, the expected outcome is to reduce this time by 90%, the supply chain visibility is realized if 70% of the commitment decisions can be done automatically. A possible automated solution would also work towards the goal of automation.

Principles in the motivation layer represent the means to realize a goal [15], [22] and they are usually heavily influenced by requirements and constraints. A requirement in the ArchiMate motivation view describes what is needed to be able to achieve a goal and constraints are restrictions on the ways that goals can be archived [15], [22]. Regarding the current solution, there are three main requirements: ability to support data being imported from multiple systems, automated workflow for end-users and support for communication in the solution. These three are then realized with the help of the principle for having one place for data, communication and workflow. This supports the three goals of visibility, work simplification and efficiency.

There is another requirement for the solution being user-friendly, which is supported by the principle of analysis preceding development in order to influence that the tool that is being integrated or developed would actually serve its purpose. The second principle that plays a role in this outcome is the principle of following the inner rules of the company and this principle is created by the need for group-wide discussions for bigger systems, and having respectable partners. If a fully developed system is considered as a potential solution, then these constraints become important.

Another constraint is about keeping big batches of sensitive data in locally developed tools. This is a security constraint that influences development decisions. If the principle of following rules was not in place, it would result in potential data-related risks for the development.

4.2 Main value stream

A value stream consists of an end-to-end flow of activities that create a valuable result to a customer, stakeholder or end user [23]. While value streams might seem similar to business processes, they are defined at different abstraction levels. Value streams reflect the business model of an organization while processes visualize the operational model [1].

As a production enterprise, the main value stream for The Company is related to producing end products for the customers. The main value stream is visualized on Figure 2, using ArchiMate [1] value elements.

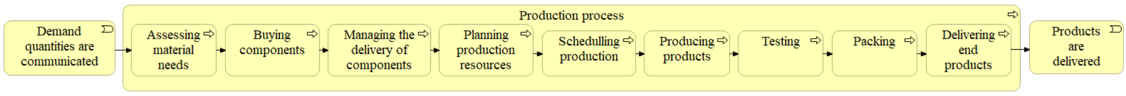


Figure 2. Main value stream of The Company

The Production process starts when demand quantities are communicated to The Company by the customers. It starts with assessing material needs that is mostly done automatically using the Enterprise resource planning (ERP) system. This system assesses if The Company has anoughenough resources to fill the requirements. It does not assess if other suppliers or sites have enough resources to fill the requirements. There is an ongoing communication about the orders until they are received.

Material capability and production capacity are estimated in the production resources planning stage after which commitments are calculated and production is scheduled onto the production lines. Production starts after that and is followed by testing to ensure the quality of the products. When testing is finished and issues are cleared, packing and delivery will follow, giving the customer delivered end products,

To realize the stages of the value chain, The Company needs several business capabilities. TOGAF´s value stages are often mapped to business capabilities in order to analyze the organization's current and needed abilities that deliver the value to the end customer [23].

4.3 Business capabilities

A business capability reflects a particular ability or capacity that a business may have or exchange to achieve a specified outcome. It defines what a business does, not where, how or why [24], [25]. Capabilities provide a common language for understanding and communicating about what portion of a business needs changing [24].

It is recommended to use one business capability map for the whole organization, regardless of what business units are mapped to those capabilities. It gives a united view on the business as a whole and brings transparency to strategic initiatives. The alternative process tends to focus on IT-solutions first which makes it further disconnected from the business strategy [24].

Capability maps are often structured as three layers [24]:

1) Strategic layer gathers executive priorities. These can vary from company to company as the main operations and strategies differ.
2) Value-add layer gathers the core-business capabilities that are needed for the company to ensure viability. Three of the usual big areas under that layer are customer, product and account management.
3) Support layer has the capabilities that represent supportive activities that an organization needs to function as a business. Prime examples of that are HR, financial management and legal management.

The author created the capability map on That shows company-wide capabilities in a structured way.

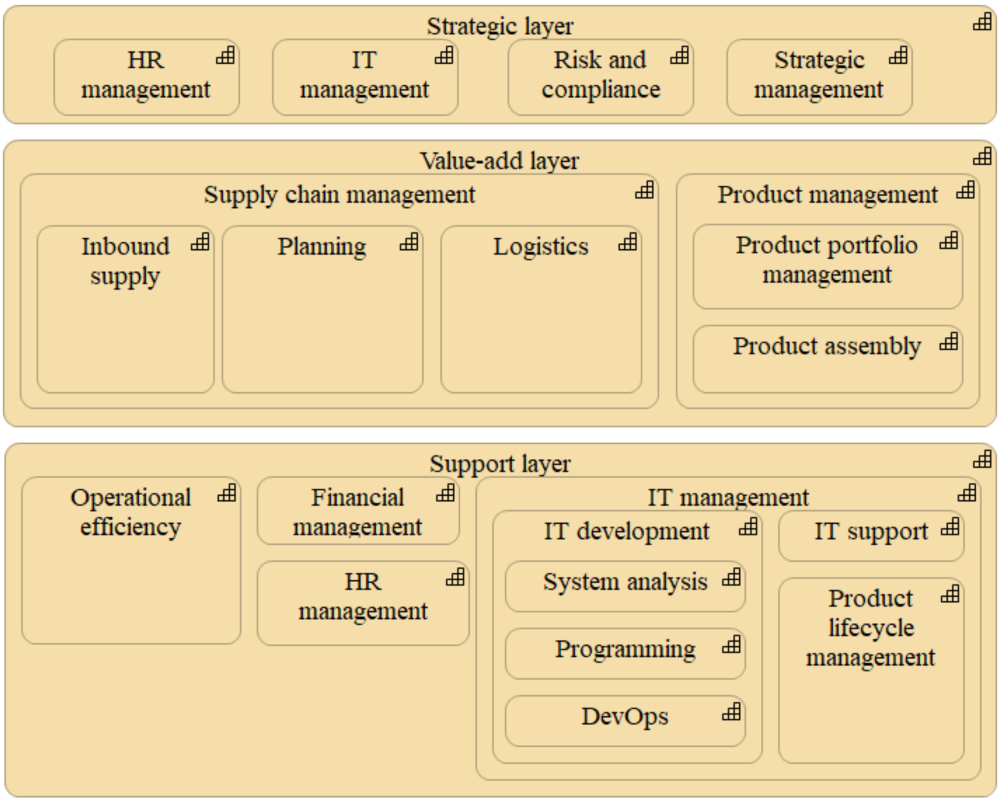


Figure 3. Capability map for The Company

As per theory [24], the strategic layer of the business capability map is composed by capabilities that are a high priority for the company's strategy. These are HR management, IT management, risk and compliance and strategic management. When connecting the strategic business capabilities to the drivers in the ArchiMate motivation layer on Figure 1, these four business capabilities are connected to the following drivers: employee engagement is a driver in HR management area, process automation is important for IT management area. Risk and compliance touches product quality and environmental sustainability. Strategic management deals with how The Company creates value for the customers.

The value-add layer should visualize the main business capabilities that bring value to the end customer [24]. As a manufacturing company, the main areas at that level are product management and supply chain management. Product management decomposes into two business capabilities, product portfolio management and product assembly. Supply chain management includes all the other capabilities needed to realise the main value steam: inbound supply, planning and logistics.

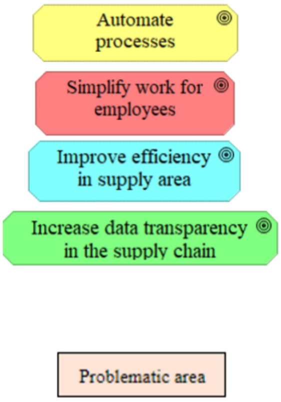
Third layer is the support layer that collects all the support capabilities. Support layer has such capabilities as operational efficiency and HR management, financial management and IT management. IT management has three main capabilities: IT development, IT support and Product lifecycle management. IT developmentdivides into system analysis, programming and DevOps.

4.4 SIPOC analysis

SIPOC is a Six Sigma mapping tool that is usually used across the DMAIC roadmap for problem solving. The name SIPOC corresponds to the five elements: Supplier, Input, Process, Output, Customer [7].

Using SIPOC instead of usual process diagrams can have the following advantages: customer requirements are more visible, SIPOC helps to identify potential Six Sigma improvement projects and SIPOC provides a common language for organizing key processes [7]. SIPOC allows for identifying the essence or core of the process and identifying waste [9].

The strategic goals that were visualized on Figure 1 connect to the first four main value stream stages: needs assessment, component purchasing, component delivery management and production resource planning.On Figure 4, the author has visualized the result of the SIPOC analysis and mapped the strategic goals to the main value stream stages.



S	I	P	O	C
Suppliers	Inputs	Process	Outputs	Customers
Customers, ERP system, Component distributor system, Component Forecasting system	Product demand, component demand, prognosed component stocks	1. Assessing material needs Automate processes · Simplify work for employees · Increase data transparency in the supply chain · Improve efficiency in supply area	Actual component demand, possible suppliers	ERP system, purchasers
Customers, ERP system, Component distributor system, Component Forecasting system	Component demand, supplier stocks, supplier forecasts, price, order specifications	2. Buying components Automate processes · Simplify work for employees · Increase data transparency in the supply chain · Improve efficiency in supply area	Delivery time, components	Production
Suppliers, ERP system	Estimates from suppliers, order confirmations	3. Managing the delivery of components Increase data transparency in the supply chain	Components delivered on time, delivery confirmation	Production, supply chain planners
Supply chain planners	Calculated product commitments	4. Planning production resources Automate processes · Simplify work for employees · Increase data transparency in the supply chain · Improve efficiency in supply area	Production capacity requirements, HR needs	Production
Supply chain planners	Production quantities,	5. Schedulling production	Production plan	Production
Suppliers	Components, production orders	6. Producing products	Products	Customers
Production	Products	7. Testing	Quality-approved products	Customers
Production	Tested products	8. Packing	Safely packed end-products	Customers
Packing facility	Packed products	9. Delivering end products	Safely and on time delivered end-products	Customers

Figure 4. AS-IS SIPOC analysis for main value stream with strategic goals

The problematic areas in the SIPOC analysis are marked with pink and the goals are colored in order to find them easily on the SIPOC mapping.

As seen on Figure 4, the first problematic area lies in the supplier side of assessing material needs. There is a lot of information to be considered in this step and as seen in the suppliers area, the number of suppliers for related information is high. This is where a technical solution can possibly solve the problem. The relevant strategic goals are automating the processes and simplifying work. Efficiency improvement connects to reducing time spent in going through all the systems and finally, this problem is strongly related to the data transparency goal in supply area.

The second problematic area is in the supplier side of buying components. Again, the inputs for this value stream stage are mostly information-related and the necessary information is about what supplier to contact for supply improvement. The problem relates again to process automation, work simplification, efficiency improvement and data transparency. The suppliers for the input information are the same as in last stage and finding that information still means going through multiple systems to find it.

The third problematic area is on the customer side of component delivery management. When resources are scarce and they are planned to be arriving just in time, then it is vital to have the delivery information in place. The information is not being gathered automatically and there is a possible automation project there as well, which is left out of scope by the author. The current issue is that there is an unfulfilled need to keep this information in a way that the status can be easily seen by the supply chain planners. This problem mostly relates to the data transparency goal.

The fourth problematic area is on the supplier side of planning production resources. A very important input for this value stream stage is product commitment. Calculating and agreeing on that commitment is a process for supply chain planners that takes a lot of time as they also collect data from different systems before the calculations. Again, this problem connects to all four of the strategic goals: process automation, work simplification, efficiency and data transparency.

In order to see how business capabilities connect to value stream steps, the author mapped the necessary business capabilities to the steps in the main value stream as seen on Figure 5.

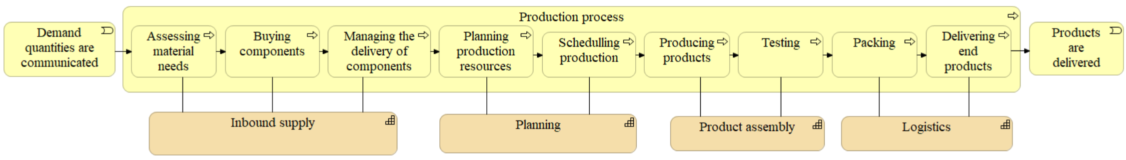


Figure 5. Capabilities mapped to the main value stream.

As a next step, the author considered a gap analysis in order to clarify what parts of the business capabilities needed improving. The results of the gap analysis are seen in Table 3 and Table 4.

Table 3. Business capability gap analysis for inbound supply capability

Area	**AS-IS**	**TO-BE**
People	in a good state	not changed
Process	currently ineffective as supply improvement process duplicates steps with material capability analysis process	will remove the process steps duplication
Technology	the state of technology is low as there is a lot of manual work that could be automated	automation will allow to collect data from different systems automatically and both data quality and efficiency will be improved

Business capability gaps for inbound supply capability are in the areas of process and technology as seen in Table 3. The process area can be improved by removing the duplicated steps from the supply improvement and material capability analysis process. The technology area needs improvement in the form of a system that collects data from different systems, resulting in reducing used work hours.

Table 4. Business capability gap analysis for the planning capability

Area	**AS-IS**	**TO-BE**
People	in a good state	not changed
Process	in a good state	not changed
Technology	as data transparency is low, the quality gets bought down with it, that is because there is no system to collect the data into one place	automated system will allow to improve the input data quality

Some improvement is needed also needed in the planning capability, where technical shortcomings result in a lot of manual work. The change that would support the improvement would be to allow manual input into a system that collects data from different systems so that the input for planning is as good as it can be.

As a result of the gap analysis, two business capabilities were seen that needed improvement – inbound supply and planning capabilities. This was visualized in a heatmap style on Figure 6 to further connect the improvements to the main value stream. Business capability maps can be visualized as heatmaps in order to show the gap analysis results [23].

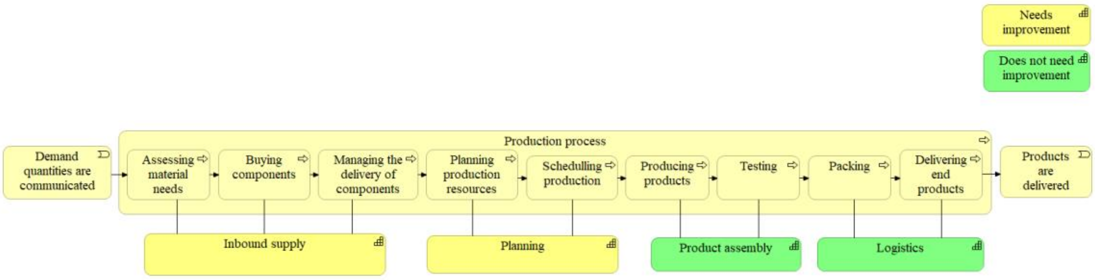


Figure 6. Main value stream with mapped business capabilities as a heatmap

In order to understand, how these business capabilities connect to the the full business capability map of The Company, the capability map for the company was also visualized as a heatmap on Figure 7.

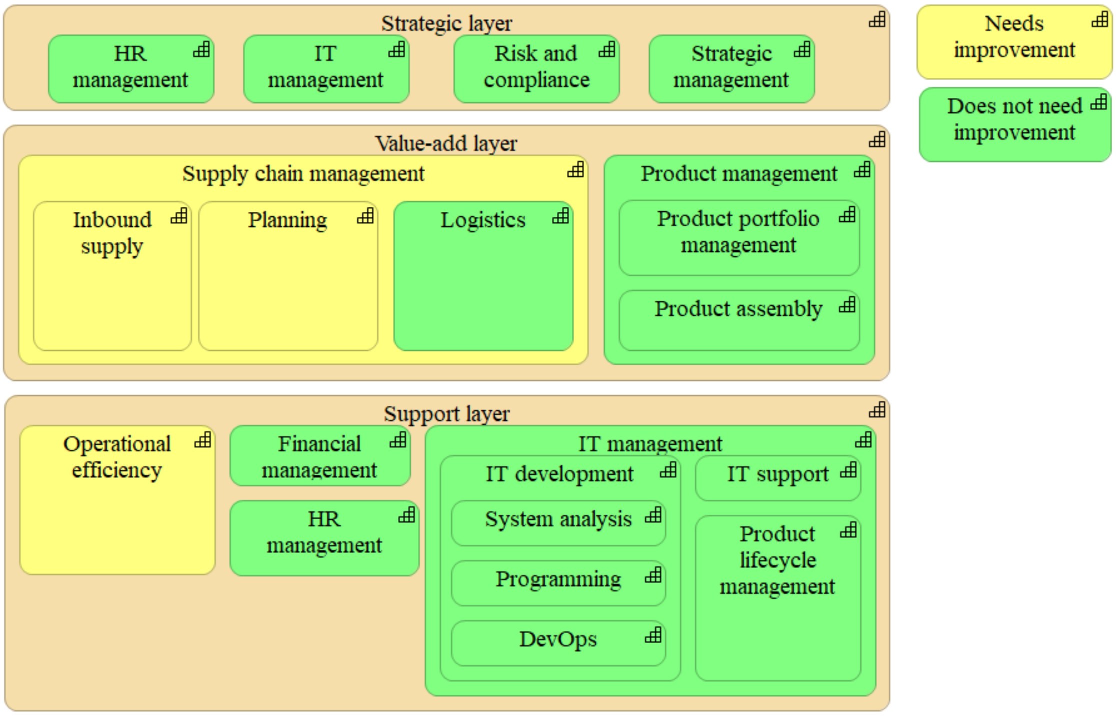


Figure 7. Business capability heatmap for The Company

This business capability heatmap gives a good starting point when discussing possible investments into these areas where business capabilities need to be improved.

Problematic areas in processes can more easily be understood using process analysis tools and these tools can also be used to create a better process as an improvement.

4.5 Processes

The author has used previously created process mappings [27], [28] as a basis and unstructured interviews with representatives of purchasers and supply chain planners in order to adapt them to represent the real-life AS-IS process as best as possible but remove unnecessary detail from these processes.

BPMN (Business Process Modeling Notation) is a standard created by the Business Process Management Initiative (BPMI). BPMN defines a Business Process Diagram (BPD), which allows communication about business processes in a unified manner throughout the organization.[29], [30]. BPD is based on a flowcharting technique and consists of four basic element categories - flow objects, connecting objects, swimlanes and artifacts [30].

4.5.1 AS-IS Supply improvement process

Supply improvement process is one of the main processes that the purchasing department follows as the ordering is mostly done by the automated MRP system. Purchasers try to improve the supply situation by looking into future periods where demand is changing and prognosed shortages can appear. As each purchaser deals with their own vendor(s), they look at the component shortages that their vendor(s) might have during the coming periods. Purchasers can contact supplier to try to improve the supply situation. The current supply improvement process is shown on Figure 8.

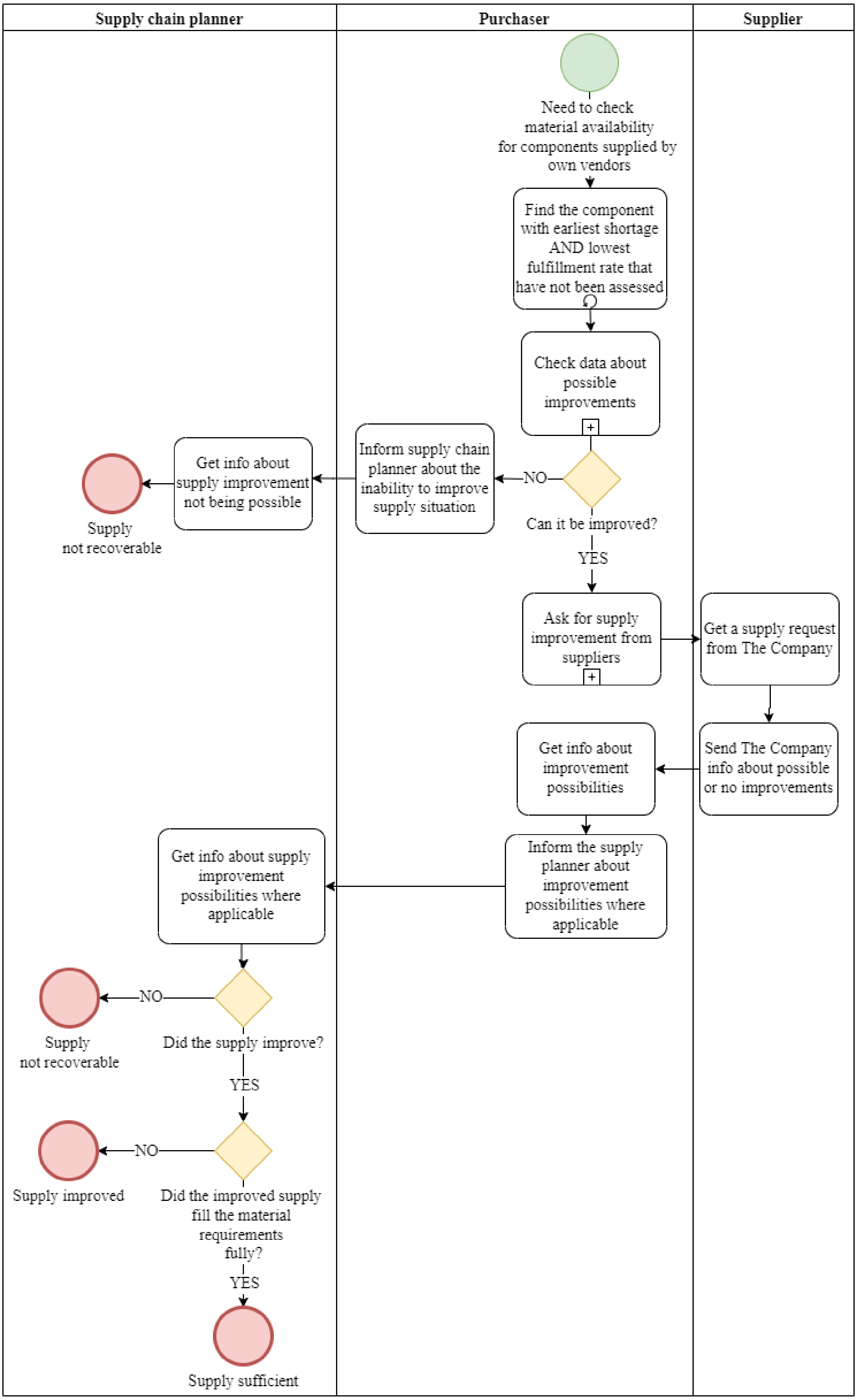


Figure 8. AS-IS Supply improvement process

Currently purchasers create their own workflow by going through components with shortages from lowest fulfillment and earliest shortage towards highest fulfillment rates (under 100%) and later shortage periods. This workflow is often interrupted by the supply chain planners going through the Material capability analysis process and needing purchasers to take some component into their workflow as a priority.

4.5.2 AS-IS Material capability analysis process

Material capability analysis, visualized on Figure 9, is a process mostly started by Supply chain planners. They look at the supply situation from a different angle than purchasers, trying to get the shortages improved so that the products they manage can be built. Supply chain planners cannot contact vendors on their own and they will delegate that part to the purchasing department.

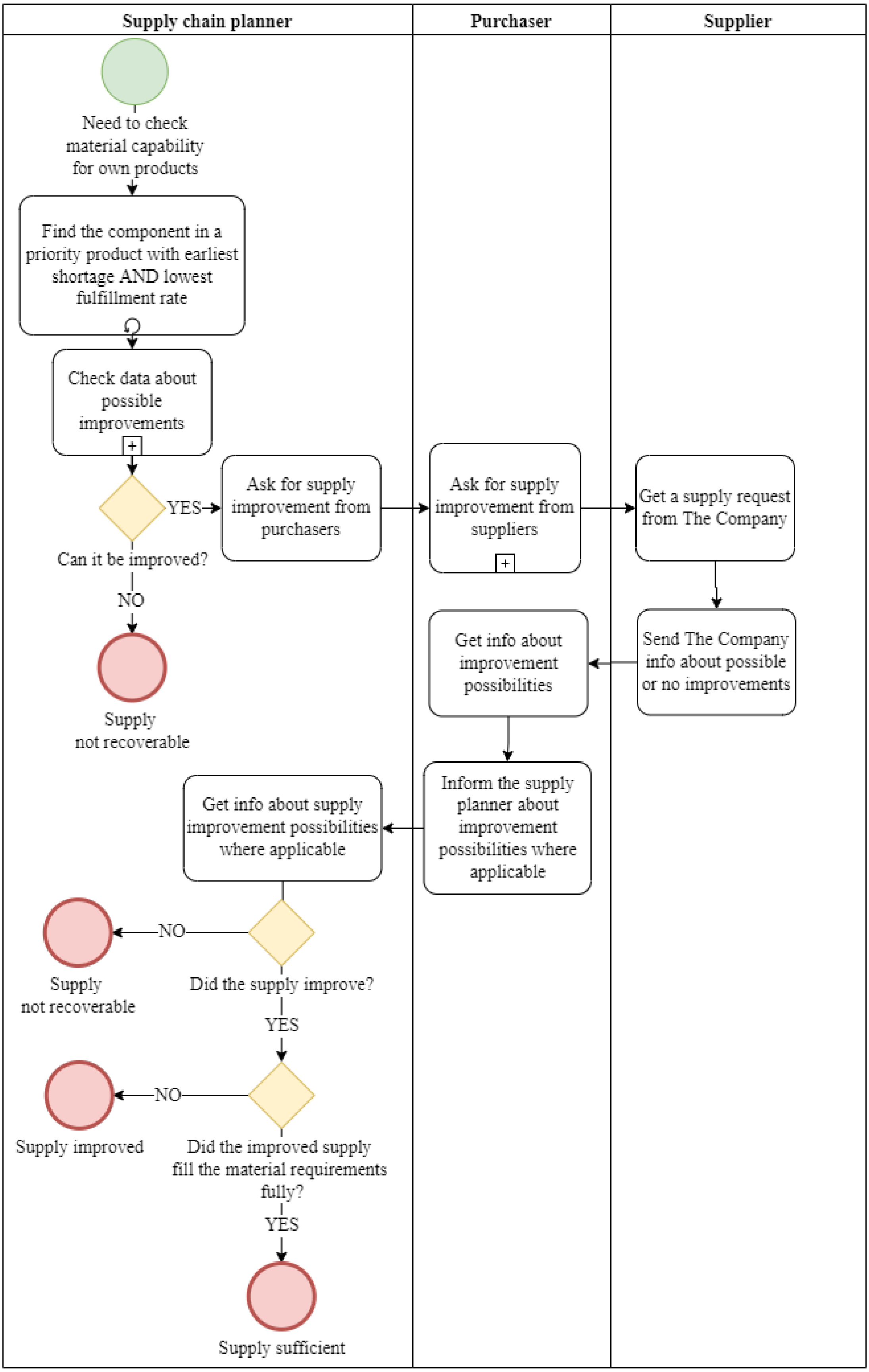


Figure 9. AS-IS Material capability analysis process

Here is where the duplication of process steps happens. As seen in the process mapping on Figure 9, supply chain planners start their process similarly to the supply improvement process, checking whether there is data about possible shortage improvement. When they notice a chance for improvement, they must forward the action to the purchasers as supply chain planners are not allowed to contact suppliers.

Briefly, these processes seem to have duplicated some of the work as two roles are analyzing the material capability situation from two different angles while looking at the same components and same data. This duplication of process steps is considered a waste in Lean process improvement [12] and should therefore be removed. While considering waste, the other problematic area in these processes is transportation, which is visible as an unnecessary transportation of information. The third waste here would be waiting that happens while a purchaser checks improvement possibilities and supply chain planner cannot move on with their own process steps.

The process has developed this way over time because of poor access to information by purchasers regarding how to prioritize component shortages while working through them. There was no way of understanding which shortages the most important and which ones were secondary when it came to the building of products. There is now a tool that allows the calculation of demand fulfillment rates, which has solved this problem for the purchasers.

4.5.3 Process change suggestions

The author suggests putting all the responsibility of analyzing material capability and improving supply to the purchasers, thus removing the duplicate work altogether and reducing the waste from unnecessary information transportation and waiting. The end result that the Supply chain planners need in order to resume with their work is having the numbers of improved or not improved stock levels in order to start the calculation of commitment for their products.

While this change would simplify the processes and make the employees use time more efficiently, there is even more efficiency to be won by implementing a technical system that allows to manage the information for purchasers in one place and mark down agreed-on improvements, allowing Supply chain planners to see this information in a usable form and take it fully into account for material capability planning process.

4.5.4 TO-BE supply improvement process

The author visualized the TO-BE supply improvement process on Figure 10. Main changes are marked with blue. Instead of starting with the usual process or going through components with the lowest fulfillment rate and earliest shortage, the purchaser will now start with component shortages for products that are seen as priority products. Supply chain planners will not be able to set the priorities and priority products will be chosen by their managers. This reduces the noise that would be created by all supply chain planners prioritizing their own products.

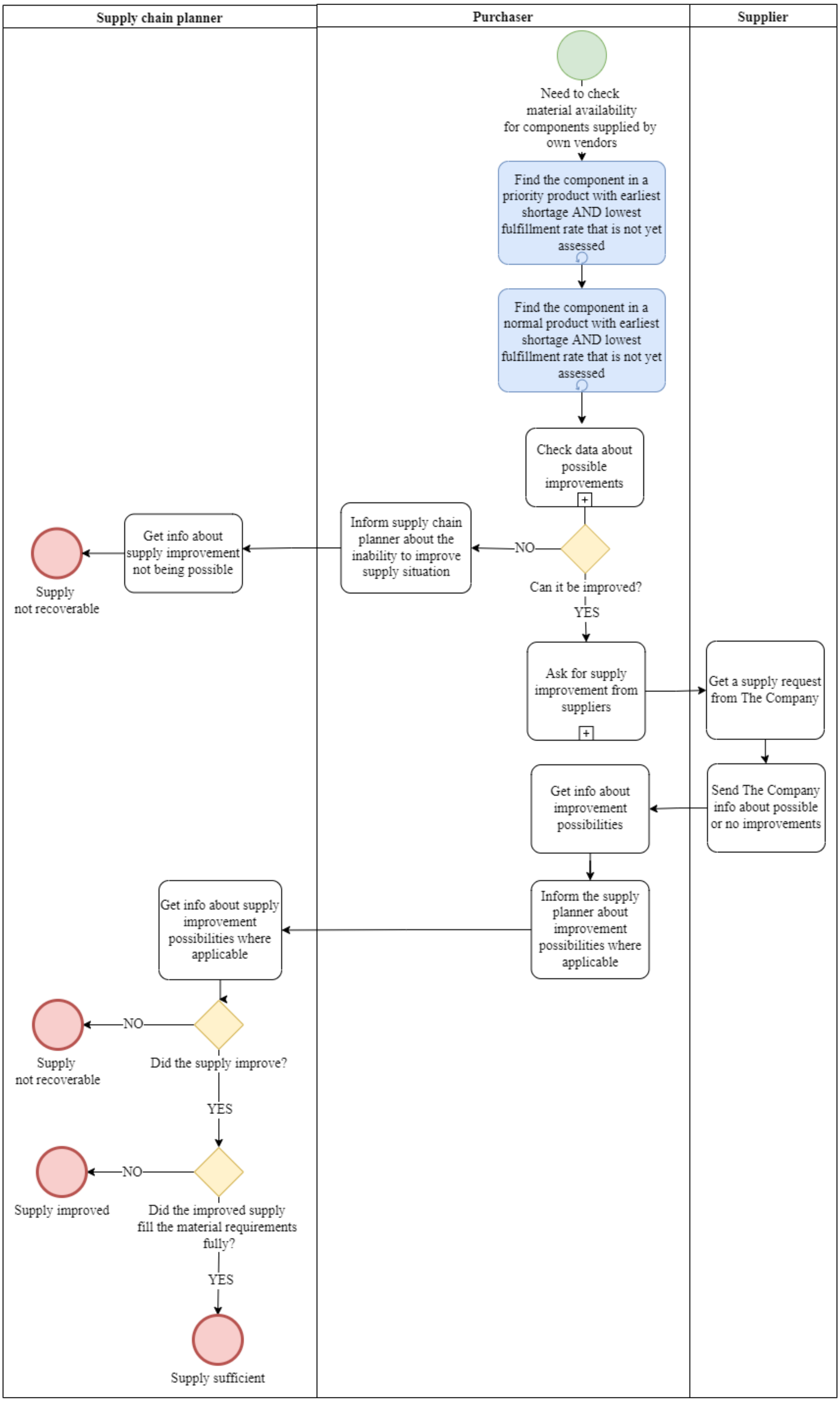


Figure 10. TO-BE Supply improvement process

After going through the components in priority products, the purchaser then continues going through the components within products that are not higher priority products similarly as in the usual supply improvement process.

4.5.5 TO-BE Material capability analysis process

While the Supply improvement process will be changed in relatively small ways, then Material capability analysis process would change much more as they would stop checking separate components on their own.

Supply chain planner will continue checking the results of what have been done about supply improvement but they will lose the steps of checking possible supply improvement possibilities.

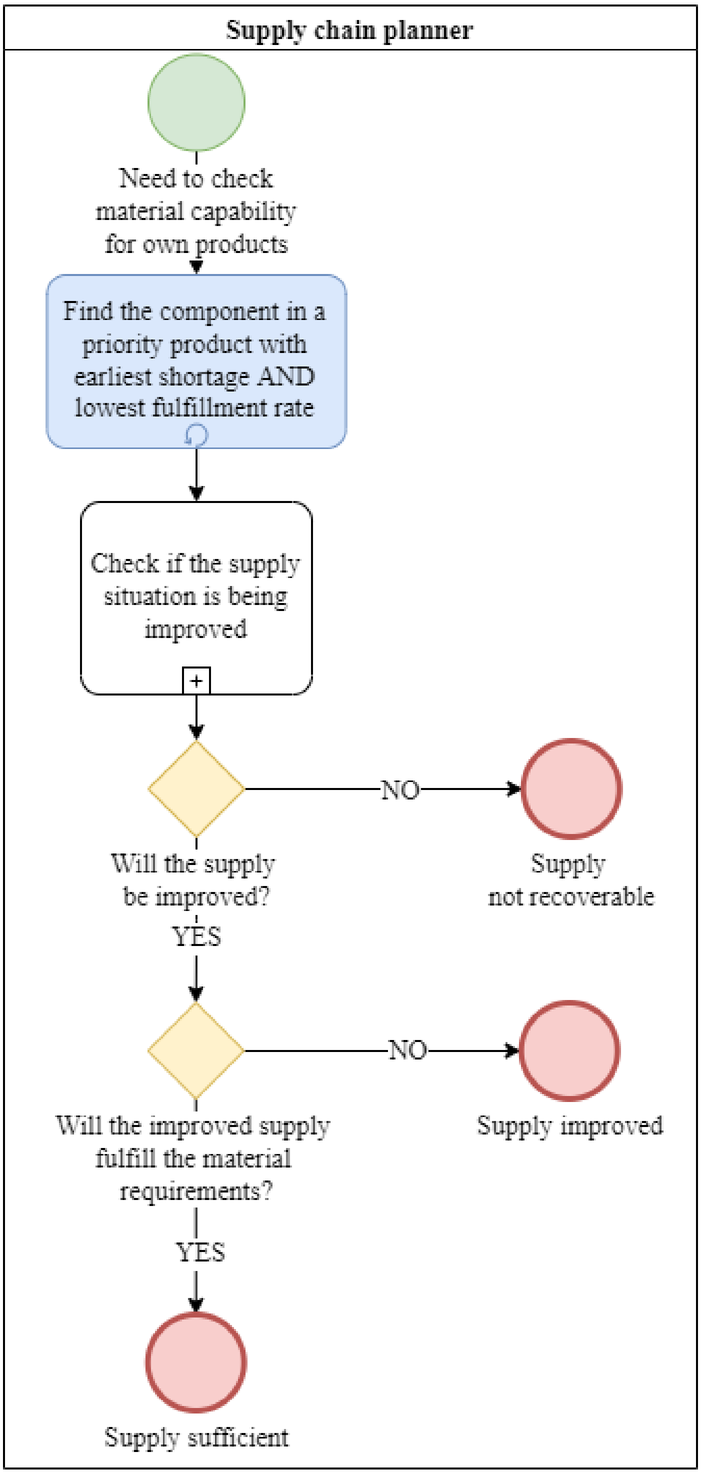


Figure 11. TO-BE Material capability analysis process

As a result of this change in process, the Supply chain manager can concentrate on analysis and prioritization of products that need to be built.

4.6 Business requirements

As part of the analysis for understanding the user needs for creating a technical solution and automating these processes, the author mapped and validated business requirements that have to be filled. These requirements are presented in Table 5.

These business requirements were divided into four categories by the author: main requirements, data requirements, collaboration requirements and customization requirements.

Table 5. Business requirements

ID	Type	Requirement
BR1	Data	System should allow data exchange with ERP (Enterprise Resource Planning) system
BR2	Data	System should allow data import from MES (Manufacturing Execution System)
BR3	Data	System should allow data import with Component distributor system and similar systems
BR4	Data	System should allow data import with Component forecasting system
BR5	Data	System should allow data import with Contract management system
BR6	Data	System should allow data import with our Technical approval system
BR7	Main	System should calculate prognosed material stocks and shortages
BR8	Main	System should calculate fulfilment rate
BR9	Main	System should support equal pain principle
BR10	Main	System should allow manual division of components between products
BR11	Main	System should allow primary calculation of product commitments
BR12	Main	System should allow finalizing decisions about product commitments
BR13	Main	System should allow for manual data input

BR14	Main	System should allow commenting manual data input
BR15	Main	System should allow seeing information about data imports
BR16	Main	System should log all data changes made by the user
BR17	Main	System should support workflow management in order for purchasers to keep track where they are
BR18	Collaboration	System should allow collaboration and information exchange between users
BR19	Collaboration	It must be possible to substitute other users during vacations or sick leaves
BR20	Collaboration	System needs to allow sharing material capability results with outside stakeholders in a changeable format (f.e Excel)
BR21	Collaboration	Outside stakeholders should have limited access to the tool
BR22	Collaboration	Should allow role management for data security
BR23	Customization	Data sources and calculation principles should be customisable
BR24	Customization	System should allow customizing the user interface for specific users

As seen in the business requirements table, many of the requirements are connected to reaching data from different systems and then automatically calculating prognosed stocks and shortages to assess material capability. These steps currently take a lot of time in the process.

4.7 Alternative solutions

When trying to find a fully-developed system that fits our needs, there are two important constraints for the possible solution.

1) To reduce the built-in risk for The Company, any procurement from another company is put under a restriction that allows procuring only from companies that are big enough that they are seen as responsible partners.
2) The company cannot select its own ERP system or similar big planning solution without an agreement inside the group. Big technical systems cannot be locally implemented if they are not relevant for the other sites.

While looking into the requirements, it was briefly proposed to solve the problem with data visualization tools like Tableau [32] or Power BI [33], which would have been easier and a faster solution to develop compared to a full application.. While many of the business needs could be solved by using these tools, they were left out because these tools didn’t fill data insertion and communication requirements.

4.8 IT development in The Company

The IT development in the Company is mostly done in an agile way. Agile development teams can make autonomous decisions about choosing the methodologies they use in their teams and how to customize them according to the needs in the team.

The agile methodology used in the team that the author works in is Scrum. Scrum [34] is a lightweight framework. It is an iterative and incremental approach to software development that helps people and teams create adaptive solutions to complex problems. Scrum has a number of roles that should usually be filled and this means that some customizations are made in the team that the author works in.

The other methodology that applies onto the IT development in The Company, is SAFe. SAFe for Lean Enterprises [35] is the leading framework for business agility. It integrates the vital parts of Lean, Agile and DevOps into a comprehensive framework that allows to manage IT development in software-intensive systems in an agile way

5 System analysis

5.1 Overview of the IT-systems in The Company

ERP system - The Company is using an Enterprise Resource Planning system, which is modified to fill the company-specific needs. The ERP system keeps track of the product recipes and component stocks in multiple locations. The ERP system also has a MRP (Material Resource Planning) business capability which means that it allows automated purchasing based on product demand.

MES system – The Company has also introduced a Manufacturing Execution System that keeps track of the actual manufacturing workflow.

Technical approval system – this system contains information about the components used in production and their approval statuses. This is especially important for new products.

Contract management system – this system contains information about the vendor contracts and their statuses. Having a vendor contract means that there is a price and forecasted or forecastable quantity agreement between the company and the vendor.

Role-management system – this system allows all accesses to internal tools to be managed in one place.

Component forecasting system – this system gathers vendor forecasts for supplying components in the future. This system does not include forecasts from our current component distributor.

Component distributor system – this is a tool for one component distributors, it gives an overview of the upcoming estimated balances and takes into account both the demand from The Company and other buyers but also demand forecasts from The Company and other buyers. It shows the stock prognosis for coming periods.

5.2 Requirement management

Requirements management is a systematic approach for eliciting, organizing, communicating, and managing the requirements for a software system.

The benefit of effectively managing requirements is that it gives good control and better understanding of complex projects which then results in better software quality that brings higher customer satisfaction. Clearly managed requirements decrease possible errors in development, which reduce development costs [36].

Requirements are dynamic in a software-extensive system. They change during the product's lifecycle. Even the identification of core requirements is a continuous process. It is not possible to state all the requirements before the start of development [18].

RUP defines requirement as a condition or capability that a system needs to possess [18].

There is often a need to classify the requirements to manage them more effectively. One such classification system, FURPS+ was created by Robert Grady at Hewlett-Packard. FURPS stands for functionality, usability, reliability, performance and supportability, the + stands for design requirements, implementation requirements, interface requirements and physical requirements [37].

5.2.1 Functional requirements

Possible functional requirements consider auditing, licensing, localization (e.g. language support), e-mail services, help, printing and reporting, security, system management and workflow services in addition to usual functional requirements [37].

Requirements Engineering (RE) is fundamental for software development processes. Incomplete and vague requirements can be one of the main reasons for project delays [38]. In agile software development environments such as in The Company, user stories aare one of the more frequently used methods [38].

The author prepared the functional requirements as user stories for this development and added them to Appendix 3. As requirement prioritization is part of the requirement management the author asked SME-s to prioritize the functional requirements using the MoSCoW method.

MoSCoW [39] is a simple prioritization method, which allows to sort features or user stories in a list. This allows to understand what is essential for the end-users for launch and what is not.

MoSCoW stands for:

1) Must have (or Minimum Usable Subset) – development cannot be launched without these features;
2) Should have – important and high-value features but not critical for launch;
3) Could have – nice to have features that can be implemented if the cost is not too high;
4) Won't have – requested but explicitly excluded features.

In order to validate and prioritize the functional requirements with the stakeholders, the author carried out workshops with SME-s (subject matter experts). The author decided to add all the „Must-have" requirements into Table 6.

Table 6. „Must have" functional requirements in the form of user stories

ID	AS a (role)	I would like to (goal)	To (reason)
US1	User	have the system calculate prognosed component stocks and shortages	save my time calculating the numbers
US2	User	have demand fulfillment rates calculated for all components on future periods	get an overview of material capability
US3	User	substitute another employee in my role	take care of their responsibilities
US4	User	log in into the system using my computer username and password	not have to remember too many passwords
US5	User	see logs about data import runs	evaluate the data I see
US6	User	use one system for all related information	not waste my time going through multiple systems
US7	User	use the system to communicate with my coworkers, share data	keep all data in one place
US8	developer	have the system log all user activities	allow for troubleshooting the issues
US9	developer	have the system log all data imports/exports	allow for troubleshooting the issues

US10	supply chain planner	divide all components into products based on the equal pain principle	I have a starting point for deciding components
US11	supply chain planner	manually divide components into products	see what are the other product combinations that can be built
US12	purchaser	manage my workflow in the system	not repeat going through the components one-by-one
US13	security manager	allow login only for active employees	fulfill safety requirements
US14	security manager	allow role management for the system	keep data secure
US15	security manager	have all actions in the system log	keep data secure
US16	security manager	have the system fulfill the login requirements	keep data secure
US17	security manager	have development, testing, and operational environments separated from each other	reduce the risks of unauthorized access or changes to the operational environment
US18	security manager	have the same control mechanisms added to the development and test systems as those in a production environment	be able to use live data in these systems
US19	security manager	have the system protected against malicious code	keep data secure

The functional requirements essentially convey different subtypes of requirements. There are requirements that all end-users need to be filled and then there are specific requirements for only purchasers or supply chain planners. Additionally, there is a set of security-related requirements that are simplified forms of the inner security requirements from The Company IT-security document [40]. The „security manager“ role is created by the author to allow managing security requirements as user stories. It does not exist in The Company.

5.2.2 Nonfunctional requirements

In addition to the structure and behavior of applications, software architecture is also concerned with other topics such as performance, resilience, reuse, etc [18].

The remaining URPS categories in FURPS [37] allow bringing together architecturally significant non-functional requirement categories - usability, reliability, performance, and supportability.

1) Usability represents such characteristics as aesthetics and consistency.
2) Reliability connects to the availability of the system. recoverability and accuracy of system calculations.
3) Performance stands for throughput, response time, recovery time, start-up time, and shutdown time.
4) Supportability is concerned with testability, adaptability, maintainability, compatibility, configurability, scalability, and localizability.

The Company does not have a company-wide form of nonfunctional requirements for software development. The author made a recommendation to use the applicable requirements from the published nonfunctional requirement list [41] that is created by the Republic of Estonia Information System Authority. Nonfunctional requirements presented in Table 7 are customized versions of the requirements represented there.

Table 7. Nonfunctional requirements

ID	**FURPS classification**	**Nonfunctional requirement**
NFR1	Performance	The app needs to load quickly in the browser.
NFR2	Performance	The system should be automatically scalable
NFR3	Reliability	The application must be resilient to failures in external systems.
NFR4	Supportability	The source code documentation, the source code itself, and the log messages must be in English.
NFR5	Supportability	The source code must be provided with unit tests.
NFR6	Supportability	The software must be security tested before being deployed in a production environment
NFR7	Supportability	Starting from the integration level, automatic tests must be parameterized.
NFR8	Supportability	Automated tests must report results in human-readable and machine-readable formats (e.g. JUnit XML and HTML).
NFR9	Supportability	Follow up-to-date web standards (HTML5, CSS3, etc.)
NFR10	Supportability	Error messages must be logged.

NFR11	Supportability	When referencing from one data table to another, foreign keys must be used. All foreign keys must be indexed with a non-unique index and described as foreign keys.
NFR12	Supportability	All database tables must have an integer-type primary key defined, which is a surrogate key. Real-life data fields must not be used as primary keys.
NFR13	Supportability	All primary keys must be indexed with a unique index.
NFR14	Supportability	Field lengths in a database must be described in the Data Description Language (DDL) in symbols, not bytes.
NFR15	Supportability	The application must be agnostic to table partitioning, i.e. changing the partitioning structures of tables must not affect the operation of the application.
NFR16	Supportability	All application upgrades (including changes to the database structure and code) must be fully reversible until the next upgrade, i.e. the upgrade must be accompanied by the means and procedures to roll back the upgrade.
NFR17	Supportability	Input control on both the front-end and back-end. Important inputs must be checked (cleaned) (also) on the server-side.
NFR18	Supportability	Logs are written in English.
NFR19	Supportability	Security-critical events (logging in, logging out, role change(s)) and activities with financial or legal consequences are logged in a separately configurable security log.
NFR20	Usability	The system should support at least two last versions of Chrome and Edge
NFR21	Usability	The dates are written in the form YYYY-MM-DD. Example: 2nd June 2012 write as 2012-06-02.
NFR22	Usability	Times are written in the format hh:mm:ss, where he follows the 24-hour time format.
NFR23	Usability	If there is no web browser support, the application will give an error message. If the user interface which the user is accessing is not compatible with the web browser used, the application must inform the user in a clear and instructive manner.
NFR24	Usability	Use clear, consistent, human-readable web addresses (URLs).
NFR25	Usability	Each page must have a unique web address.
NFR26	Usability	Fault and other notices must be clear.
NFR27	Usability	Error situations must be provided with error codes. The error code shall be provided to the user together with the error message.
NFR28	Usability	Exiting the system must be done in an explicit, clear, and secure way for the user.

NFR29	Usability	A user can leave the system in two ways: his session is longer than a configurable limit for the session length or the user terminates the session on his initiative.
NFR30	Usability	Application logging must be organized using standard tools in a way that allows the application administrator to define and modify the log output (at least file, database, Syslog), the logging level,a nd the logging format.
NFR31	Usability	Interrupted processes should be able to be resumed
NFR32	Usability	The System user interface should follow the design system of The Company

5.3 Use a case diagram

Requirement management is important. If it is not done on a necessary level, it may have a detrimental effect on the reliability, cost, and safety of the developed system. The cost gets much higher when a mistake needs to be corrected during or after development [42].

Use case diagram provides a useful communication tool between developers and end-users. It allows the end-users to grasp the functionality in an easily understandable form and give feedback where necessary [42].

A use case represents a unit of functionality that a system, subsystem, or class performs together with one or more outside actors or systems. An actor represents the role that an entity may play when interacting with the system. A use case diagram visualizes the relationships between use cases within a system or between use cases and actors. A use case is visualized as an ellipse [17].

As part of the system analysis, the author created a use-case diagram with the sole purpose of acting as a communication tool when discussing functionalities with end-users or developers. Use cases were not described as the author considers them to be area duplication of user story descriptions. The use-case diagram is visualized in Figure 12.

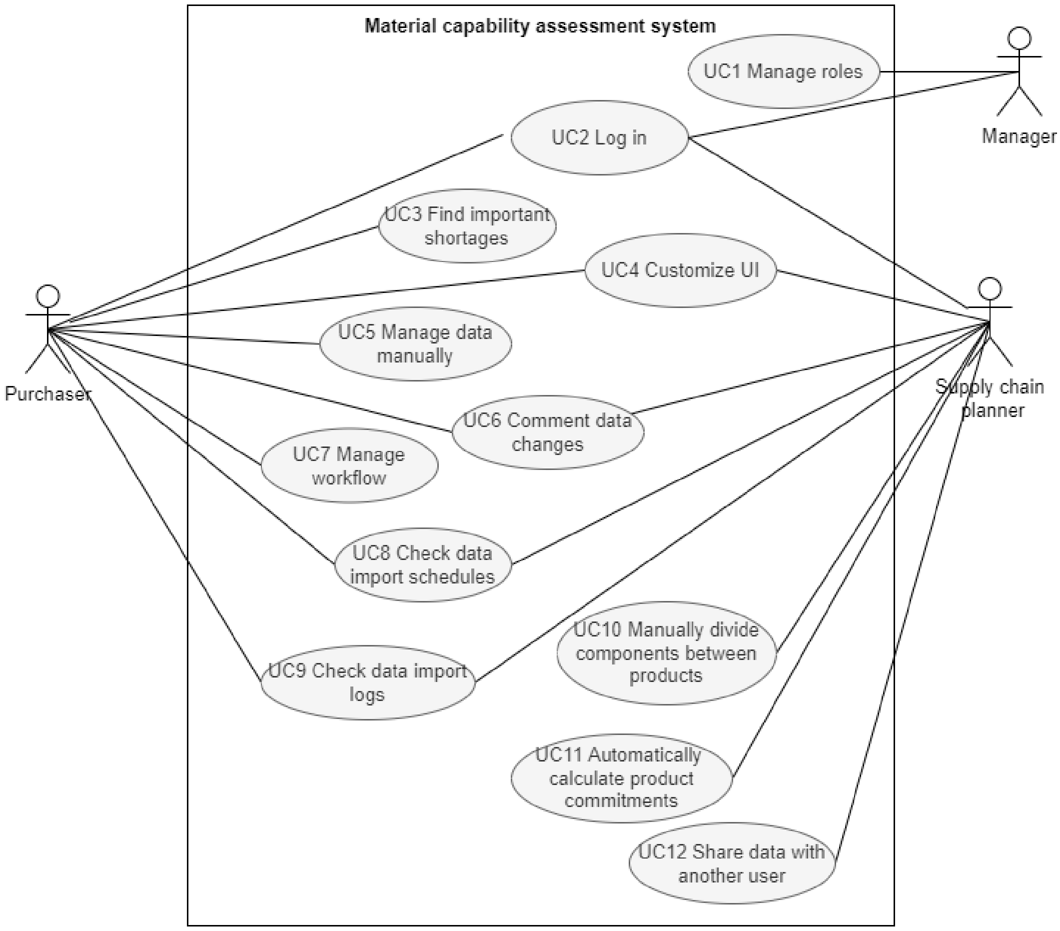


Figure 12. A use case diagram for the Material capability assessment system

On the use-case diagram, the functionalities that were assessed to be in the MoSCoW „Must-have“ category are visualized. There is an added role for the managers, who can log into the system and assess data when necessary but they are the only role in the system that can manage roles for the end-users.

5.4 Business impact analysis

The impact of implementing the changes and developing a system corresponds to multiple strategic goals. To visualize the changes to the main value stream, and goals the author created another SIPOC diagram with a TO-BE SIPOC description. This is shown in Figure 13.

S	I	P	O	C
Suppliers	Inputs	Process	Outputs	Customers
Material capability assessment system	prognosed shortages	1. Assessing material needs Automate processes; Simplify work for employees; Increase data transparency in the supply chain; Improve efficiency in supply area	Actual component demand, possible suppliers	ERP system, purchasers
Material capability assessment system	proposed solutions for shortages	2. Buying components Automate processes; Simplify work for employees; Increase data transparency in the supply chain; Improve efficiency in supply area	Delivery time, components	Production
Suppliers, ERP system	Estimates from suppliers, order confirmations	3. Managing the delivery of components Increase data transparency in the supply chain	Components delivered on time, Improved delivery confirmation information	Production, supply chain planners
Material capability assessment system	Calculated product commitments	4. Planning production resources Automate processes; Simplify work for employees; Increase data transparency in the supply chain; Improve efficiency in supply area	Production capacity requirements, HR needs	Production
Supply chain planners	Production quantities,	5. Schedulling production	Production plan	Production
Suppliers	Components, production orders	6. Producing products	Products	Customers
Production	Products	7. Testing	Quality-approved products	Customers
Production	Tested products	8. Packing	Safely packed end-products	Customers
Packing facility	Packed products	9. Delivering end products	Safely and on time delivered end-products	Customers

Figure 13. TO-BE SIPOC analysis for the main value stream with strategic goals

The proposed solution would allow simplifying work for employees by removing unnecessary and dull work and improve efficiency by reducing work hours that are spent on unnecessary steps in the process. As the automated system collects data from different systems and allows manual data entry, it keeps all the useful data in one place and as a result, increases data transparency in the supply chain. Subsequently, the automation of this process would align with another strategic goal, process automation. In SIPOC terms, the new system will now become the only information supplier for assessing the material needs. As a second quality, it would allow purchasers to quickly understand who to contact for improvements in case a shortage is happening. The third change would raise the data quality for components being delivered. Finally, there would be an improvement that automates some of the product commitment calculation and this is an input for the production resources planning stage.

One of the proposed outcomes for these connected strategic goals would be the reduction of work hours by 90% which corresponds to the activities of finding correct data and communicating inside the company. Data access would allow around 70% of material commitment calculation to be done automatically, further reducing the number of hours spent, this time on material capability analysis.

Financial impacts are calculated and shown in Table 8 and Table 9. Calculations use the previous cost-related data from Table 1 and Table 2 as inputs.

Table 8. Estimated financial impact per one supply chain planner calculated based on Estonian average cost per employee

Activity	**Yearly hours spent before the implementation**	**Cost (EUR)**	**Yearly hours spent after the implementation**	**Cost (EUR)**	**Impact**
Finding which components have important shortages and when	300,6	3869,9	30,1	387,0	3482,9
Inner communication about the material shortages and solving them	493,5	6354,0	49,4	635,4	5718,6
Performing material capability analysis to calculate product commitments	741,3	9544,0	222,4	2863,2	6680,8
SUM	1535,4	19767,9	301,8	3885,6	15882,3

Table 9. Estimated financial impact per one purchaser calculated based on Estonian average cost per employee

Activity	**Yearly hours spent before the implementation**	**Cost (EUR)**	**Yearly hours spent after the implementation**	**Cost (EUR)**	**Impact**
Finding which components have important shortages and when	168,6	2170,3	16,9	217,0	1953,3

Inner communication about the material shortages and solving them	316,8	4079,1	31,7	407,9	3671,2
SUM	485,4	6249,4	48,5	624,9	5624,4

As seen in the tables, the potential yearly impact of the changes would be EUR 15882,3 for a supply chain planner and EUR 5624,4 for a purchaser. They are calculated on the assumption that the time spent on the first two activities – shortage finding and communication – will be reduced by 90% and the time spent on material capability analysis, which is done only by supply chain planners, would be reduced by 70%.

Implementing this solution is fully in line with Six Sigma values, as development projects are often selected on the basis that they align with strategic goals.

5.5 Risk analysis

The Company is ISO 27000 certified and this means that a risk analysis is mandatory for all development projects. As the connected data – risks, controls, treatment plans, and supporting documents – are considered confidential in The Company, the results of this risk analysis can not be shared in this thesis.

6 System design

6.1 Business information model

Conceptual data modeling allows for the representation of real-life data. It is done to have a system that fulfills user needs better, is less error-prone, and is better at adjusting to changing user requirements. Conceptual data modeling is easy to understand and adapt [43].

To be able to create the conceptual data model for the supply chain management area, the author collected the business rules and validated them with stakeholders. The business rules are shown in Table 10.

Table 10. Business rules in the supply chain management area

ID	**Business rule**
BR1	One supply chain planner manages one or many products. One product is managed by one supply chain planner.
BR2	A product has zero or one or many demand quantities. One demand quantity always connects to one product.
BR3	A product is made of zero or one or many subassemblies. One subassembly is used in one or many products.
BR4	A product is made of one or many components. One component can be used in one or many products.
BR5	A subassembly is made of one or many components. One component can be used in zero or one or many subassemblies.
BR6	One purchaser manages one or many components. One component is managed by one or multiple purchasers.
BR7	One purchaser communicates with one or many suppliers. One supplier is managed by one or many purchasers.
BR8	One supplier supplies one or many components. One component is supplied by one or multiple suppliers.
BR9	One supplier estimates zero or one or many forecast quantities. One forecast quantity is always estimated by one vendor.
BR10	One component has zero or one or many forecasts, One forecast is always connected to one specific component.
BR11	One supplier can have one or many component lead times. One component lead time is always connected to one specific vendor.

BR12	A component has one or many component lead times. One component lead time always responds to one component.
BR13	One component has zero or one or many purchase orders. One purchase order always has one or many components.
BR14	A component has zero or one or many demand quantities. One demand quantity always connects to one component.

These business rules were then used as a basis to create the business information model. It is a helpful tool for database design and creation. The business information model is shown in Figure 14.

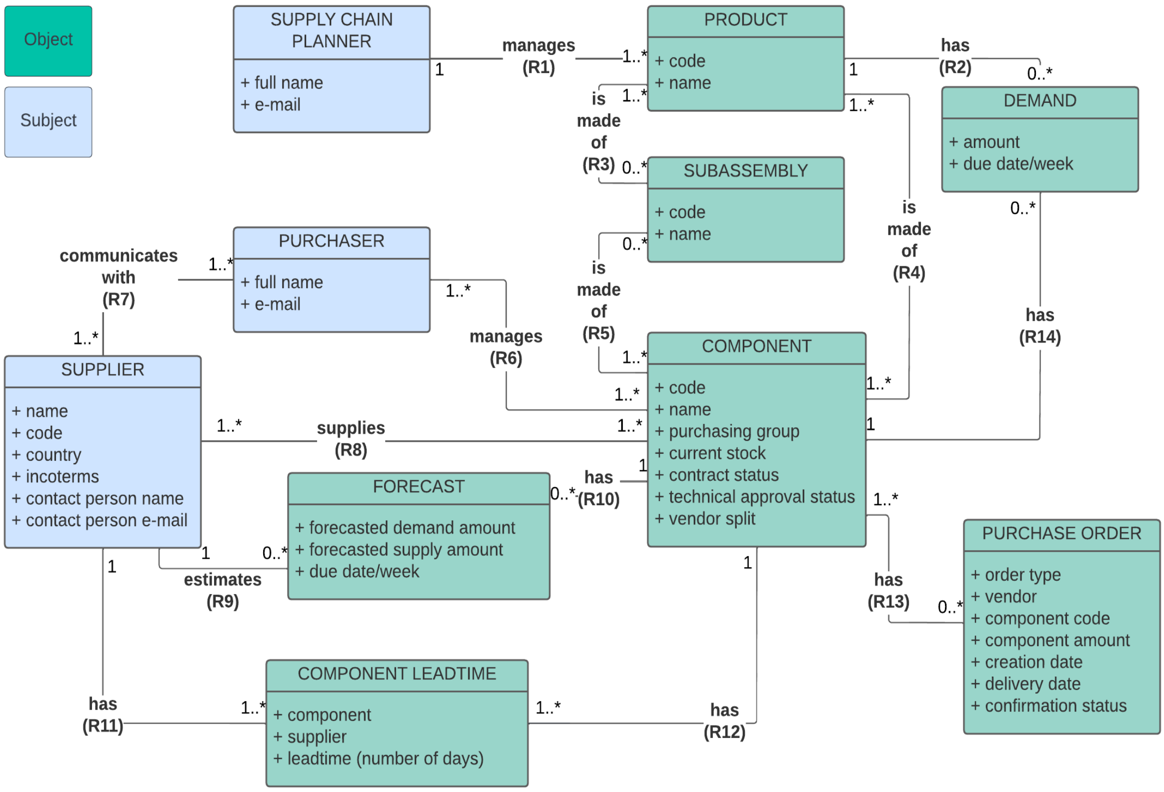


Figure 14. The business information model of the inbound supply area

The Business information model visualizes the main entities: subjects such as supplier, supply chain manager, and purchaser and objects such as product, component, subassembly, purchase order, forecast, demand, and component lead time.

6.2 Component diagram

A component diagram consists of a graph of software components that are connected by relationships. There can also be composition relationships that are then modeled by having components inside other components [37].

As a part of this thesis, the author decided to create an architectural vision to show how different systems should be connected, to acquire the necessary data to fill the main requirements of the system. In Figure 15, the main systems and connections are visualized.

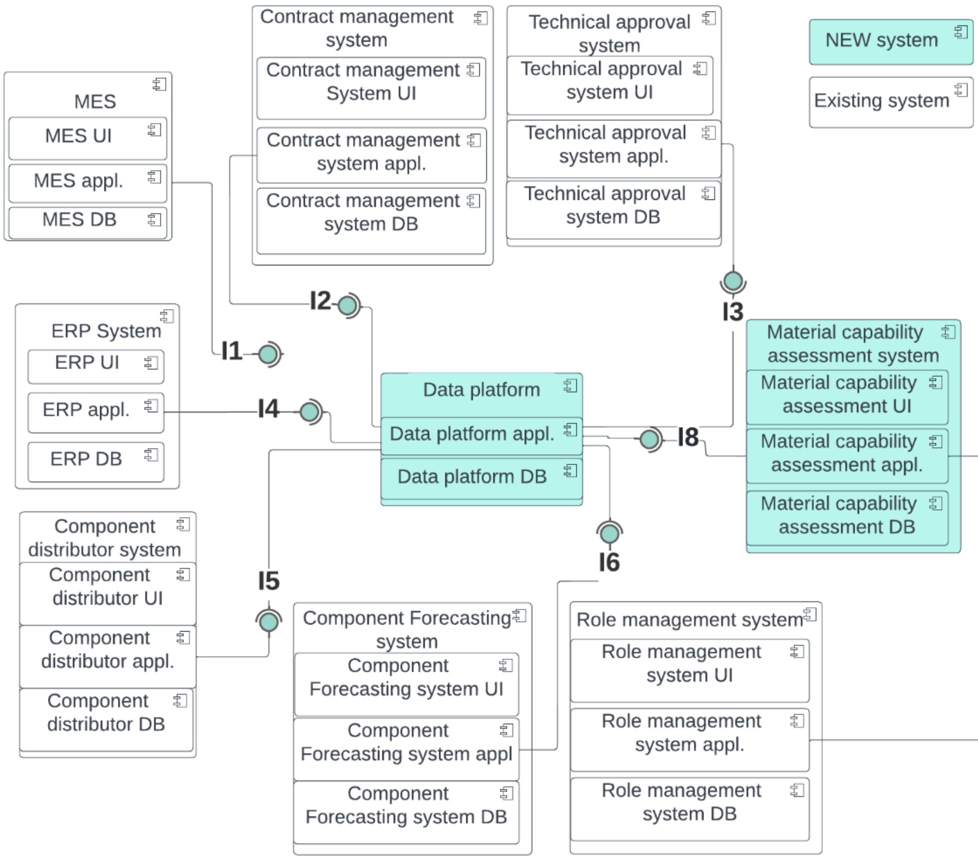


Figure 15. Component diagram for the proposed solution

As seen on the component diagram, part of the solution will be creating a Data Platform to collect and keep the data from different systems. The Material Capability Assessment system will then access the data with an API. The reason for this is that The Company does not allow local tools or developments to keep large quantities of sensitive data in their database. The second reason is that the same data needs to be used for other development projects as well and integrations with connected systems are not easy to develop. The author cannot go into details on this matter as it would give out too much information about the systems that The Company uses.

The data that the Data Platform will collect is briefly described in the integrations overview in Table 11.

Table 11. Proposed integrations between systems on the component diagram

ID	Data	From (system)	To (system)
I1	Latest material movements	MES appl	Data Platform appl
I2	Procurement contract status, contract type	Contract Management System appl	Data Platform appl
I3	Technical approval status	Technical approval system appl	Data Platform appl
I4	Product master data, Bills of Material (BOM), component master data, component stocks, inbound components, component demand, vendor master data	ERP appl	Data Platform appl
I5	Planned stock movements, component balances	Component Distributor system appl	Data Platform appl
I6	Vendor supply forecasts, component stocks and demands	Component Forecasting system appl	Data Platform appl
I7	User role, first name, last name, e-mail	Role Management System appl	Material Capability Assessment System appl
I8	Masterdata and BOMs, vendor master data, component stocks and movements in all systems, contract status and type, technical approval status	Data Platform appl	Material Capability Assessment System appl

When the data platform has been developed, the Material capability assessment system will be integrated with the data platform to access the necessary data using API-s.

6.3 Prototype

Prototyping is a process during which teams draw out their ideas visually, either on paper or digitally. Prototypes are made to capture design concepts and test them on users. Prototyping allows to get feedback and to refine ideas before development starts, thus lowering the development costs that add on if mistakes are made [44].

Prototyping allows to give a clear picture to all the stakeholders of the benefits, costs, and risks. It fosters ownership among the stakeholders [44].

There are different fidelity levels when prototyping. Fidelity shows that level of detail and functionality. The level usually depends on the development stage. At the beginning of development, it is useful to start with a wider views and a low-fidelity prototype.

When development has already started, the higher fidelity prototypes can be used to capture all the small details of the user experience. Low-fidelity prototypes are easier to create and lower in cost, while high-fidelity prototypes allow for a more engaging understanding and therefore better feedback [44].

As a part of this thesis, the author created a few prototype views for login, component shortage search, data input, and data import log checking. These views were added to Appendix 4.

7 Conclusions

The main results of this master's thesis are as follows:

1) An analysis of the main value stream and strategic goals was performed to highlight the business capabilities that need to be improved.
2) An analysis of two current processes was performed to reduce waste and simplify the process for the end-users. As a result of the analysis, two improved processes were proposed to The Company.
3) Business requirements for an automatic system were gathered.
4) Possible options for automating the processes were considered, and a suggestion was made to develop a system inside The Company.
5) System requirements were gathered and prioritized.
6) A use case diagram was created for easier communication between stakeholders and the development team during the development phase.
7) Business rules were clarified and visualized on a Business information model to create a basis for database design.
8) Systems were visualized on a component diagram, creating a planned architectural vision of the systems.
9) System integrations were mapped and data was organized to create an overview of the system integrations that need to be developed.
10) A few prototype views were added to visualize the vision of the solution.

The research questions for this thesis were as follows:

1) How to improve the material capability analysis and supply improvement processes?
2) Is a software solution needed for making the processes more effective and if yes, what requirements should that solution fulfil?
3) How does the business process need to change?

These questions got answered in the thesis.

The author found two ways for improving the material capability analysis and supply improvement processes. Part of this improvement is changing the processes in a way ttat removes waste from the process. The proposed solution was visualized in the TO-BE process models. Changing the process should result in supply chain planners spending less time looking for material shortages. The second part of the proposed change is automating the process in order to further reduce time spent in finding the correct data and communicating about it.

As a result of the analysis done in this thesis, the author suggests automating the process by developing a system inside The Company. The requirements were clarified and prioritized in chapter 5.2. Main requirements for the solution are the ability to import data from different systems, to allow communication in the system and to be customizable in order to fulfill the needs in The Company.

As a result of the business process analysis, the author highlighted the steps that are considered waste in a business process and created a TO-BE diagram to visualize the new process and changes. Most important proposed change is moving the supply improvement and shortage checking fully on the role of the purchaser, removing the duplicating steps done between purchaser and supply chain planner. In the TO-BE process, purchaser starts supply improvement from the components in high priority products and continues with the components on regular products. When supply chain planner needs to check material capability, they will do so on the basis of the data left for them by the purchasers or, in case there is an automated system, the data will be automatically calculated and presented to them.

The business analysis in this thesis was performed in a company that has high expectations for confidentiality and brand representation. This sets limits to the information that the author was able to share.

The main parts of the thesis that had an impact from that:

1) While calculating the cost and impact numbers, the author replaced the actual complex employee cost calculation and salary data with a simplified calculation and Estonian average salary information in order to not share trade secrets.
2) Complex SIPOC and business capability maps were simplified to remove any specific information that would allow recognizing the company or learning trade secrets in case the company was already recognized.

3) Parts of the business problem description were removed as they would allow to recognize The Company. As the scope for this thesis stays inside The Company, this does not have an impact on the solution.
4) Risk assessment was planned and conducted during this project. As both methodology and results of the risk assessment are considered confidential, the risk assessment process has been left out of the thesis.

The outcome of this analysis supports the ongoing development of this system in The Company. The process change and development will go hand-in-hand as the automation supports the overall change.

Next steps in this project will include increasing the number on people in the current development team, mapping detailed integration possibilities with the mentioned systems and continuing with development of the data platform.

8 Summary

In the introduction of this master's thesis, the author gave an overview of the business problem. They also set up research questions to be answered, and defined the scope and limitations connected to writing this master's thesis.

In the second part, the author gave an overview of the frameworks and methodology that was used during this analysis.

In the third part, the author briefly described The Company.

In the fourth part of this thesis, the author analyzed the strategy and main value stream of the company and as a result, mapped business capabilities that needed improvement. The author also analyzed the current processes to remove waste. As a result, the author proposed suggestions for process change and mapped and validated business requirements for a technical solution. Alternative solutions were briefly discussed.

In the fifth part of this master's thesis, the author gathered and analyzed the system requirements, created a use case diagram for a good overview and easier communication and analyzed the business impact of the solution.

In the sixth part of this thesis, the author created a business information model to be a basis for database design, gave an architectural view with a component diagram and added a prototype to visualize the functionality even better.

In the conclusions part of the thesis, the author considered the main results of this analysis.

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Appendix 2 Workflow questionnaire for business value assessment

Welcome to this questionnaire.

I created the questionnaire with the goal of quantifying the business need for a development project. In the future, this data will be used to support the requirements for further development in cases where the need might not be obvious.

This questionnaire will in no way be used to assess your personal skill or workload. The connected question is to understand your time estimates better. I would still like to keep the answers not anonymous so I could ask some more questions if I see that they might be relevant.

Thank you in advance!

* Nõutav
* See vorm salvestab teie nime, palun sisestage oma nimi.

Questionnaire

For purchasers and supply chain planners
Please assess how much time it takes you to do the following activities at work on average.
I know that days can vary a lot. What also varies, is your product/component count/shortage count etc. That's why I would like to get as many people to answer the questionnaire as possible to get a good overview. When you answer, please think about the last 4 week period. The unit for this assessment is estimated hours per day on average. You can also answer with a percentage but then please use the % sign :)

1. Finding REAL material shortages
What is included: searching and filtering data, checks into Component Distributor System, checks into Component Forecasting System, checking Technical approval system for code differences.
What is not included: communication with vendors, other sites.

2. Communication about supply improvement inside The Company
What is included: calls, e-mails, chats, finding info in order to talk about it
What is not included: communicating with vendors, communicating outside The Company.

3. Choose your role in The Company
Supply chain planner
Purchaser
Muu

4. Please rate the validity of those statements
(Don’t agree at all, disagree a little, hard to say, mostly agree, fully agree).

> 4.1 I check multiple systems before I know if a shortage is real or not
> 4.2 I ask additional questions about information given to me
> 4.3 I am a new employee in my role (this is how you see yourself, there is no right or wrong answer).

Extra questions for supply chain planners
Please assess how much time it takes for you to do the following activities at work on average.

5. Performing material capability analysis in order to calculate product commitments
What is included: preliminary material capability analysis
What is not included: agreeing on priorities, simulating quantities for common components etc.

6. Please assess the current data quality in regards to you being able to fulfill your daily work needs.

7. Add a comment to the last question if necessary.

8. Please rate the validity of those statements
(Don’t agree at all, disagree a little, hard to say, mostly agree, fully agree).

> 8.1 In the communication sent by purchasers, I have enough information to not contact them separately or find additional information myself.
> 8.2 Data from comments is easy to take into account when doing material capability analysis.

9. If you chose one or multiple options with disagreement in the last question, please mark down the info you would like to ideally have - think out of the box here.

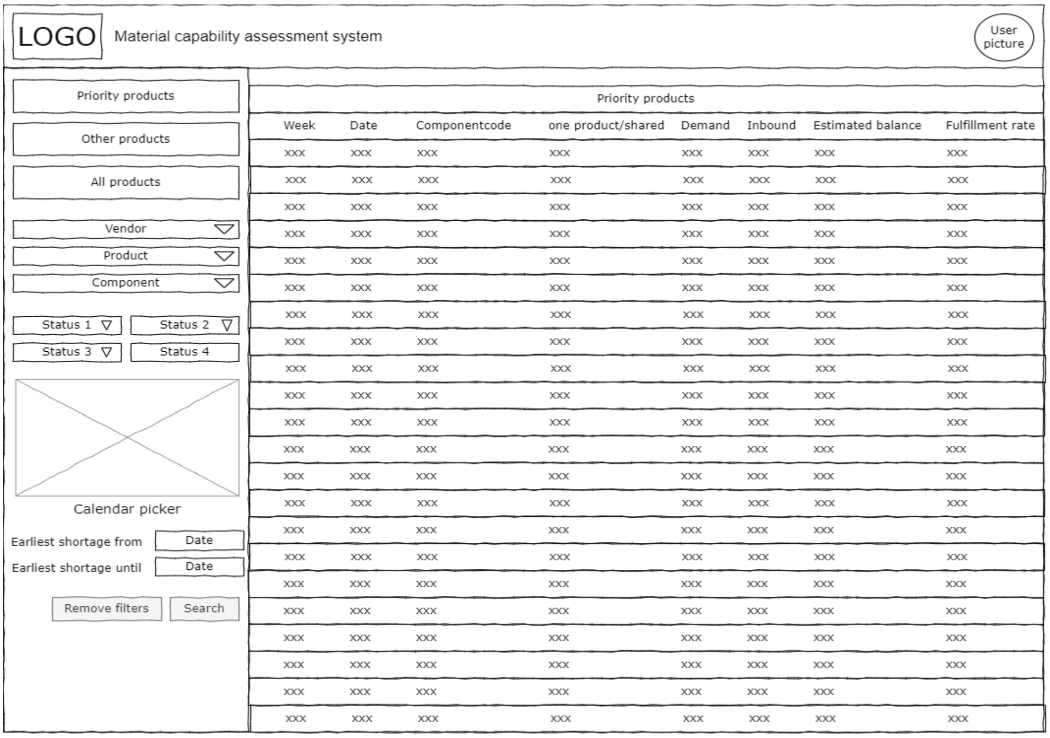
Appendix 3 Functional requirements

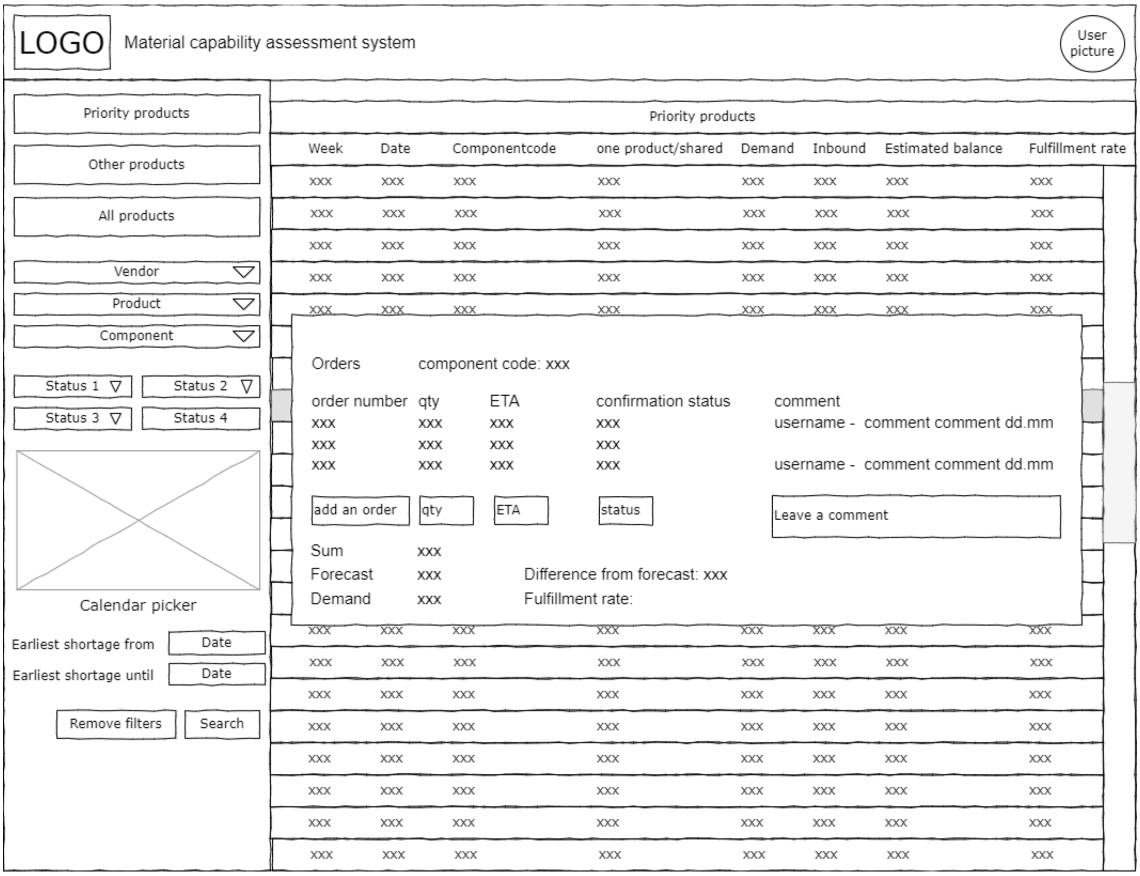
ID	MoSCoW prioritizarion	As a (role)	I would like to (goal)	in order to (reason)
US1	must have	user	have the system calculateprognosed component stocks and shortages	save my time calculating the numbers
US2	must have	user	have demand fulfillment rates calculated for all components on future periods	get an overview of material capability
US3	must have	user	substitute another employee in my role	take care of their responsibilities
US4	must have	user	log in into the system using my computer username and password	not have to remember too many passwords
US5	must have	user	see logs about data import runs	evaluate the data I see
US6	must have	user	use one system for all related information	not waste my time going through multiple systems
US7	must have	user	use the system to communicate with my coworkers, share data	keep all data in one place
US8	must have	developer	have the system log all user activities	allow for troubleshooting the issues
US9	must have	developer	have the system log all data imports/exports	allow for troubleshooting the issues
US10	must have	supply chain planner	divide all components to products based on the equal pain principle	I have a starting point for dividing components
US11	must have	supply chain planner	manually divide components into products	see, what are the other product combinations that can be built
US12	must have	purchaser	manage my workflow in the system	not repeat going trough the components one-by-one

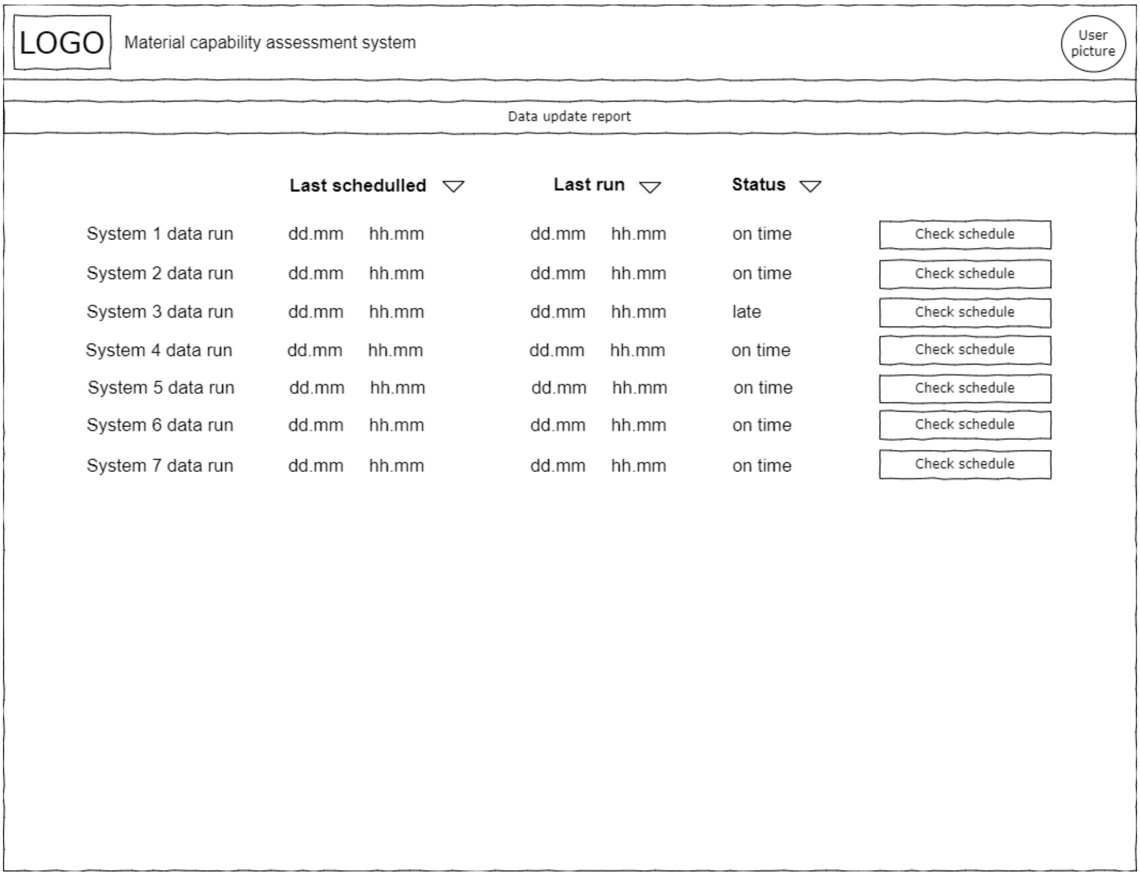
US13	must have	security manager	allow login only for active employees	fulfill safety requirements
US14	must have	security manager	allow role management for the system	keep data secure
US15	must have	security manager	have all actions in the system logged	keep data secure
US16	must have	security manager	have system fulfill the login requirements	keep data secure
US17	must have	security manager	have development, testing, and operational environments separated from each other	reduce the risks of unauthorized access or changes to the operational environment
US18	must have	security manager	have the same control mechanisms added to development and test systems as those in production environment	be able to use live data in these systems
US19	must have	security manager	have the system protected against malicious code	keep data secure
US20	should have	supply chain planner	share the estimated component stocks and shortages with outside stakeholders	not waste my time copying data into Excel
US21	should have	supply chain planner	share restricted access to the tool with outside stakeholders	allow outside stakeholders to analyse the data
US22	should have	supply chain planner	finalize the decisions about product commitment	keep the data in one place
US23	should have	supply chain planner	share data about the product commitment with outside stakeholders	do not waste time copying data into an excel file
US24	should have	user	choose how the data about shortages is calculated and what is taken into account	work through different scenarios
US25	should have	user	customize my user interface	not have to change settings all the time, wasting useful time
US26	should have	supply chain planner	get a good overview of what purchasers have done about improving supply	not waste time sending e-mails and messages

US27	should have	purchaser	have a place to mark down improvement steps in an easy way	not waste my time sending e-mails and messages
US28	should have	purchaser	comment on data changes done in the environment	reduce communication time by keeping data in one place
US29	should have	supply chain planner	get a good overview of how the inbound supply quantities have changed from purchasers communicating with vendors	not waste my time sending e-mails and messages
US30	should have	purchaser	have a place to mark down communication results in an easy way	not waste my time sending e-mails and messages
US31	could have	user	see information about data import schedules	know how often data is imported into the system

Appendix 4 Prototype views for the material capability assessment system




LOGO
Material capability assessment system
User picture
Priority products
Other products
All products
Vendor
Product
Component
Status 1
Status 2
Status 3
Status 4
Calendar picker
Earliest shortage from
Date
Earliest shortage until
Date
Remove filters
Search
Priority products
Week
Date
Componentcode
one product/shared
Demand
Inbound
Estimated balance
Fulfillment rate
Orders
component code: xxx
order number
qty
ETA
confirmation status
comment
username - comment comment dd.mm
username - comment comment dd.mm
add an order
qty
ETA
status
Leave a comment
Sum
Forecast
Demand
Difference from forecast: xxx
Fulfillment rate:


LOGO
Material capability assessment system
User picture
Data update report
Last schedulled
Last run
Status
System 1 data run
System 2 data run
System 3 data run
System 4 data run
System 5 data run
System 6 data run
System 7 data run
dd.mm hh.mm
on time
late
Check schedule