Tallinn University of Technology
SCHOOL OF ENGINEERING
Department of Mechanical and Industrial Engineering

TALLINNA TEHNIKAÜLIKOOL

ERP AND ADVANCED PLANNING AND SCHEDULING SYSTEM INTEGRATION IN STANDARD AS

ERP JA TOOTMISE PLANEERIMISE SÜSTEEMI INTEGREERIMINE ETTEVÕTTES STANDARD AS

MASTER THESIS

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Tallinn 2020

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Hereby I declare that I have written this thesis independently.
No academic degree has been applied based on this material. All works, significant viewpoints, and data of the other authors used in this thesis have been referenced.

25 May 2020.

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The thesis is following terms and requirements

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THESIS TASK

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Thesis topic:

ERP and Advanced Planning and Scheduling System Integration in Standard AS

ERP ja tootmise planeerimise süsteemi integreerimine ettevõttes Standard AS

Thesis main objectives:

1. Expanding the capabilities of SAF ERP system and connecting it with APS Preactor
2. Standard AS digitisation
3. Production planning efficiency growth

Thesis tasks and schedule:

No	Task description	Deadline
1.	To explore and describe the capabilities of the considered ERP and APS systems.	15 March 2020
2.	To develop the general structure for the data connection of both systems (IDEF1x method).	5 April 2020
3.	To describe and compare all steps for data using current and new approaches (DFD method).	19 April 2020
4.	To manage with a case study of new approach implementation.	3 May 2020
5.	To do a financial estimation of new approach implementation.	17 May 2020

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05.05.2020

TAOTLUS

Palun tagada Kristiin Bauer'i (tudengikood: 191652MARM) magistritöö „ERP süsteemi integreerimine APS süsteemiga tootmise planeerimise eesmärgil ettevõttes Standard AS" („Integration of the advanced planning and scheduling system with ERP in Standard AS company") konfidentsiaalsus ehk piirang lõputöö avalikustamiseks kuni tähtajani 05.05.2025 järgmistel põhjustel:

- Lõputöös esitatakse Standard AS-i varasemalt avaldamata materjale.
- Töö sisaldab olulisi ettevõtte arengut puudutavaid andmeid.
- Töö avaldamine võib konkurendile anda oma ettevõtte arendamiseks olulise eelise.

Lugupidamisega,

Priit Tamm

Standard AS

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PREFACE

The author managed to do the thesis as one part of the Standard AS production digitisation project, where she is included as well. It is essential to mention, that the author started working in Standard in the year 2014 as a technologist/process engineer. In 2017 she was offered to be a production planner and since the end of 2019 being as a manager of production planning, who is dealing with production development projects and planning and coordinating the Standard AS Tallinn factory.

This work is about the ERP system SAF and the Preactor APS integration process in Standard AS, which is one of the biggest Estonian furniture producers. Standard tried the implementation process of Preactor in 2017-2019, but the outcome was too time-consuming, demanding and inaccurate without an automatic route map generating possibility. This master thesis will help AS Standard to create the most optimal technological paths for different projects and its phases that meet the enterprise and its employee's needs.

First, to manage the goal of effective production planning system assumes the steps of the development of SAF. The technological path generation expects to list all the resources Standard AS manufactories has. In addition, adding the operational resources and workforce capacity, and considering the standard times of all the operations for calculating the total run time of the specific processes. The data obtained must be in a form that is importable to the production planning program SIMATIC IT Preactor APS Professional.

This thesis is done with the help of Tallinn University of Technology researcher Tatjana Karaulova, who helped the author to formulate the topic and to find precise title for the master thesis. Author of the view would like to thank her for her advice, support, and forbearance to supervise this topic. In addition, author wants to acknowledge the controller of Standard AS and one of its digitisation team member Tiina Tomson and also AS Sysdec developer Arvo Jägel for pleasant and welcoming cooperation.

From foreign countries, be obliged Columbus Lithuanian consultant Daiva Greičiūnė, whose support and help was essential in the implementation process of Preactor. Moreover, it could not be forgotten Standard AS and its management for the opportunity and trust to do the thesis with them and receiving the guidance it could offer.

Keywords: Advanced Planning and Scheduling System (APS), Enterprise resource planning (ERP), SAF, Preactor, Data modelling, master thesis

ABBREVIATIONS AND GLOSSARY OF TERMS

Abbreviations:

APS - advanced planning and scheduling

BOM – bill of materials

CASE - computer-aided software engineering system

DFD – data flow diagram

ERP - enterprise resource planning

IDEF1x – integrated definition for data modelling

PLC - public-limited company

SCA - sustainable competitive advantage

Glossary of terms:

APS is an advanced planning and scheduling system that aligns the production plan with objectives, prepares an optimal plan, transforms it into a production schedule, and establishes operational targets to meet the schedule.

ERP relates to being a type of software that organisations use to manage day-to-day business activities such as accounting, procurement, project management, risk management and compliance, and supply chain operations. A complete ERP suite also includes enterprise performance management, software that helps plan, budget, predict, and report on an organisation's financial results.

CASE is a software package that provides support for the design and implementation of information systems. It can document a database design and provide invaluable help in maintaining the consistency of a design.

The data model is a graphic and textual representation of analysis, which identifies the data needed by an organisation, to achieve its mission functions, goals, objectives, and strategies, and to manage and rate the organisation. A data model identifies the entities, attributes, and relationships with other data and provides the conceptual view of the data and its relationships.

DFD is a way of representing a process or an information system flow. The DFD describes the flow of information about the outputs and inputs of entities and processes.

Gantt chart is a horizontal bar chart to represent a schedule to help planning, coordinating, and tracking specific tasks in a project.

IDEF1x is a data modelling language for semantic data models development. IDEF1X gives a graphical information model to represent the structure and information within an environment or system.

Preactor is a planning tool in which can be modelled the processes and capacity and then work out a sequence in which to run the jobs.

Primary data is unprocessed data the system stores in the database. The user enters information that the computer starts to process.

The production module is one SAF module that consists of a purchasable materials list, producible products, manufacturing technologies, and a guide for packing the details and the fittings.

SAF is a business software that is customisable according to the company's needs to use it as an ERP system.

1. INTRODUCTION

1.1 Background

The purpose of most organisations is to be profitable and survive. To manage the purpose is necessary to fulfill in today's constantly changing economic environment and increasing global competition to gain a sustainable competitive advantage (SCA) (Reial, 2019). Standard AS (Figure 1.1) is in dignified age furniture producer whose ERP system is somewhat custom made and whose production plans have been done in Microsoft Excel for years. They face difficulties that require a very accurate assessment of production volumes and optimal production planning capabilities. As the volumes are increasing and products are more customised than ever, Standard AS is in a need of a production-scheduling program that is capable of managing its production volumes and does it in the unified system but still separately to all of the factories.

Figure 1.1 The newest logo of Standard AS since summer 2019

Standard AS has three factories. One of them, the Kose MV factory is situated in Estonia, Harju County in Kose and two others are located in Tallinn and are called Marja PMV (soft furniture factory) and Marja KMV (cabinet furniture factory). All of the machinery is listed under the general resources list. Production planning will take into account the production capacity of each. Also considers the resources and deadlines required to complete the incoming projects.

Standard AS started production planning with a particular planning program Preactor in 2017, but at that time, they had not finalised their ERP system SAF development as far as Standard's production planning software Preactor insists. In 2020, Standard AS have a possibility to give a push to the development process part in the SAF system. AS Standard's choice is to combine SAF and Preactor Scheduling to distribute the workload evenly between the factories and resources according to the production plan.

After the program development, the system should be able to detect and list all the resources Standard AS has in their manufactories. When adding operational resources, workforce capacities and standard operational times, this program should calculate the total run time of the specific processes. The data obtained must be in a form that is importable to the production planning program.

1.2 Standard AS sales overview

AS Standard is one of Estonia's longest-running brands, which started producing and selling furniture in 1944. (Standard AS, 2020) According to the consolidated annual report of 2018, the AS Standard Group consisted of the furniture production and distribution parent company AS Standard in Tallinn and two sub-companies, SIA Standard Latvia and StandardPro Rus in Russia. AS Standard shareholding is 100% in both companies.

In 2017, the AS Standard sales revenue was 27.3 million euros, which was 9.4% higher than estimated (25 million euros). In 2018, AS Standard hoped to get their revenue to 30.9 million, but they had to agree to fall short of the budget by 1.4%. None the less, Standard AS still finished the year 2018 with 9.3% turnover increase.

From the total sales revenue in 2018, 33.8% was hotel furniture and 21.5% office furniture. The sales of services were 14%, and the rest was home, school, and other project furniture sale. The higher sales revenue in 2017 increased budget overrun by 9.4% and 27.2% of the increase in turnover comparing in 2016. The budget of AS Standard for 2018 provided for a profit number of 1.97 million euros. The profit number in 2018 was 0.4 million euros which were well below the budget, due to one major failed project.

The company' selling forecast during a period is based on experience, an appraisal of consumer demand, and the economic value of products to be sold in comparison with the value and appeal offered by the competitors. It should be mentioned that economic value is not the same as price. It is a factor secured by balancing cost against intrinsic worth, utility, demand, and other elements. The overlook of the economic value of the product from different categories should not be omitted. (E.H.Mac Niece, 1961)

The majority of the group's turnover was by the sale of furniture and related services in AS Standard's domestic market, which generated for 34.1% of turnover, an increase of 1.38 million euros compared to 2017. The sales outside Estonia in 2018 increased by 1.23 million compared to 2017. As Figure 1.2 describes sales channels in total exports were: Finland 19.8%, Germany 10.1%, Sweden 6.3%, Norway 5.1%, Lithuania 4.8%, Ukraine 4.7%, Croatia 3.3%, Great Britain 3.1%, Denmark 2.1% and Latvia 1.9%. Intra-Community turnover was 87.7% of total turnover. (AS Standard, 2017-2018)

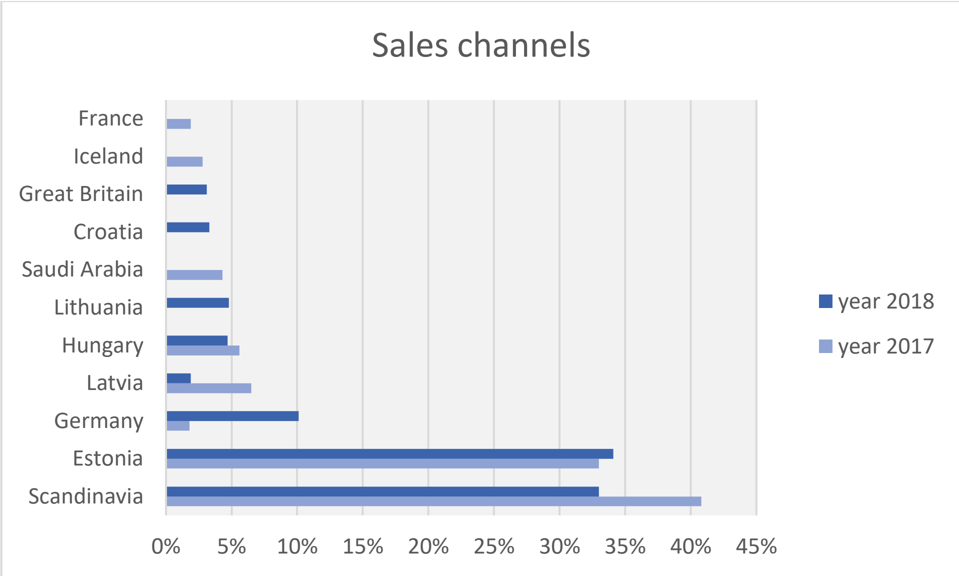


Figure 1.2 Standard AS sales channels and their growth and decline in 2017-2018

The total volume of investments in 2018 was 925.9 thousand euros. 93.3% of this were invested in buildings, machinery, equipment, means of transport, and into other equipment. The remaining 6.7% was spent on computing and software, as well as unfinished projects and advances. In 2019, AS Standard planned to invest 1.2 million euros. (AS Standard, 2017-2018)

In 2018, the sales of the products of Standard AS three factories were divided as 53.6% for the Marja KMV factory, 37.7% for Kose MV factory, and 8.7% for the Marja PMV factory. As could be seen, Marja KMV is the most profitable factory for AS Standard, and that is why the first step of Preactor implementation was held only there. The need for different development possibilities for the production at first took place in Marja KMV because these problems were also related to the need for project processing management capacity.

1.3 Problem identification

This thesis is one part of the Standard AS development and digitisation project. Its goals include production simplification, time efficiency and managing deadlines while increasing turnover and production throughput capacity. To be clear, Figure 1.3 demonstrates how digitisation could push the company's results in two directions. On the one hand, it is possible to improve the company customer experience and find new business opportunities to increase turnover. On the other hand, it allows digitisation to make existing processes more cost-effective to increase profits. The need for a superior system has appeared since the production volumes have increased and projects and orders have become more complex. Projects could include high variations of products and a wide range of materials that can be used in furniture manufacturing.

Figure 1.3 Main benefits of the whole digitisation process for AS Standard

Continuous improvement and development of production, including the maximum use of production planning capabilities, will enable Standard AS and its production facilities to be more environmentally friendly and cost-effective in their use of materials and costs. By developing the SAF production planner, i.e. technology module and integrating its results with Preactor, there should be capability to produce similar products simultaneously and process the same materials in one go. This process should help on reducing the amount of energy required for processing details without an optimal planning program, which also reduces the harmful impact on our environment and people.

The following also support the primary goal with more specific objectives:

- To plan production at least three months (according to price offers);
- To plan for coming deadlines and quantities for potential incoming orders;
- To prognoses a delivery of outsourced products and raw materials;
- To find the bottlenecks that limit consistent production flow;
- To allow quick rescheduling;
- To get a real-time overview of the status of the projects in production;
- To know and stay aware of the completion forecasts about ongoing projects and its items;
- To plan the time and resources of work stations;
- To evaluate mistakes and project planning discepanicies.

In 2018, Standard AS lost approximately 1.5 million euros due to one particular project that failed. This year Standard AS finished its year with a profit of 0.4 million euros instead of 1.9 million. If there were a functioning project and production planning system, the company would not have had to bear such a loss.

1.4 Objectives and tasks

The main objective of the current master thesis is expanding the capabilities of the existing SAF ERP system by connecting it with the Advanced Planning & Scheduling (APS) system Preactor in Standard AS enterprise.

To achieve this goal is important to analyse the following tasks:

1. To explore and describe the capabilities of the considered ERP and APS systems.
2. To develop the general structure for the data connection of both systems (IDEF1x method).
3. To describe and compare all steps for data analysing purposes with the current and the new approaches (DFD method).
4. To manage with a case study of new approach implementation.
5. To do a financial estimation of new approach implementation.

The Standard AS production development team has determined that integrating ERP and APS systems will increase the accuracy and efficiency of production planning from the previous 50% to 80-90% in the future. It also means that approximately 90% of the orders are delivered on time instead 75% before the effective planning possibility. In addition to that, the number of raw materials in the warehouse should decrease, because the material delivery should be simultaneously with the production start date. All of the above reduces the cost in production with modern conditions for producing custom-made furniture in small amounts according to clients' preferences.

1.5 Thesis structure

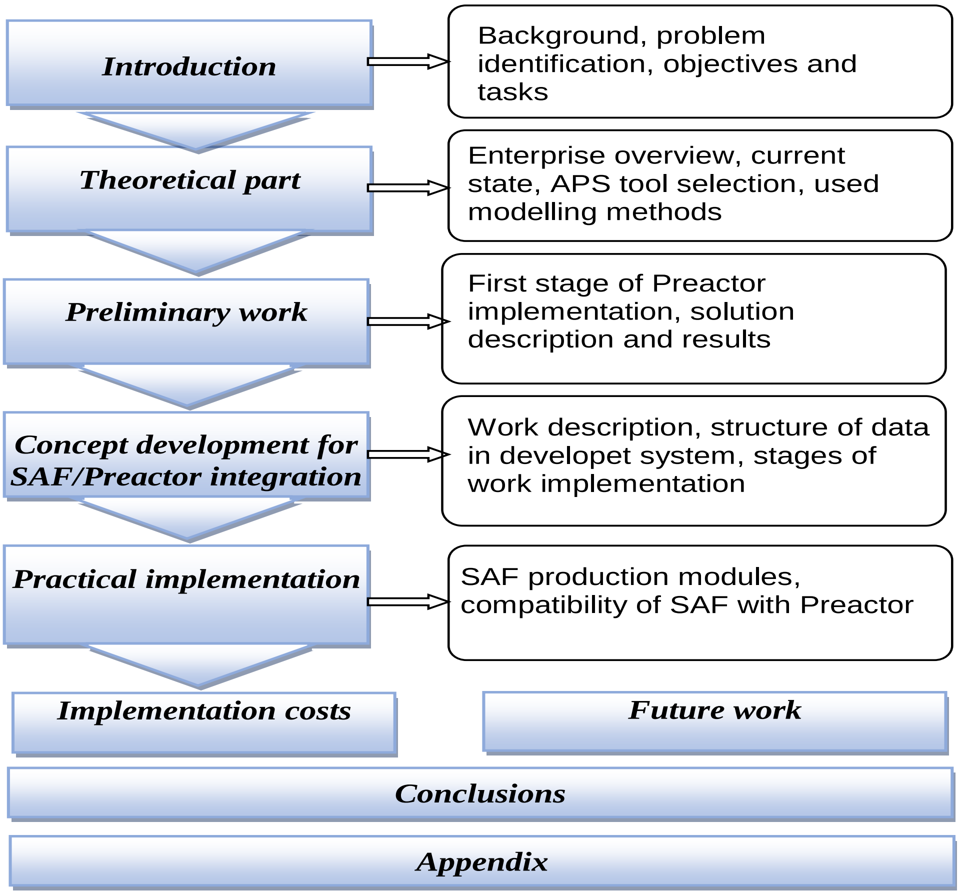


Figure 1.4 The overview of the thesis structure

The theoretical part of the thesis will give an overview of Standard AS and production over the past 75 years. That is why AS Standard came out with its new brand, which describes its excellence in every step. Furthermore, the SAF architecture, its modules, and work principles are taken out and analysed. It is also essential to have a brief overview of available production planning programs for AS Standard and why Preactor should turn out to be the right choice. At the end of the theoretical chapter, the author points out the different methods used in the work and structure analysis.

The whole thesis structure, with its progress, is visualised in Figure 1.4. The central part of this thesis starts with a preliminary work that was done with Preactor during its implementation. Additionally, the scheduling process will be defined in chapter 3. Through the whole creation, it must be considered that Standard AS three production plants must coordinate, but should be separate. The subchapter 3.1. will help to understand the need to coordinate between different production units. The chapter 3 sets forth the production planning step 1, i.e. the process of implementing Preactor in AS Standard in the years 2017-2018.

In addition, the steps that must be taken within step 2 are described in the SAF development phase. It also describes how the process should looks like once the ERP capability is ensured, and both systems are integrated. The author has used IDEFX1 and DFD methods to make the idea of data transfer between ERP and APS more understandable.

Concept development transfers the practical side of this task. In other words, the nature of the data exchange process is first outlined, and the systematic sequence of the whole data exchange is described. The part 4.3.1 i.e. blocks belonging to the SAF production module are described one by one. These are used to generate the data necessary for the production planning process. For example, all resources and operations used in AS Standard as production plants must be identified. The work includes a description of the procedures that form the basis of the various routes and technological sequences. From the information obtained from chapter 4.3, product groups generate technical maps for the project details. Among other things, the compatibility of information coming from SAF with the Preactor is described. This section finishes with a brief overview of the outcome of Preactor sequencing in the form of reports, which the production manager and the supervisors use to ensure a smooth workflow. The practical implementation of data exchange between SAF and Preactor follows and enables to see the whole process by different figures and tables.

Last but not least will be included the cost of AS Standard production planning system. It is already known that the main revenue lies in the reduction of indirect costs. The cost of transportation and delays should be reduced and the reputation of AS Standard as a reliable furniture producer as well as a partner could be improved.

2. THEORETICAL PART

2.1. Overview of Standard AS

AS Standards' history reaches back to the year 1944, when four men established an association based on a voluntary merger (in other words artell) called Standard. In 1957, the compan, built an experimental plant, which was later changed to the construction office. The output of Standard was home furniture, soft furniture, children's furniture, office furniture, kitchen furniture, and parlour chairs. Later, the company became the Tallinn Scientific Production Association Standard. lLimited Company (PLC) was founded in 1991, and renamed in 1994 to Standard AS after privatising. (Standard AS, 2020)

In January 1998, a large reorganisation began, intending to concentrate the entire production into two factories. It enabled to raise effectivity and considerably diminish the production-related costs. The production cycles also became shorter. In 2019, AS Standard announced a new brand concept to expand further to the external markets to remain competitive worldwide. (Standard AS, 2020)

Standard AS has two primary fields of business: providing full-scope interior furnishing solutions to hotels and delivering furniture for offices. The greatest strength and advantage of AS Standard over many competitors is the capacity to offer a turnkey solution. The team is responsible of everything from initial consultations and planning to production, procurement, renovation, delivery, and handover of the completed project.

Figure 2.1 References of the Standard AS projects around Europe, in Africa and in Arabian countries (Standard AS, 2020)

Most of the company's production is made for export, therefore Standard AS has sales offices in Estonia, Lithuania, Finland, Sweden, Germany, the Netherlands, and Russia. The main target area of Standard AS is Scandinavian countries, as well as Central Europe and Russia. Products have also been imported to the Middle-East in Western Asia and Africa. These references are described in Figure 2.1.

There are three different factories: for office furniture, for hotel furniture and the third one, is the soft furniture factory. Most of the office furniture is made in the factory of Kose. All the employees there belong to one large department. Standard AS Tallinn factory is one of the largest custom-made furniture production plants in the Northern Europe.

In the main building, there are four larger departments: selling teams, purchasing, design and construction and production department. For different development projects there are teams of specialists from various departments do manage them.

A professional project manager supported by a team of specialists deals with each project at AS Standard. For easier communication, AS Standard offers project management in seven different languages. They also offer a wide range of ready-made office furniture solutions designed by Estonian designers. AS Standard's furniture is manufactured at its own three production manufactories using modern and environmentally friendly technologies as well as high-quality materials. (Standard AS, 2020)

2.1.1. Current production planning in Standard AS

Standard AS has planned its production flows sketched on the paper or more analytically in Microsoft Excel spreadsheets by the Gantt chart. It has been done to increase productivity, to pay adequate wages, to ensure uninterrupted employment, increase workers and consumers satisfaction, and to get the sufficiency of return to grow and to ensure the stability of work. Standard AS is in dignified age - in different decades they have had to rethink their strategies. It used to produce orders according to the forecast for a push market and to the stock, but now AS Standard is more focused on filling customers' orders in the hotel solutions side while it still launches office design following push markets to stock strategies.

AS Standard has three differently oriented productions:

1) Marja KMV factory – produces hotel or office furniture according to the order;
2) Kose factory – produces furniture mostly for cruises and offices according to the order and sells office furniture that is delivered to stock.
3) Marja PMV factory – produces soft furniture for hotels, cruises, and offices according to the customer order.

2.2. SAF and its architecture

As an ERP system, Standard AS uses software called SAF, which is developed in the early nineties by Estonian software business company AS Sysdec (Sysdec AS, 2020). Stadard AS has been using SAF since 1994. The main implementation and customisation process got started already in 2003. Since then, they have been developing it slowly, and it has become company's main ERP system as well. At first, it was used for accounting and salaries, but in 2013, Standard AS started to generate the custom production module and started to use this part actively in 2015.

SME companies prefer to use standard type programs. However, if the need arises because of the company's increasing and complicated business process, they might require software support. What it means is that companies should consider either replacing or rebuilding existing software or investing into development processes. For the most part, a multiplex software SAF system consisting of different modules pays off for procedures that are more complex. (Alas, 2013) AS Standard chose to use SAF because it has extensive functionality, possibility to be customised according to the specific needs of the company. As SAF is an Estonian company located in Tallinn, it offers technical support and consulting in addition. Besides, it has interface capabilities with many systems and applications.

SAF architecture is based on multi-layer (n-tier) object model (Peterson, 2015), because it ensures the software to have the processing, data management, and presentation functions physically and logically separated. That means these different functions are hosted on several machines or clusters, ensuring that services are provided without shared resources. The "N" in n-tier architecture refers to any number. (Stackify, 2017)

The lower part of a multi-layer architecture consists of data objects and database interfaces. It combines the features of interacting with specific database engines, allowing the use of the same middle-layer business logic for entirely different databases. (Otsma, 2010) SAFs' database interface is implemented in the MS SQL server database, which offers support for transaction processing, business intelligence, and analytics applications (Sysdec AS, 2020). There are data collections in SQL that do not have physical location definitions with their addresses. Thus, there are no connections between the previous and next lines. Sysdec AS developer described that SQL allows the data query in a given order, but this order is not so permanent, because when the information is added, the whole query is scattered. SQL allows you to find data quickly that meets the given criteria because all data sets are interconnected. SQL makes working with SAF systemically complex but simple in terms of data management.

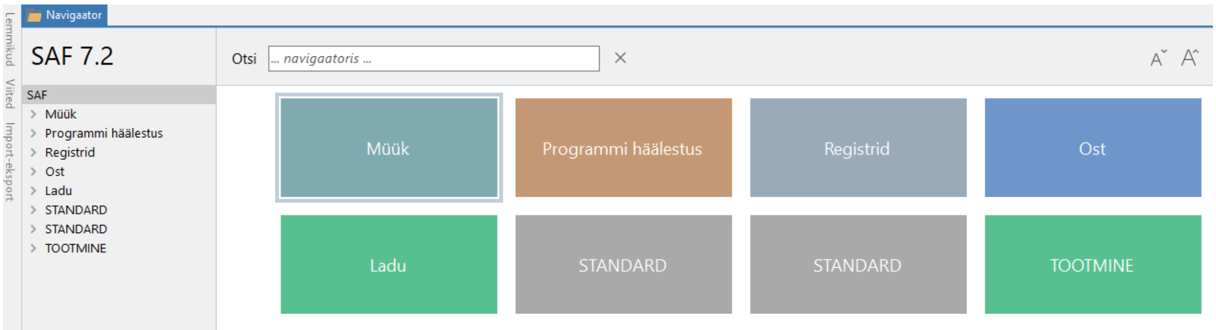


Figure 2.2 Modules that SAF 7.2 offers to use

SAF uses version 7.2 (Figure 2.2) and comprises of different modules (Peterson, 2015):

- accounting *(Raamatupidamine)* - preparation of various reports (e.g. balance sheet, income statement);
- fixed assets – e.g. accounting and depreciation of fixed assets;
- salary – e.g. payroll and vacation accounting, payroll taxes and reporting, staff documents.
- purchase and sales ledger *(Ost, Müük)* - purchase and sales invoices and bank and cash settlements;
- warehouse *(Ladu)* – e.g. movement of goods, adjustment of net cost;
- production *(Tootmine)* – e.g. resource reckoning, production orders;
- Registers *(Registrid)* are for different permanent data.

The general principle of the user interface is that all viewable documents, lists, reports. are gathered in one larger window, which forms the users' desktop, i.e. the Navigator. The menus, buttons, and status bar are similar to those of Windows applications. The navigator is a structure of data managed by SAF that allows easy and flexible access to it. The navigator has different folders and many subfolders. In addition to the subfolders, they naturally contain references to the forms representing the data (registers, reports, documents), when different sources are opened, different types of screen forms open.

As described by Figure 2.3, raw data of the information SAF system is entered into the program through purchases, sales, and orders. General data registers, such as goods, materials, taxes, customers, suppliers, are used for system compilation. Payment and receipt of purchase and sale documents can be monitored from the respective ledgers. Accounting entries arise from forms and accounting movements.

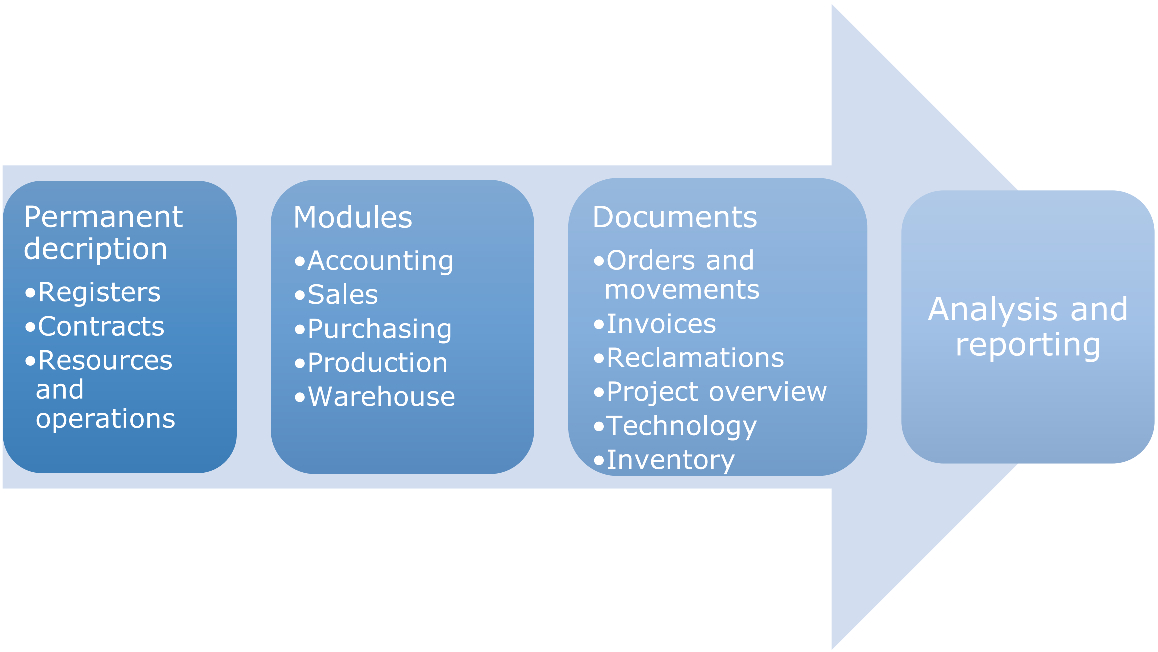


Figure 2.3 Management of registers, documents, and modules in the SAF 7.2 environment

2.3. Choosing the production planning program

Effective and efficient scheduling can give an organisation a competitive advantage via the faster movement of goods. In addition, resources are better used, which result in lower costs while adding additional capacity for speedier throughput. On the other hand, effective and efficient scheduling is not easy in manufacturing and stems from the fact that there exist the significant goals of short-term scheduling to (Myerson, 2016):

1) minimise processing time,
2) maximise utilisation of assets,
3) minimise work-in-process (WIP) inventory,
4) minimise customer waiting time.

A production scheduling decides which customer order, forecasted demand could be produced, and which resources are allocated to it and for how long period. The short-term scheduler determines the sequence of commands, putting the highest-priority orders' operations first. The process may involve making on-the-spot decisions such as interrupting a process and changing it or swapping it out for another. The short-term scheduler must redo the schedule without sacrificing capacity or output. (Myerson, 2016)

The wise choice of advanced planning and scheduling program could influence the time, efforts, costs, and the benefits that the implementation could offer. The main factors that need to be paid attention to before selecting and starting the implementation process of an APS system are data quality and availability, the use of IT systems, type and complexity of production and capability of the organisation.

The production planning program choice started with the need for help to optimise the allocation of raw materials and to fulfil the orders accordingly by fulfilling the production capacity. AS Standard as a custom furniture factory produces small batches, in different materials and uses various technologies. Therefore, it requires advanced planning functionality.

"APS software integrates with manufacturing execution systems to deploy production plans on the shop floor. Integration with ERP systems is also required to exchange information on demand, inventory, and production." (G2, 2020) If the data is already available in the ERP system, the data extraction can be easier to manage, but modelling the data during the process is feasible as well. Figure 2.4 visualises the flow of information from the ERP system to Preactor and after the planning process to Excel to "ask" about produced orders from the ERP system. After the Excel data refreshment, same orders will be imported back to Preactor.

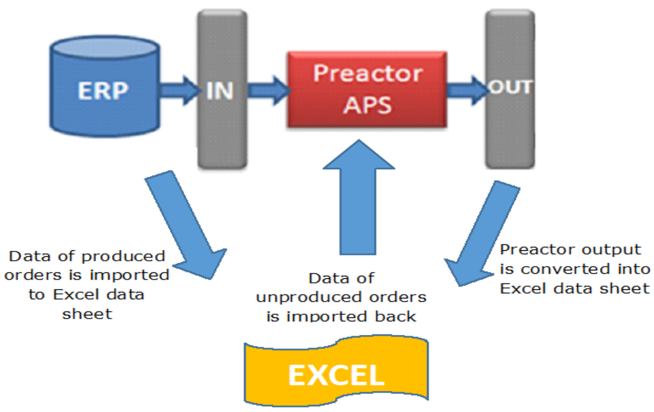


Figure 2.4 Information flow from ERP to Preactor and after the data refreshment back to Preactor APS

AS Standard management and digitisation team, chose to add a planning and scheduling program to ERP, by integrating it to ERP via Microsoft Excel tables. This way of linking two systems with each other came to the agenda due not to pause one's work if the other one has a breakdown or when an error occurs.

It must be said that, alternatively, instead of Preactor, there were two other programs AS Standard considered to use, but none of them was according to AS Standards' needs and did not meet the requirements.

2.3.1. Intelligent and adaptive systems

"Industry 4.0 allows for a combination of intelligent and adaptive systems that use shared knowledge among diverse heterogeneous platforms to make computational decisions (Leitão et al., 2016; Leitão et al., 2015; Vogel-Heuser et al., 2015). These types of systems focus on the integration of computation with physical processes (Lee & Seshia, 2016; Leitão et al., 2016), including the coordination, monitoring, and control of physical operations and engineering systems, integrated through a computing and communication core (Boulekrouche et al., 2016). Integration opens up new possibilities for the industrial sector. For instance, the Job Shop Scheduling Problem (JSP), which is one of the traditional dilemmas in industry, as well as one of the most difficult manufacturing problems (Asadzadeh, 2015), can now be tackled dynamically." (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018)

The process data will be provided by bar code technology as well as computing units at each machine of the production system. Planning data might come from the central Enterprise Resource Planning system (ERP), i.e. SAF. New production orders are created in the ERP system based on customers' demand (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018). Each newly released production order and its details circulate in the factory with a bar code tag. By using bar codes, points can be detected, individually identified, and it can store individual information being available easily and insufficient time (Grüninger, Shapiro, Fox, & Weppner, 2010). In this way, parts and sub-assemblies can store priority values as well as their needed production steps, which they receive from the ERP system through detail scanning. According to the priority values, each product pursues its way through the production system. In this way, production data can be collected and managed in a precise, complete, and real-time manner (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018).

When the master production schedule is set, detailed planning follows. From production routings, a record of necessary manufacturing information and bills of materials is tabulated for machine-load charts, equipment, personnel, and material requirements. Production planning helps to seek in the future whether the equipment of hand is adequate for the work that should be done or the parts or operations should be subcontracted (E.H.Mac Niece, 1961) from other factories of AS Standard or ordered outside the company.

2.3.2. Advanced Planning and Scheduling (APS) Systems

Lean systems tend to be manually intensive and sometimes become disconnected from a company's planning systems. Advanced planning and scheduling (APS) system can fill the gap between ERP systems and Lean thinking. It can manage time, react to changes at the operation level, and still create a schedule that synchronises multiple constraints. An APS system is for a manufacturing management process by which raw materials and production capacity are optimally allocated to meet the ordered demand. APS is especially well suited to environments where simpler planning methods cannot sufficiently address complex trade-offs between competing priorities. Production scheduling is complicated due to the interaction of limited capacity and the number of details to be manufactured. In most cases, flexibility, scalability and genericity are essential requirements, including the ability of the APS to produce optimised results and handle realistic, complex data sets. APS systems having advanced artificial intelligence methods are the only way to achieve big benefits. (MangoGem, 2020)

Planning and scheduling in a global supply chain require the coordination of operations in all stages, so the models and solution techniques have to be integrated within a single framework. Separate models that represent successive stages in the supply chain have to exchange information and interact with one another in many ways. For example, a continuous model for one set may have to interface with a discrete model for the next stage. (Myerson, 2016)

The difference between planning and scheduling software is that planning systems are "bucketed" (monthly, weekly, and daily) and do not maintain operation sequences within the time bucket. Scheduling systems are "bucketless" and have sequencing; they can generate schedules, that could use a shorter time horizon and more detailed process route than does a planning system. Scheduling the main objective is to allocate and prioritise demand to available facilities most effectively and efficiently. (Myerson, 2016)

The differences in planning and scheduling and their bucketed or bucketless entity are visualised by the SNic Solutions in Figure 2.5. It is mentioned that the preferred sequence is green, blue, and red to have the shortest setup time. If the planning system is filled with an order after another regardless of their ideal sequencing, the scheduling changes their arrangement into the most optimal to decrease the setup time and get more capacity out from it.

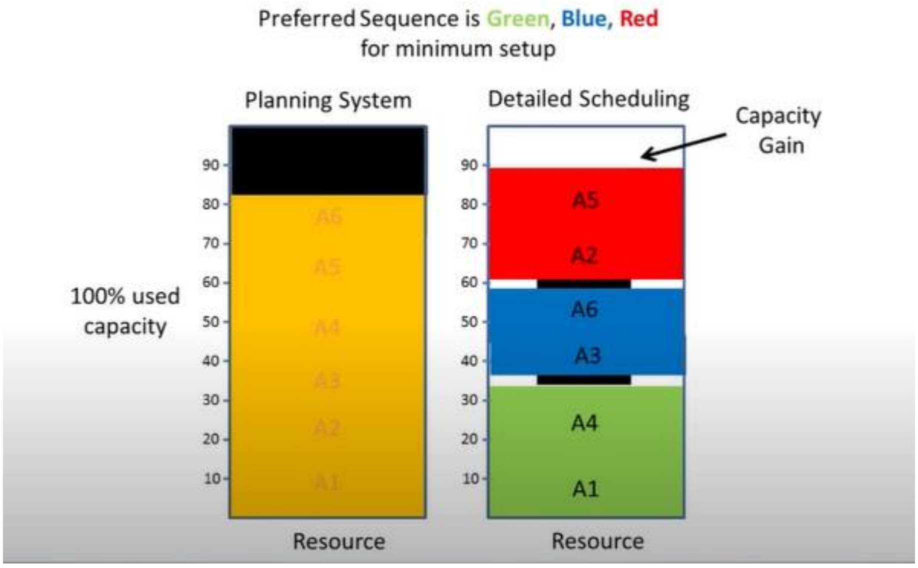


Figure 2.5 The difference between a planning and detailed scheduling system: A1 – A6 visualises details batches (SNic Solutions, 2020)

Finally, APS should take care of the maturity of an organisation. Implementing an APS is a time-consuming effort. During the implementation process, the need to manage the change and skilled people are required. Nevertheless, the APS implementation process is also the best way to improve efficiency and competitiveness (MangoGem, 2020).

2.3.3. Planning software from the United States

The most suitable next to Preactor was Schedlyzer by Optisol from the United States in Texas. The Gantt chart visualises the Schedlyzer production planning desktop as taken out in Figure 2.6. Schedlyzer describes it as an ideal tool for production scheduling in high-mix, low-volume environment. It promises to extract the best production performance from the existing resources first. Subsequently, it helps to find and implement the most cost-effective changes to the system one by one for improving production performance. It identifies constant and temporary bottlenecks in production and supports proactive capacity planning to mitigate the bottlenecks. It could also help with lead-time control, on-time delivery, order priority changes and acceptance of order growth. (Optisol, 2020) Production could consist of two types of alternation (Optisol, 2020):

1. Result of uncertain events and uncontrollable natural causes in the system including errors in estimated process times of operations, interruptions in resource availability and material delays
2. Large, known variation in process requirements of diverse orders.

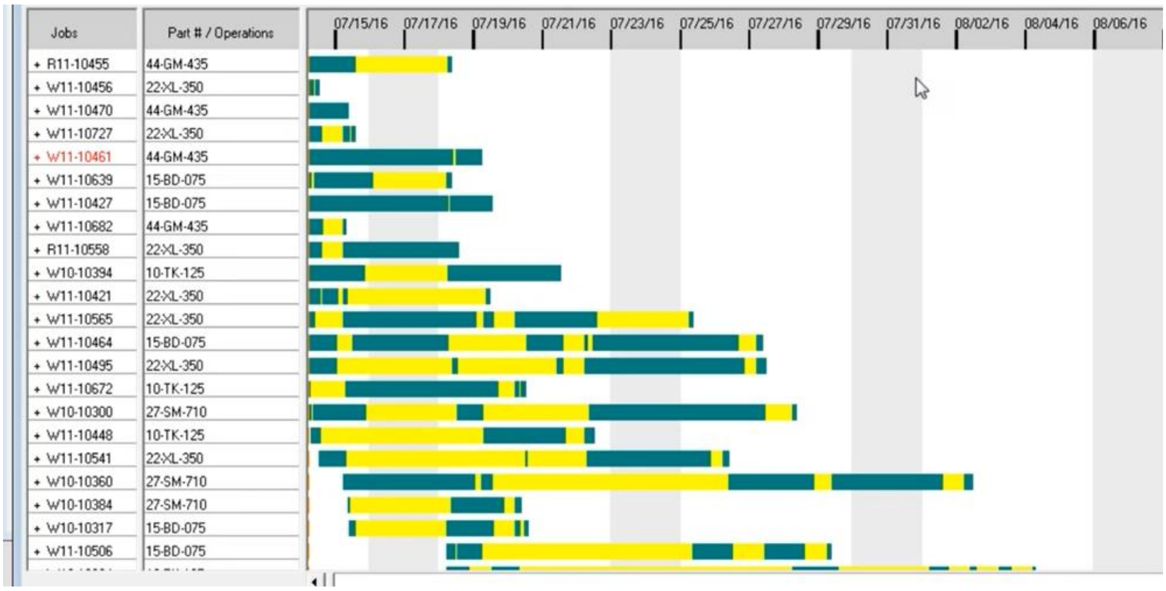


Figure 2.6 The Gantt chart of Schedlyzer desktop (Capterra, 2020)

Schedlyzer efficiently should handle both types of variation by taking in all relevant data and allowing job-waiting times to some extent at bottlenecks. Development of Schedlyzer is based on the premise that control and management of job shop production will be more efficient with the help of (Optisol, 2020):

- Operations scheduling with maximum synchronisation,
- Reliable prediction of workflow, job completion times and bottleneck formations,
- What-if analysis of production,
- Proactive capacity planning,
- Intelligent decision support to managers,
- Capable of quoting rational lead times for new orders.

Schedlyzer supports the objectives of maximising on-time delivery, throughput and overall resource productivity and minimising WIP, production lead times. (Optisol, 2020) Program main features are mentioned in Figure 2.7, and the most essential of them are automatic scheduling, what-if analysis and capacity planning, but it does not offer quality management nor MRP (Material Requirements Planning) support (Capterra, 2020).

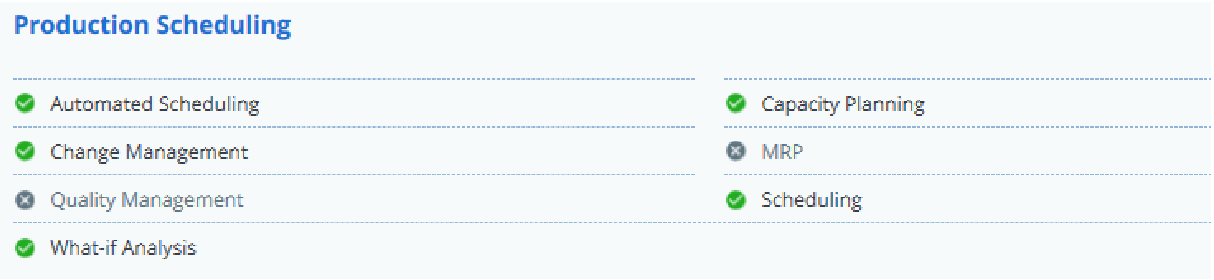


Figure 2.7 Schedlyzer main advantages and disadvantages (Capterra, 2020)

Schedlyzer is most appropriate for scheduling high-variety production and project-oriented production like fabrication. It describes it as the most economical and powerful scheduling tool for job shop production (Capterra, 2020). According to the CrowdReviews, the Schedlyzer is evaluated as 29th production planning software all around the world (CrowdReviews, 2020). It has to be mentioned, t it would have been the first choice for AS Standard, but the client support was not enough for the implementation and customisation process, and therefore it was not selected..

2.3.4. Japanese software Asprova

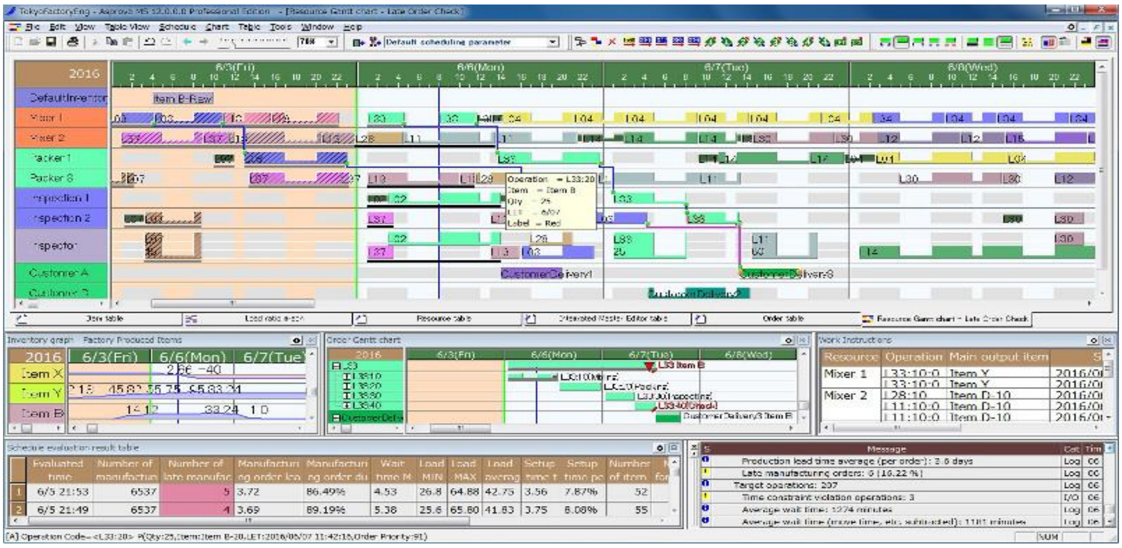


Figure 2.8 Asprovas' image of the workplace (Asprova, 2020)

Another possibility was to use a scheduling program by a Japan company Asprova, which says that it engages lean manufacturing solutions. Asprova describes its core benefits by empowering to achieve business goals and increase company profit through visual management, inventory and lean time reduction, increased throughput and improved customer service. Asprova is known as a factory-oriented production scheduling system for high-speed creation of multi-product multi-process production schedules. Its capable workplace is visualised in Figure 2.8. It could be integrated into any ERP system or pull data from any flat files and will optimise processes and track the utilisation of resources. Asprova should give visibility to daily production plans and to real-time events that occur. Its production schedule should drive the shop floor productively and efficiently, allowing the manufacturer to increase production and efficiency. (Capterra, 2020)

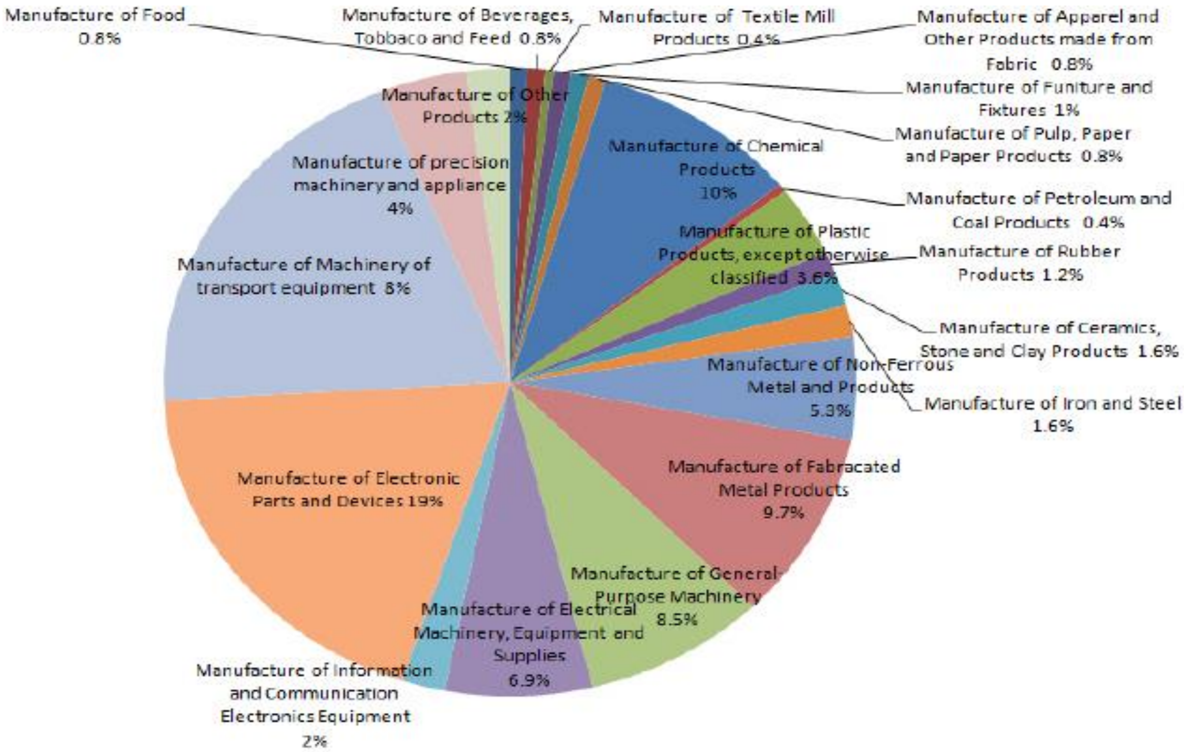


Figure 2.9 The graph of the manufacturing types of Asprova users (Asprova, 2020)

From Figure 2.9 could be seen the main kinds of manufactures who use Asprova software. As could be seen, manufactures of furniture and fixtures cover only 1% of total customers, (Asprova, 2020) what is most probably because of its more specific features (Figure 2.10), which are not meant for furniture companies. Standard AS also thought about Asprova, but no reasonable grounds were found on integrating this system into Standard AS manufacturing units considering that the nearest contact is in Germany. Asprova's software is rated as 41st in the CrowdReviews webpage (CrowdReviews, 2020), but it did not leave the impression for Standard AS to choose Asprova as its main production scheduling software.

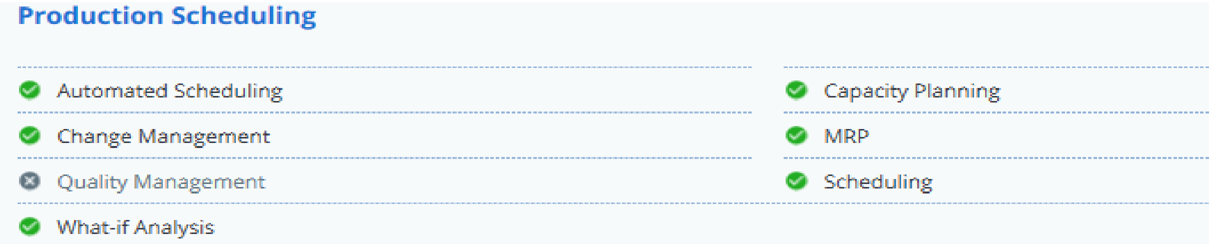


Figure 2.10 Main advantages and disadvantages of scheduling software Asprova (Capterra, 2020)

2.3.5. Production planning and scheduling with Preactor

At first, there were three different scheduling programs to choose from, but the weighting bowl was inclined towards a German production planning and scheduling software SIMATIC IT Preactor APS (for now renamed as Opcenter) whose headquarter is in Munich.

Preactor is known to be the most adaptable planning and classification software on the market. The fields and data tables in its database are addable and modifiable. Unique rules for classification could be used and specified. For a close integration of decentralised systems, special scripts can be defined for certain scenarios. This system communicates with many Preactor viewers or uses report overviews to publish the production planning information. (Schiess-Metalna Ltd., 2020)

Preactor software is a strategic decision tool designed to aid in long and midterm planning. It considers forecast and long-term orders, support decision making about the feasibility and affects the general direction of productions. Advanced Scheduling software is an interactive, multi-constraint scheduling system that provides support for decision-making for overtime, order prioritisation, production batches, due date negotiation and order processing (Siemens Industry Software Inc. , 2020). The Gantt chart in Figure 2.11 and Figure 2.12 describes the amount of data Preactor can process and how the output could be interpreted for production planning and scheduling.

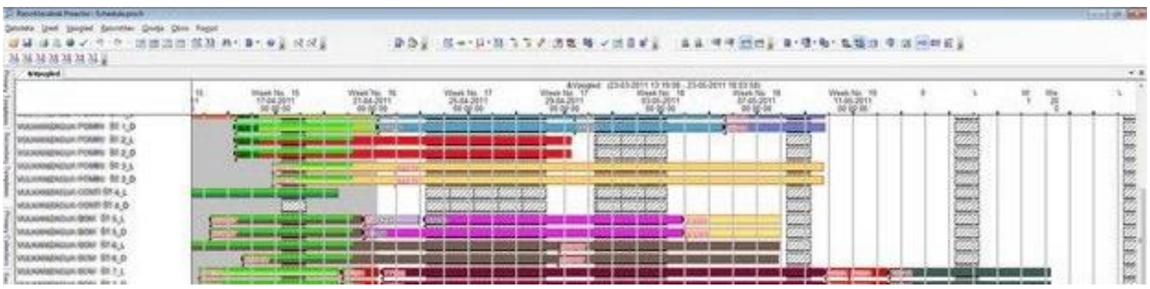


Figure 2.11 The Gantt chart of Preactor planning and scheduling screen (Schiess-Metalna Ltd., 2020)

The gained advantages of Preactor are as followed (Schiess-Metalna Ltd., 2020):

- 15 – 20% increased production,
- 40 – 50% reduced material cost,
- 40 – 50% reduced production time,
- 50 – 90% improved delivery times.

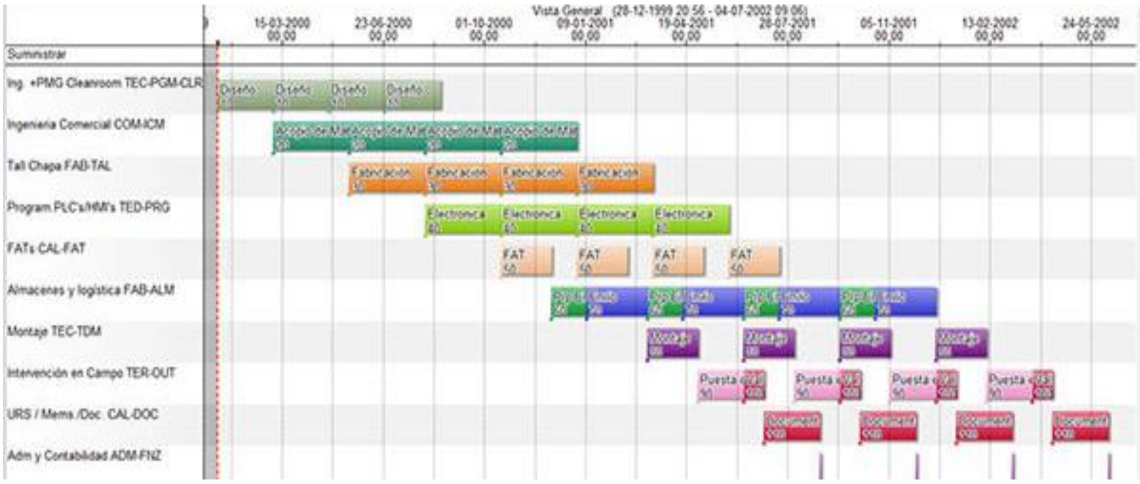


Figure 2.12 The Gantt chart of Preactor planning and scheduling screen (Bluesmart, 2020)

Preactor AS Professional solution was implemented as a stand-alone tool to provide companies with powerful production scheduling capabilities. Figure 2.13 is describing easier and convenient data management, where data import procedures were implemented, allowing the customer to use Excel files for data import. Production schedule in Preactor APS is updated with production status from the shop floor to have real-life schedule view. Additional reports in SQL Reporting Server were created to make scheduling data accessible and useful for various related departments. The range of features of Preactor is extensive. The primal functionalities are mentioned in Table 2.1.

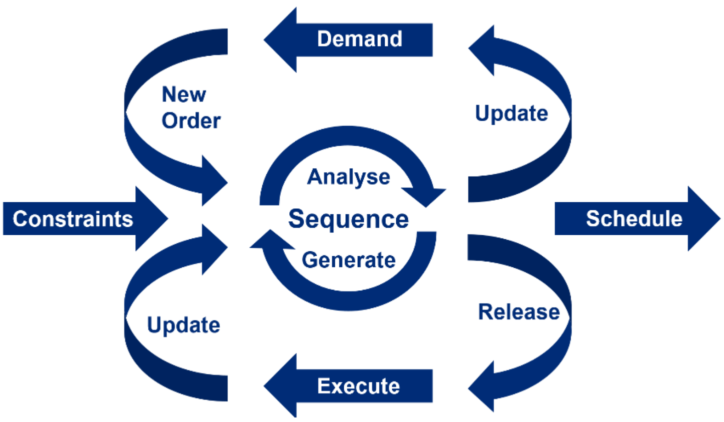


Figure 2.13 Preactor collects data outside, processes it and generates a production schedule (ATS Global, 2020)

Preactor allows planning through production campaigning method, meaning it is possible to assign resources, estimate start time, batches, and determine the time horizon for producing specific quantities of a particular batch of products to meet the market demands. Production can be defined with simplified campaigns associated with key equipment items that are likely to limit throughput. Long-term raw material planning utilises models with a level of detail similar to those of capacity analysis. (Carmichael, Siletti, Koulouris, & Petrides, 2018)

A small change in the performance of production plan analysis could mean a possible machine breakdown. If the meltdown that occurred did not affect the performance, the system could adapt and choose the next available same resource group machine to perform the same operation. (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018) The situations of removing and adding devices were created to analyse the adaptability of the agents to a machine breakdown for decision-making when new machines are included in the system. (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018)

Table 2.1 Functionalities available in Preactor AS Professional for Standard AS (Greiciune, 2017)

Feature	**Professional**
“Order at a Time” scheduling	✓
In software table and field renaming	✓
In software grid view and dialogue design	✓
Mid batch update (display only)	✓
Attribute-based simple setup times	✓
Flexible Order Routing	✓
File-Based Export	✓
File-Based Import	✓
Multi-constraint scheduling (primary, secondary and materials)	✓
Material consumption at the order level	✓
FIFO material linking rule	✓
ADO .Net Data Source Import	✓
Preactor Workflow tool (PESP) with Custom Actions to run external code	✓
Transfer batching and Slack Times	✓
Order Enquiry	✓
Mid batch update with recalculation	✓
Full Sequence-dependent attribute-based setup times	✓
A set of standard advanced planning rules	✓
Preactor workflow (PESP) Scheduling actions for multi-pass rules	✓
Material consumption and production at the operation level	✓
Custom material linking rules	✓
Material Explorer for material data visualisation	✓
Advanced resource constraints to model complex concurrent resource usage	✓
Advanced operation constraints for complex inter-operation relationships	✓
Exclude invalid resources based on attribute	✓

Another opinion while using Preactor for production planning is using recipe-based scheduling tools. A batch process describes a series of steps, the resources they require, and their relative timing and precedence. A production run is represented as a prioritised set of batches where each batch is one execution of a recipe with specific resources. Groups may be scheduled forward from a release date or backward from the due date. The scheduling algorithm generates feasible solutions that do not disrupt constraints related to the limited availability of resources (Petrides, Carmichael, Siletti, & Koulouris, 2014). Partial optimisation is attempted through the minimisation of the production make span that keeps track of the consumption and generation of materials, utilities, labour, and other resources. Furthermore, these tools may consider equipment capacity during resource allocation. (Carmichael, Siletti, Koulouris, & Petrides, 2018)

Though Preactor is evaluated to 63rd place according to the CrowdReviews ratings (CrowdReviews, 2020), it was the one AS Standard managers in collaboration with production chose to implement and use. Considering AS Standard's growth forecasts and potential sales growth Preactor is an entirely suitable APS system, which is considered being the most suitable choice for Standard AS production planning according to the development team as well. Besides, AS Standard got good help and consultations from Columbus Lithuania, who has the experience on implementing Preactor solution and working with it. Columbus Lithuania is the only official Partner of Preactor in Baltics states. (Standard AS, 2018)

2.4. Used modelling methods

In work for modelling data and description of the process was used CASE (Computer-Aided Software Engineering) system *CA AllFusion*.

The primary objectives of CASE systems are (Feldmann, 2000):

- To provide means for entirely and consistently modelling the functions (activities, actions, processes, operations) required by a system or enterprise, and the functional relationships and data (information or objects) that support the integration of those functions (CiteSeerx, 2020);
- To provide a modelling technique which is independent of tools, but which can be used in conjunction with those methods or tools (Feldmann, 2000);
- To provide a modelling technique that has the following characteristics:
  1. Generic (for analysis of systems of varying purpose, scope and complexity) (CiteSeerx, 2020);
  2. Rigorous and precise (for production of correct, usable models) (CiteSeerx, 2020);

3. Concise (to facilitate understanding, communication, consensus and validation) (Feldmann, 2000);
4. Conceptual (for the representation of functional requirements rather than physical or organisational implementations) (Feldmann, 2000).

Data for the company is an essential resource, so it is necessary to provide a method to describe or model the data, such as data structures and relationships among data. The most commonly used is the IDEF1X model.

2.4.1. Integrated Definition Method (IDEF1x)

IDEF1x method was used in current work for modelling data structure. It identifies the needed data by an organisation to achieve its mission, objectives, and strategies. A data model provides the conceptual view of the data and the relationships among data. (IDEFX Standard, 1993)

IDEF1X is a method for designing relational databases (as Appendix 1) with a syntax designed to support the semantic constructs necessary in developing a conceptual schema (IDEF, 2020). One of the essential features of IDEF is its ability to link the drawings to an underlying database. A conceptual schema is an individual integrated definition of the enterprise data that is unbiased toward any available application and independent of its access and physical storage. An entity in IDEF1X refers to a collection or set of similar data instances that can be individually distinguished from one another. Individual members of the group are called entity instances. (IDEF, 2020)

Purpose of the IDEF1x method is that information modelling technique is used to model data in a standard, consistent, predictable manner to manage it as a resource.

The primary objectives are (IDEF, 2020):

- To provide a means for completely understanding and analysing a system's data resources;
- To provide a common means of representing and communicating the complexity of data;
- To provide a method for presenting an overall view of the data required in the system;
- To provide a means for defining an application-independent view of data which can be validated by users and transformed into a physical database design;
- To provide a method for deriving an integrated data definition from existing data resources.

2.4.2. Data flow diagram (DFD)

DFD model is used for the description of the central concept of the work and the visualisation of data processing. Dada flow diagram helps to understand the exact model of a system. The purpose of data flow diagrams is to provide a semantic bridge between users and systems developers.

A data flow diagram (DFD) maps out the flow of information for any process or system. It uses defined symbols like rectangles, circles and arrows, plus short text labels, to show data inputs, outputs, storage points and the routes between each purpose. (Lucidchart, 2020) Data flowcharts can range from simple process overviews to in-depth, multi-level DFDs that dig progressively deeper into how the data is handled. They can be used to analyse an existing system or model a new one. DFD can visually describe things that would be hard to explain in words. It could be used for both technical and nontechnical audiences, from developer to CEO (Lucidchart, 2020). Like every model, in particular, DFD also has its positive and negative sides that are decisive while using. Its main advantages and disadvantages are mentioned in Table 2.4.

Table 2.2 Advantages and disadvantages while using DFD models

Advantages	Disadvantages
Promotes quick and easy code development;	Difficult to translate and read;
Easily understandable symbols;	Time-consuming in construction;
The used syntax is simple;	Could be confusing for programmers;
English nouns or noun adjective- verb constructs employed.	Different models employ different symbols.

DFDs consist of four main elements, as described in Figure 2.14: entities, processes, data stores, and data flows (ConceptDraw, 2020). First, the process transforms input data streams into output data flows. Then data depositors serve to keep ingoing data and do not allow a change. As final, the data flow changes in the external entities are not considered (ConceptDraw, 2020)

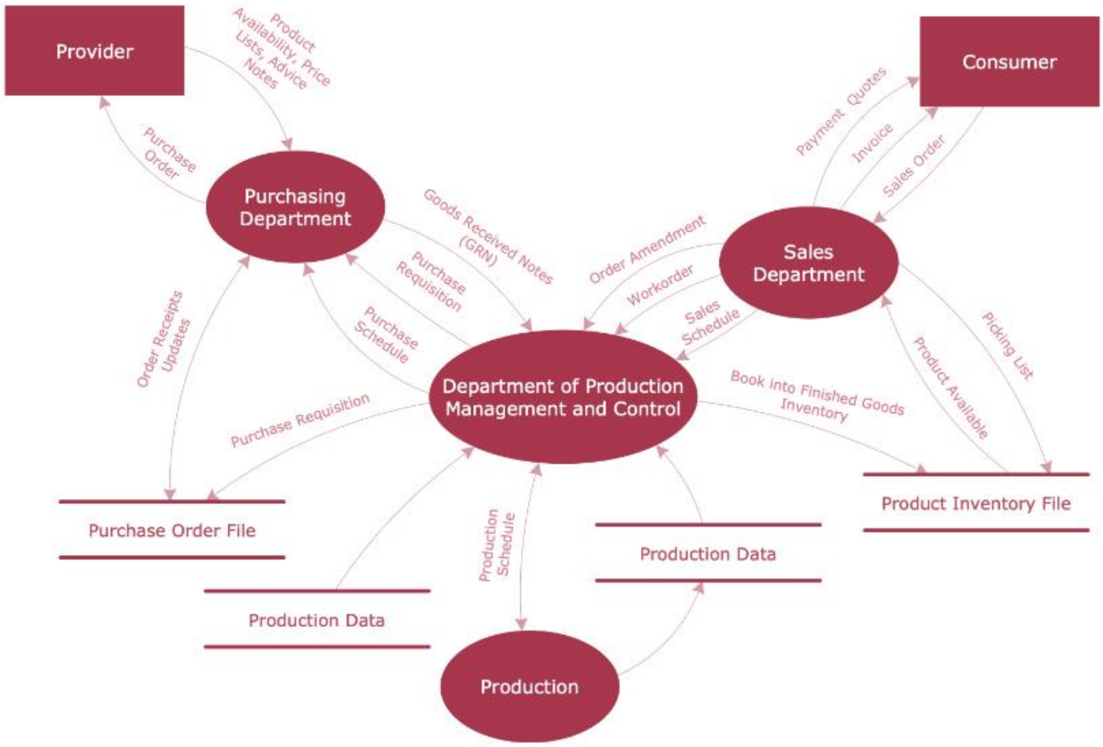


Figure 2.14 DFD schema of a traditional production company (ConceptDraw, 2020)

3. PRELIMINARY WORK

Production planning project in Standard AS has lasted with varying degrees of success for three years. The first stage of the project is passed and employees have learned to use and take into account the Preactor specific system and its features, which was important for AS Standard to have the most accurate vision possible so that its existing custom-made ERP system could be developed to work together with Preactor.

3.1. Definition of the scheduling process

The definition of the scheduling process in Preactor (Greiciune, 2017):

- Includes making decisions about the allocation of available capacity on resources (work centres, personnel) to orders and operations that are part of the routing.
- Indicates what has to be done and by which resources.
- Chooses to use one production plant or suggests to process details in different Standard AS production plants.

The role of the scheduling system is to prepare a detailed plan of production for different resources taking into account-limited capacity and using the available rules. Those rules include scheduling of orders by due date which is arising from related production orders.

Presentation of the actual capacity is achieved by choosing the primary calendar, which defines the availability of resources and the definition of additional constraints such as operators. Detailed scheduling focuses on the presentation of the operations queue to be performed on production lines.

Detailed scheduling aims to confront the expected due dates of production orders with available resources and to identify the risks of possible delays. Scheduling is done in one central Preactor Sequencer, and the results of the scheduling can be sent as a report to the relevant departments. (Greiciune, 2017)

3.2. First stage: implementing Preactor

Preactor planning procedure defines the process of preparing a production schedule that is intended by Preactor AS Professional system to present the current production plan for orders to be produced by existing resources. Part of the planning procedure is the process of preparing data for production scheduling. It must include a reference of departments that are responsible for the preparation process. (Greiciune, 2017)

3.2.1. Responsibilities within planning procedure

With the help of global IT services and consulting company Columbus team from Lithuania, Standard AS started to achieve goals as automating production schedules and scheduling process with possibility to apply manual changes, re-scheduling, creating scenarios and applying solutions for easy access and the use by employees. Figure 3.1 brings out the links between responsibilities for the operation and implementation of the production plan.

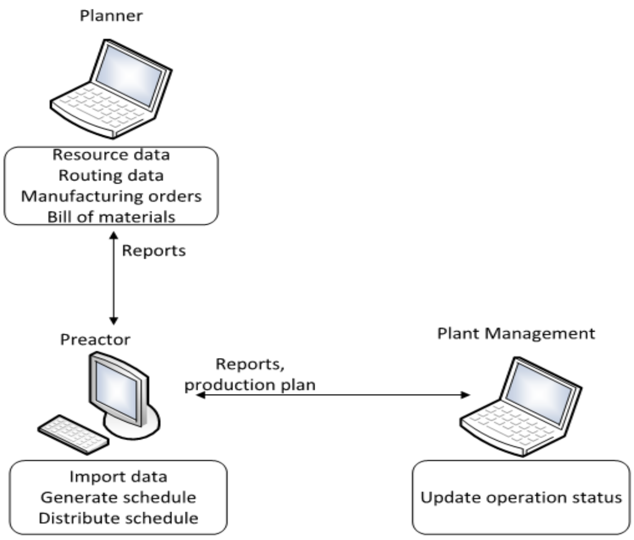


Figure 3.1 A diagram of links between crucial info within the planning procedure (Greiciune, 2017)

Planning and scheduling procedures in a supply chain are used in various phases. The first phase is usually a multistage medium-term planning process (using aggregate data). Next one performs detailed short-term scheduling of those stages separately. Typically, each step could have its scheduling procedures. However, scheduling procedures are usually more frequent than planning strategies. (Myerson, 2016)

Preactor Sequencer user is the production planner, who shares the generated schedule (e.g. possible production plan) with the production manager and discusses what information should be taken into account while producing. Production planner role is to offer the best solution to fulfil all orders according to the due date in the most optimal way. When unallocated operations appear in the production plan, the planner selects a rule by which orders are placed on the Gantt chart. The available commands are either forward or backward scheduling. Unproduced and unlocked orders could also be allocated and regenerated in the schedule. Production planner can manually freeze the plan for selected days. (Greiciune, 2017)

Standard AS production planner is responsible for (Greiciune, 2017):

- Entering new manufacturing orders;
- Entering new manufacturing orders with the type of “Enquiry”. Removing order enquires when new manufacturing orders are entered. Removing order enquires that are not needed anymore;
- Maintaining correct routing information and adding new routing data for new producible products;
- Maintaining a correct bill of materials information and adding new.
- Preparing a production schedule in Preactor.

Plant management will be responsible for:

- Updating the status of work orders operations;
- Monitoring the timely fulfilment of orders.

3.2.2. Description of the solution

Preactor AS Professional solution was first implemented as a stand-alone tool to provide Standard AS the powerful production scheduling capabilities.

Data import procedures are allowing to use Microsoft Excel files for easy and convenient data management. Production schedule in Preactor AS is updated with real production status to have a live schedule view. Additional reports in SQL server are created to make scheduling data accessible and useful for related departments.

The core functionalities for Standard AS while using Preactor (Standard AS, 2018):

- interactive Gantt Chart scheduling board provides visibility to the overall production schedule and have a detailed view of every particular production order;
- possibility to schedule production orders by using scheduling rules or manual scheduling in a backward or forward direction;
- links between related production orders ensure that latest operations could start only after related sub-products are produced;
- scheduling based resources and material constraints ensure that production can begin if there are available materials and help capacities;
- possibility to have several schedules for “what-if‟ scenarios.

3.2.3. Results of the first stage

After the implementation process of the Preactor, AS Standard team hoped that in the short term production planning works in this way. The result was useful and decisive enough to further development of existing ideas. The initial project results were delivered within the agreed period.

The implementation process showed that the created solution may cover AS Standards' main needs and allows production schedule creation while keeping the possibility to apply manual changes, re-scheduling and creating different scenarios. When the implementation process ended, Standard AS production development team decided that the made solution allows them to expand it in the future by adding data flows between Standard AS ERP systems (Standard AS, 2018)

4. CONCEPT DEVELOPMENT FOR SAF AND PREACTOR INTEGRATION

After managing with Preactor implementation process, the goal was to achieve half-automated, exact and more detailed manufacturing schedule for custom-engineered case goods. Also, to detect production overloading and bottlenecks faster and compliance with production deadlines. At first, these objectives were almost reached, but it also meant that the main work - planning and scheduling - took so much valuable time and work from the production planner. To accelerate the process, Standard AS had to supplement their ERP system possibilities by adding the route maps with details technology to the existing production module. After contacting with SAF development department in Sysdec AS came out that, the whole technology generation block to SAF takes approximately six months and includes about 700 hours of work.

4.1. A unified production planning system for Standard AS production plants

The main objective of this work is to find out the most optimal solution to manage Standard AS three factories in one production planning and scheduling system using SAF as an ERP and Preactor as an APS system. Their continuous production flow should depend principally on delivery dates and product-specific route maps. The outcome will be a unified system that takes into account both existing and future modifications in SAF capabilities as well as the Preactors' small-batch planning capabilities.

This thesis concept is to set the manner for converting info that comes from Standard AS's ERP system SAF into dataflow that is importable to the planning software Simatic IT Preactor APS by Siemens. The idea is to add a module enabling the technological description of the details production processes to the SAF system. The outcome must be easily inferable and usable for production planning.

The central thesis concept in Figure 4.1 performs the data flow between SAF and Preactor and is divided into two steps. Step 1 covers the inserting process of the new order(s). Three different Excel tables gather information from SAF and perform it in a form (resources data (1), new products data (2), orders data (3)) that could be imported to Preactor. After the process, APS takes the inserted data, analyses it and schedules to generate a production plan. The outcome is used as a work order for the factory.

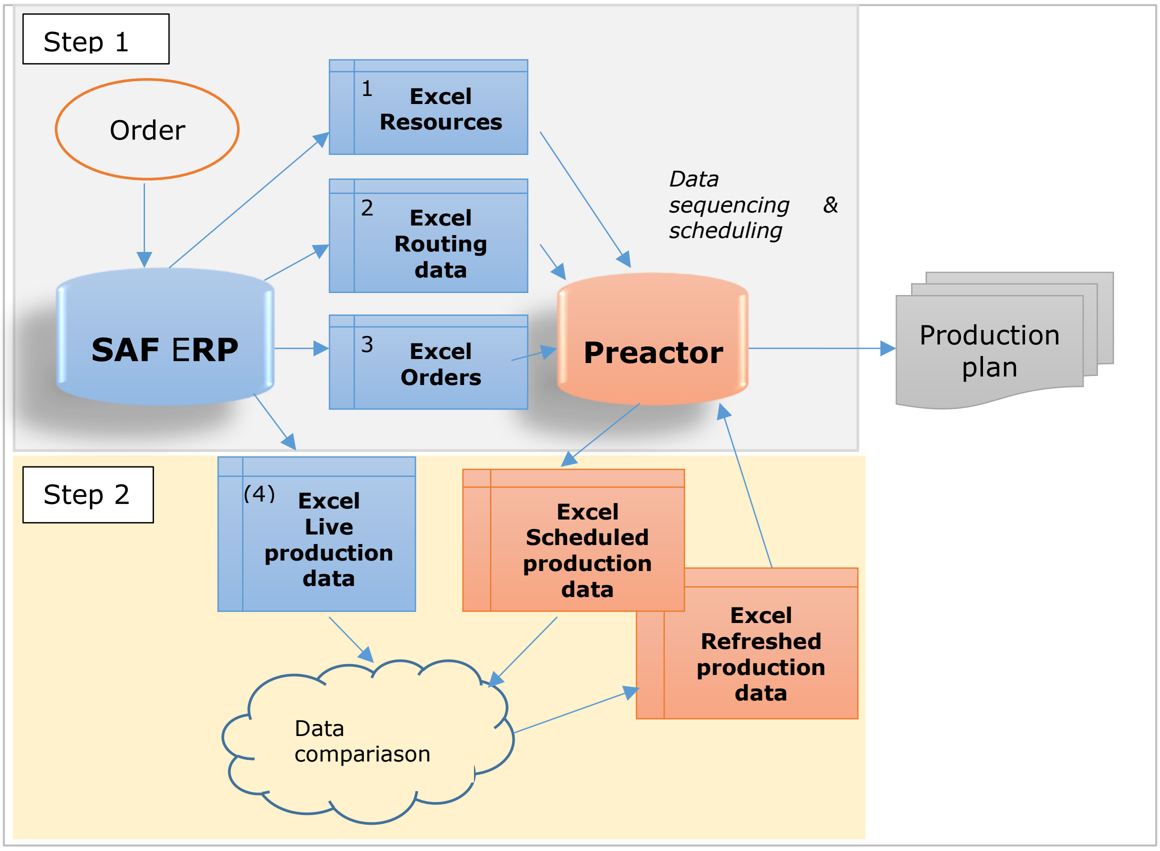


Figure 4.1 Thesis central concept

Step 2 starts when some operations from that order are already done, and the schedule must be refreshed. For that production, the plan is converted into Excel. SAF produces a scanned, i.e. done operations overview in the same form. This info is compared by an Excel macro. The outcome is an Excel file with refreshed, i.e. incomplete operations data that should be now imported back to Preactor. Then Preactor could refresh the production plan with up-to-date data.

Three different Excel tables must be included to be compatible with Preactor:

- Resources – overview of all of the resources, their standard time, available operations and amount of needed workforce. The Excel table must contain the same information as the SAF table of resources and operations.
- Product data and BOM – Product data points out the routes for different product groups and their materials. BOM gives an overview, which materials are used for which product groups and which products are included in one group.
- Orders – list of unfilled production orders formalised by a project manager.
- Schedule – production plan in the form of Excel list that shares information about completed operations with Preactor.

This implementation will be the most useful to find out what, how and when to produce to meet deadlines and to coordinate productions more effectively across three production plants. In accordance, it means that the output from SAF will be imported to the production-planning program Preactor.

The route card associated with each order defines the operation steps to make the product. The production planner can then load the orders onto individual resources, using scheduling rules, and interact with the schedule using the Gantt charts and plots that are generated (Myerson, 2016).

4.2. The logical structure of data exchange

The role of the system is to process data into production information using information technology, processes and resources (Jalal, 2020). From the Figure 4.2 could have an overview of an IDEF1x schema about the data of SAF production modules that Standard AS is going to use to generate production plan from Preactor for production managers and supervisors of various manufacturing sections. The diagram visualises how Preactor uses SAF data as input. SAF shares info about stocks, orders, routings, BOM and production updates with Preactor. Scheduling generates the production plan lying on the gathered data and “asks” about performed operations from SAF. Scanning the barcode in the manufacture tracks every project and its details throughout the whole production. According to received information, Preactor can generate the next plan for another period. The yellow area is manually inserted initial data. The info generated for planning has a grey background: Product_data, BOM, Orders. Light blue visualises the output of Preactor: production plan and overview in Excel.

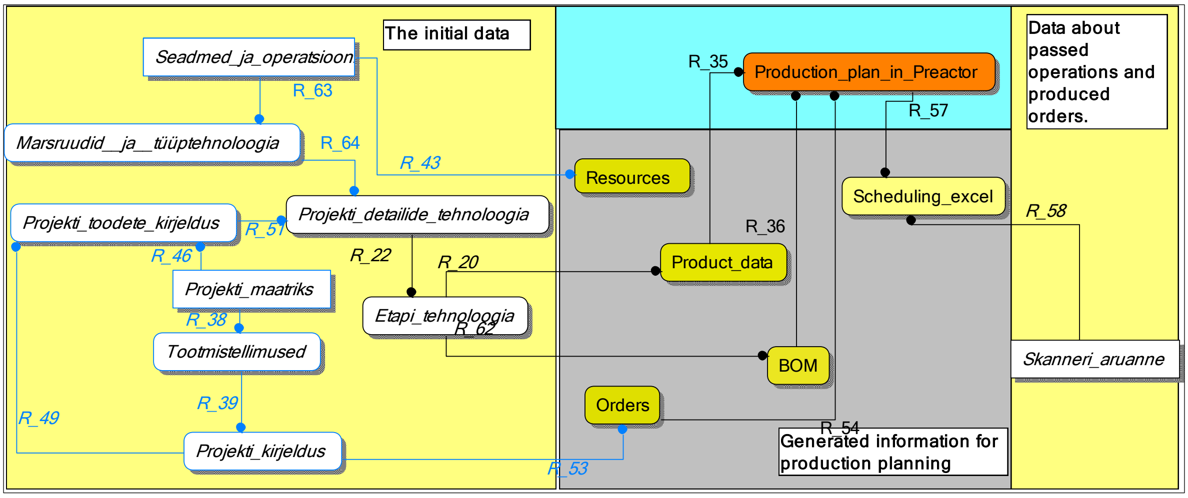


Figure 4.2 IDEF1x diagram (Logical level) describes linked SAF blocks and tables for scheduling

Resources, operations and routes are manually inserted primary data. Project details route maps are a list of details that are inserted previously and where technologists describe its main routings and specialities. Routings should be added by one click, but there could be manually included as many operations as needed. SAF converts information to the form that is suitable for Preactor import. Planning software needs an input of product data, BOM and orders. These intermediates are still missing from SAF, and that makes it one of the goals of this thesis.

Data as a project matrix (*Projekti_maatriks*) and project description (*Projekti_kirjeldus*) are used as basic info for creating other blocks.

4.3. The physical structure of data flow

The amount of data is used to combine information for production planning consisting of different parts. Its initial data has two distinct layers: existing information and addable data. The existing data starts with the info of the project matrix that is used for entering the orders. Orders basic info as project, products, amounts and delivery date will be mixed with the products description. According to this info is ready and should be converted through project description (bill of materials) to the list of producible products and details. This information is then mixed with resources, operations and routings. The result is the route map that is used in Preactor while generating the production plan.

Appendix 1 IDEFx1 diagram describes the SAF production module blocks that are used for generating the information from SAF to Preactor. It takes out all of the primary keys that are important to pass from one block to another to arrive in Preactor. The initial data in grey filling has SAF necessary information that belongs under the SAF production block and is in use already. The white area has information about products and their details route maps, which is the part SAF is missing right now and should be developed until the Excel import to Preactor takes place (i.e. info from yellow boxes has the importable data that could be inserted to Preactor). The production plan (in orange) is then compared with produced orders information (*Skanner_aruanne*) and is then imported back to Preactor for the plan renewal. Next sections will describe these parts a little more specific.

4.3.1. SAF existing blocks

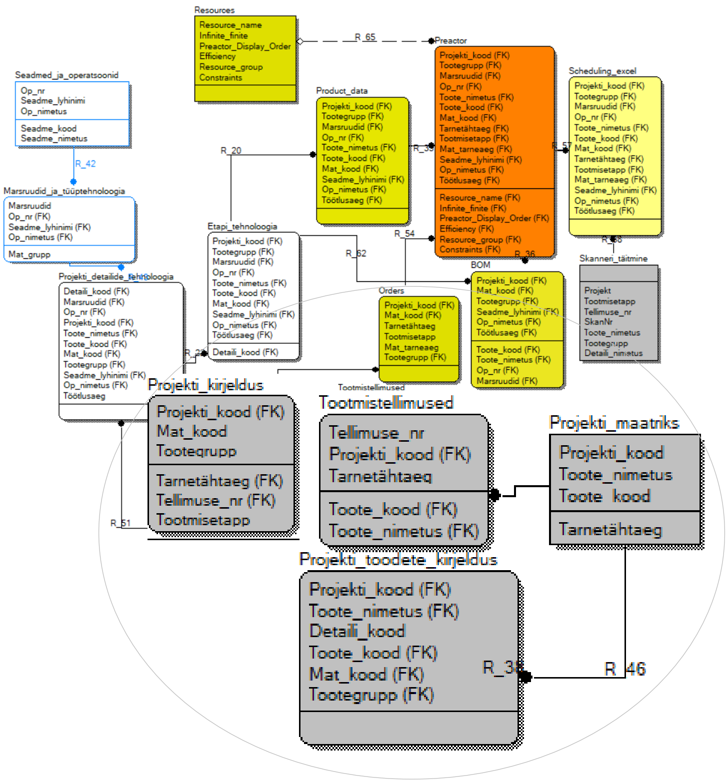


Figure 4.3 IDEF1x diagram of SAF existing production module blocks: Projekti_kirjeldus, Tootmistellimused, Projekti_maatriks, Projekti_toodete_kirjeldus

The current part of the production module (zoomed out in Figure 4.3) includes screens as project description, i.e. bill of material (*Projekti_kirjeldus*), products description (*Projekti_toodete_kirjeldus*) and production orders (*Tootmistellimused*). Production matrix (*Projekti_maatriks*) is the basis as well and has some useful data to draw up the production order and worksheets. Additional blocks will be mainly based on these four.

4.3.2. Production planner blocks

This production planner block will be developed during the SAF and Preactor implementation process. Figure 4.4 visually defines the new parts in white. Production module blocks consist of resources and operations (*Seadmed_ja_operatsioonid*), standard routings (*Tüüptehnoloogia*), details routings (*Projekti_detailide_tehnoloogia)* and routes of the project stages, i.e. orders technology (*Etapitehnoloogia*). These blocks are intended being able to extract information from one place as output and transfer it to another one as an input.

Production planner blocks should make clear:

1. what resources could be used and what operations they are capable of,
2. what are the most typical production technologies in Standard AS production,
3. what is the most optimal path of the movement for one part,
4. how it is possible to combine the details of one project into one batch.

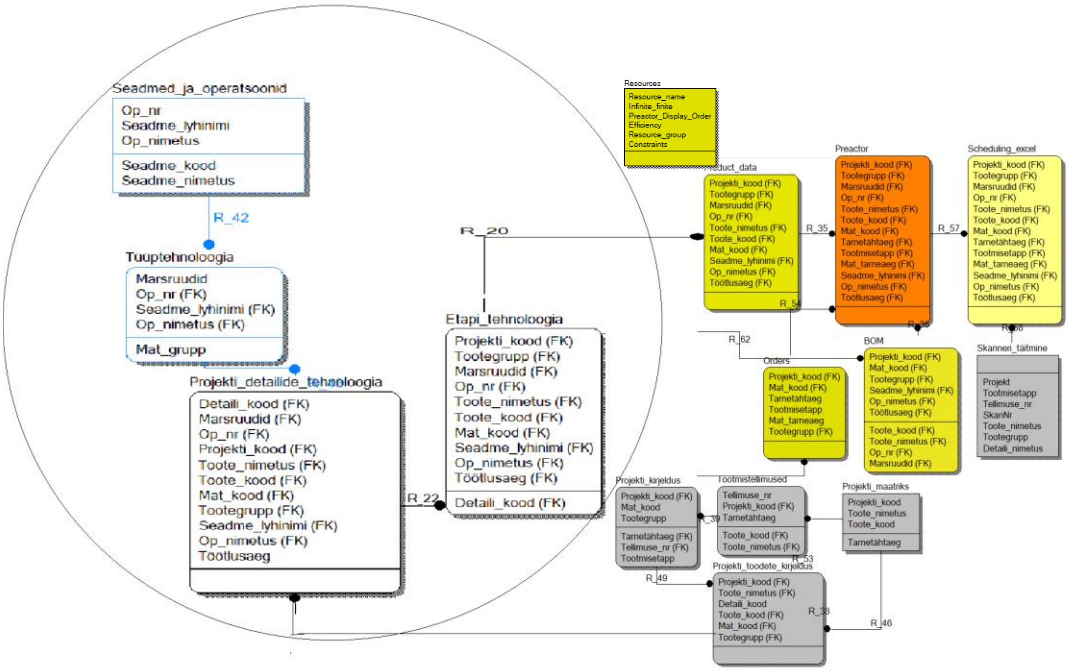


Figure 4.4 IDEF1x diagram of SAF production planner, i.e. technology module blocks *(Seadmed_ja_operatsioonid, Tüüptehnoloogia, Projekti_detailide_tehnoloogia, Etapi_tehnoloogia)* that must be developed to SAF before production planning implementation part in Preactor takes place

Resources, operations and standard technology are all primary data. Details and stage technologies, i.e. technologies for an order, are both processed data, which are formed out from previously mentioned fundamental data. For the most optimal use Standard AS needs previously mentioned technology submodule blocks:

- Resources and operations (Seadmed_ja_operatsioonid) include usable resources, processes and their norms of Standard AS's three manufactures.
- Routings and standard technology (Tüüptehnoloogia) describes mainly used technological paths for different materials, treatments and some of the particular processes.
- Details technological path of one project (Projekti_detailide_tehnoloogia) depicts the designations of specialised routes of one project every detail.

- Technological path of a project one stage (Etapi_tehnoloogia) adumbrates one-stage details/ one order specialised routes, amounts and times and reconstitutes syllabus technical path for only one set of this project.

4.3.3. Process of data exchanges between SAF and Preactor

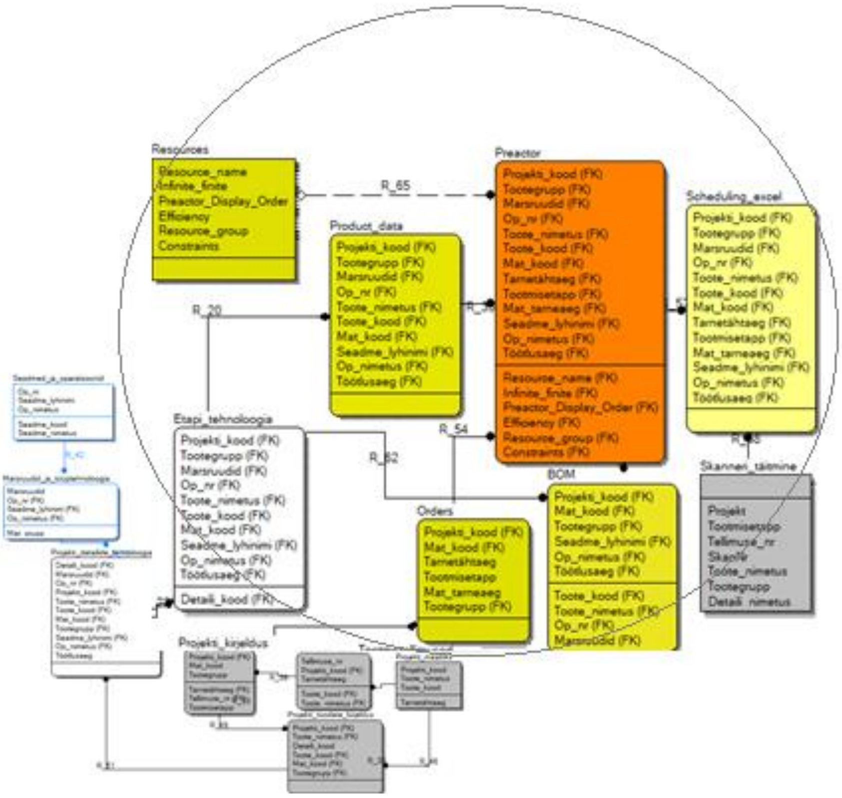


Figure 4.5 The practical and applicable part of the thesis, e.g. information flow from ERP to APS.

One goal of this thesis is to synchronise the production-scheduling program Preactor and Standard AS ERP system SAF in the most efficient way as possible. The central part can be seen from Figure 4.5, where the implementation part is zoomed out. It includes Orders, BOM info and Product_data Excel tables (e.g. the information of details routings). The central element is production planning in Preactor, which is linked again with another sheet of Scheduling_excel for taking off processed operations according to the information from SAF. These tables are responsible for that:

1. Preactor could know what resources need to be managed (Resources);
2. batch movements would be specifically described for production planning (Product data);
3. each sub-material finds its parent-material (BOM);
4. all of the orders are planned and could be scheduled to production plan (Orders);

5. the production plan is in line with real-time information and the production situation (Schedule).

The goal is to make the information flow dynamic and immediate. The creation of technological routes is created accordingly to the logical path and because of both existing and future system capabilities. The production preparation, planning and producing itself are designed to meet Standard AS's long-term requirements and are configured and expanded with every needed functionality. SAF should be working as a key IT system to ensure the seamless operation of a business and allows fast decision making on production management or a business management level.

As productions have raw material as an input, producing processes and the final output. (Jalal, 2020) ERP systems, including SAF, have the same phases of information: processing the intake of raw data to reports and production info. Organization requires the system to be agile and flexible when integrating the data across and support all the major functions of the organization. It follows the highest criteria of this development process: production tracking for the Preactor Gantt chart. The barcode scanning ensures details and projects in time, which accountancy SAF outlines. The full data exchanges between SAF and Preactor takes place only through Microsoft Excel tables. It is arranged this way to ensure the dependability of different programs when one of them is having a breakdown. The result should be corresponding systematic sequence: SAF → "Product data" + "Orders" Excel data → Preactor scheduling → "Schedule" Excel (→ background comparison) → refreshed data to "Schedule" Excel ←→ SAF. This process looks as follows:

1) The output of the technical route maps to "Product data" Excel as a technological sequence.
2) The output of production orders, including stages, amounts to "Orders" Excel.
3) Importing previous data to Preactor and generating a production plan.
4) Planed operations with their exact outlined production time and amounts are in "Schedule" Excel after refreshing (Excel-Data-Refresh All) the data.
5) Comparison of SAF scanning output and "Schedule" Excel file with a particular macro.
6) Data in OperationFinished column in "Schedule" Excel changes from FALSE (undone) to TRUE (operation passed). Half-passed operations Run time in ProductionPlanTotalProcessTime column will decrease.
7) Information update import to Preactor.

4.4. Creating a production plan

At this time Standard AS production module in SAF is comprised of three main blocks (with the white background in Figure 4.6): drafter, technologist and production supervisor. Figure 4.6 describes the main parts of the module, with its primary keys and attributes. These three blocks are those on what the new production planner, i.e. production technology module (on yellow background) will be based. Their interrelationship starts from scratch by the product engineer, who makes the drawings and describes the whole project and its details. Process engineer (i.e. technologist) takes their created drawings and product specifications and generates production orders, route maps and product packaging instructions. The production planner manages the blocks under the technology module and generates a production plan according to the gathered information.

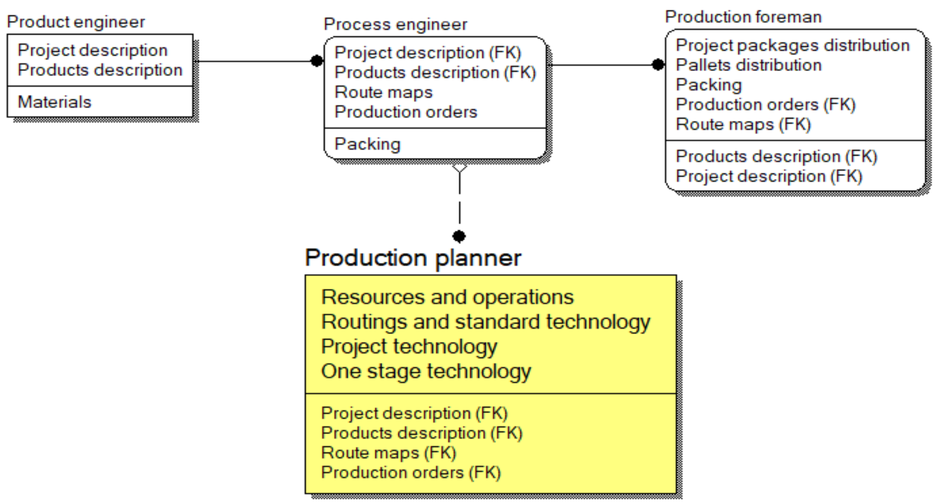


Figure 4.6 SAF existing and addable production blocks and their interdependence in AS Standard

Overview of the production module blocks that are used and combined to reach data for Preactor are visualised in Figure 4.7. To describe Excel data for Preactor existing SAF blocks (Orders, Project description, Product description) should be combined with addable blocks (Resources and operations, Routings and standard technology, Project details technology, Project stage technology). The outcome will be Excel tables: Orders, Product_data and BOM. These three are used as order information input to Preactor.

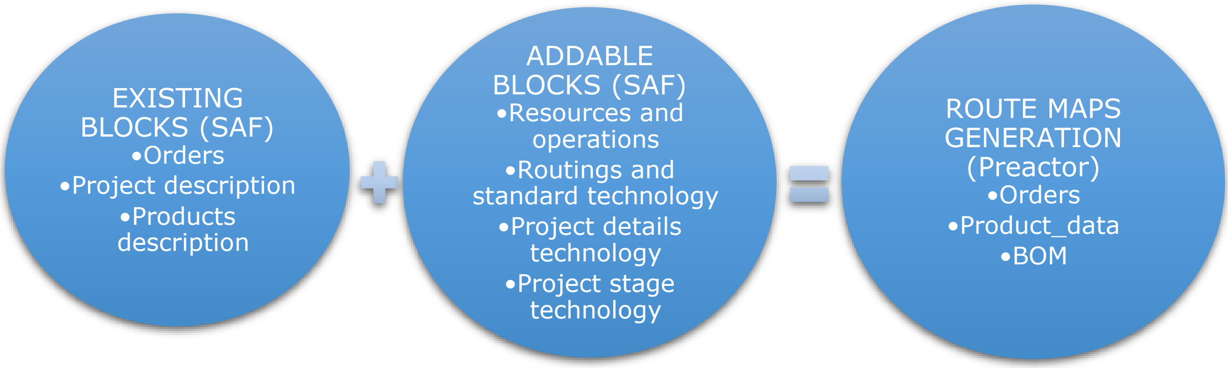


Figure 4.7 Existing and addable blocks overview from SAF production module for generating route maps in Preactor

The final overview of the technology module for production planner is made according to the project and product description, the route maps and list of production orders. The BOM (bill of materials) in SAF is named as project description and describes a list of parts, items, assemblies and other materials required to create a product, as well as instructions needed for gathering and using the materials required (BOM Management, 2020). The development and description of production technology of details are mostly lying on the product specifications (details measurements and materials), on resources capacities and operations, on the routings and previously defined standard technologies.

The DFD model in Figure 4.8 describes the origin of the production module blocks (in blue) and Excel sheets (in yellow). Information that is gathered from these blocks is converted to Microsoft Excel tables that Preactor uses while importing data for planning. According to the diagram and information deviation, SAF database needs production-planning blocks that belong under production planner, i.e. technology module, consists of resources and operations ("Seadmed_ja_operatsioonid"), routings and standard technology ("Tüüptehnoloogia"), and details the technological path of one project ("*Projekti_detailide_tehnoloogia*"). The last one should be convertible data of the technical way of a project one stage, i.e. technological router for an order ("*Etapi_tehnoloogia*").

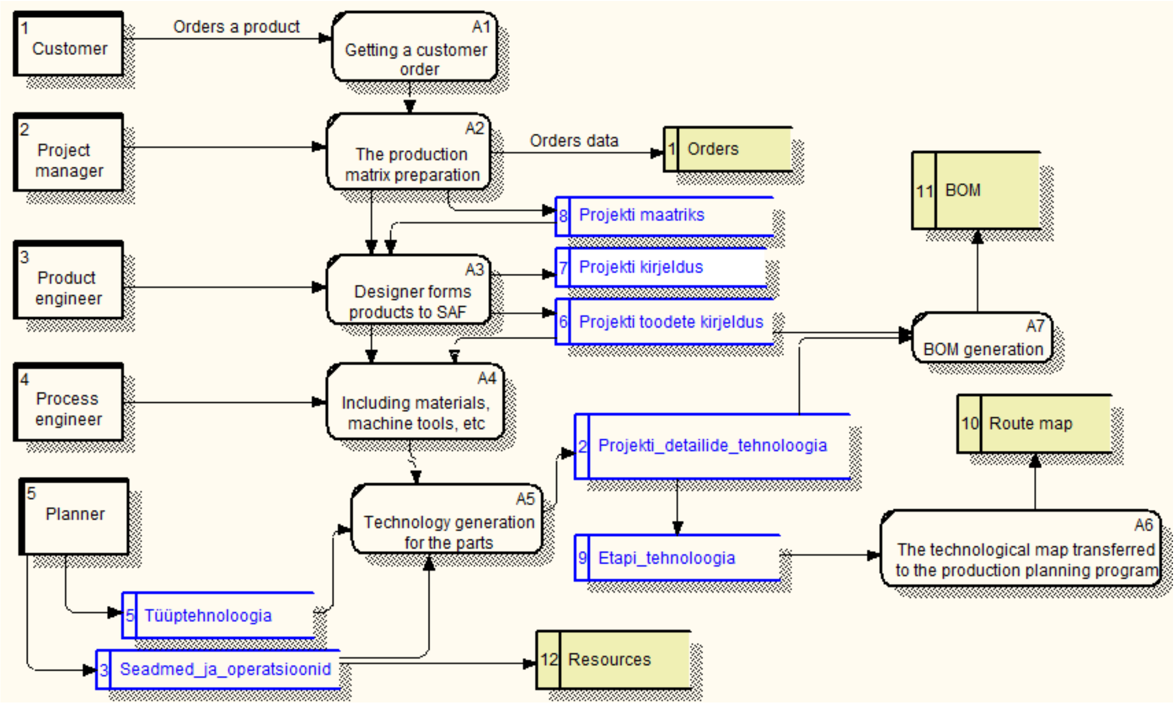


Figure 4.8 DFD model for work steps description of different parties and the needed input journey from SAF database to Preactor Scheduling

4.4.1. Resources and operations

The first and most primal data (focused on Figure 4.9) of the solution makes it possible to have an overview of all resources and operations. Standard AS is capable of using and accomplishing. It describes the machinery norms, prices and workforce amount for a process. A Figure of this table as a draft could be seen from Appendix 2.

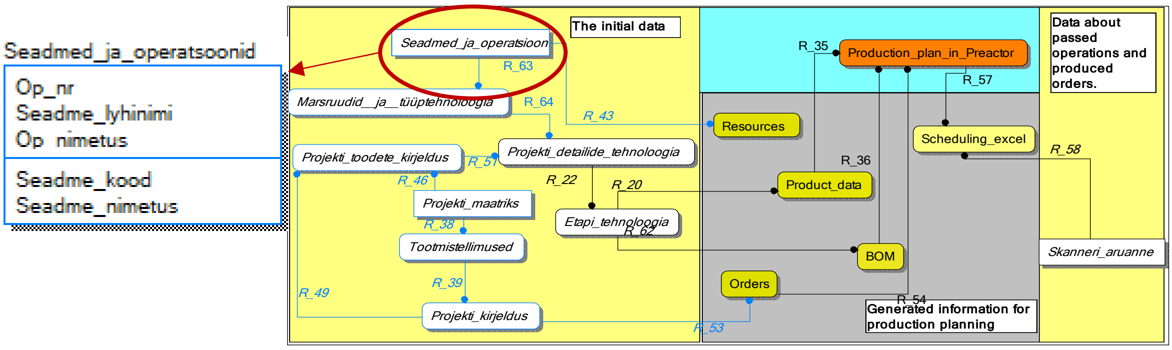


Figure 4.9 IDEF1x diagram closer overview of resources and operations in Standard AS

The header of the resources table describes all the resources Standard AS have. The mid-part consists of operations this unique resource can manage. The footer takes out the standard time per batch during the process. Most important components of this resources and operations table include the resource-unique code, price per hour, operation, standard time and factory where this resource locates.

It must be said that some of the resources belong in a bigger group because there are operations achievable with more than only one device. If one device is busy, the needed operation could be done with another device. It is in justification of why in AS Standard are five different drilling machines. These five also have a function that could be done only with this device, because the operation just takes too much time, or it is not optimal to use another machinery.

Name	Resources
Holzma	Holzma1
Holzma	Holzma2
Wild	Wild
Italpresse	Italpresse
Kalibreer	Kalibreer
Spooni koostamine	Spooni koostamine
Homag 2-poolne	Homag 2-poolne
Homag 1-poolne	Homag 1-poolne
Puit+frees+puur	Puit+frees+puur
Skipper	Skipper
Heesemann	Heesemann
CNC	Rover 1332
CNC	Bima

Figure 4.10 Half of Standard AS resources of SAF screen *Seadmed ja operatsioonid*

Resource data in Figure 4.10 represents a SAF output in the form of Excel, which performs machines and production lines required in the production process (Figure 4.9 on the grey area). This Excel table will be imported to Preactor, which allows grouping resources with similar capabilities to resource groups and automatically assign work orders for resources. Preactor will allocate operation to one of the resources within a group. For example, the spray finishing has four chambers that should be included in one resource group. (Greiciune, 2017)

It must be taken into account that devices could perform in limited quantity, for instance, spray devices that are needed for operations on finishing resource. Therefore are used tools as secondary constraints. Spray devices are assigned not to resource, but to an operation that can be conducted by a resource.

4.4.2. Routings and standard technologies

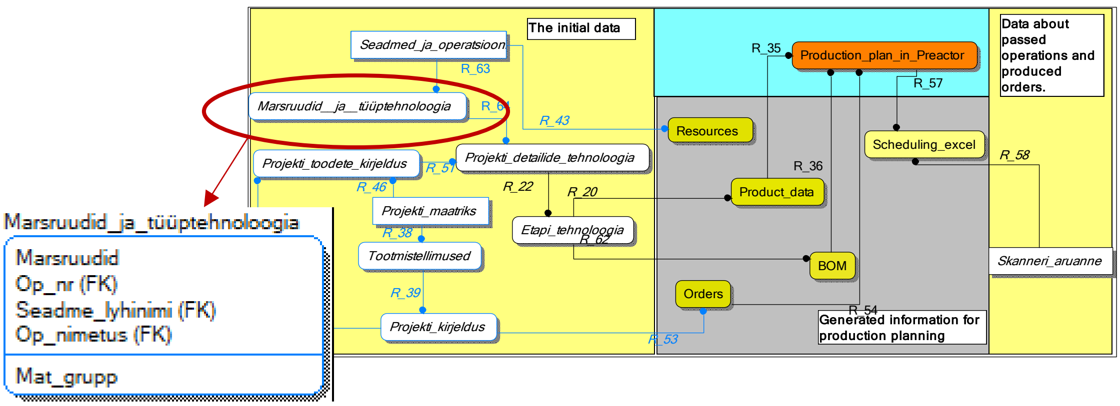


Figure 4.11 IDEF1x diagram closer overview of routings and traditional technologies data flow in Standard AS

The routings and standard technologies (i.e. *Marsruudid_ja_tüüptehnoloogiad*) block in Figure 4.11 is an individual screen and the basis for the project details technology. This block is not imported separately into Preactor because it only describes the main prerequisite or sequential devices and operations.

Based on standard technology, the route of details is a set of different operations and devices, which together creates a technological route map for the detail. According to the information from specification, SAF assigns attributes a default technology, a routing (or a set of routings) and operations. After that, the technologist must be able to change and add processes and equipment from the project details technology block. SAF describes the detail technological path with operations, resources and adds the estimated run time. Standard AS has many different projects-products-details. It creates the need to make a description of the technology and production planning as easy as possible. Therefore, the set of routes or standard technologies are defined in Appendix 4 and will be manually inserted to SAF.

Most important information of this block is the operation and a resource code; thereby a resource and sequence of the operations show up. In this regard, the technological path of details consists of standard technology and manually defined routes and functions. Standard technology includes routes and operations, which is a unique mix of operations for special material treatments. Different operations use resources belonging to diverse resource groups.

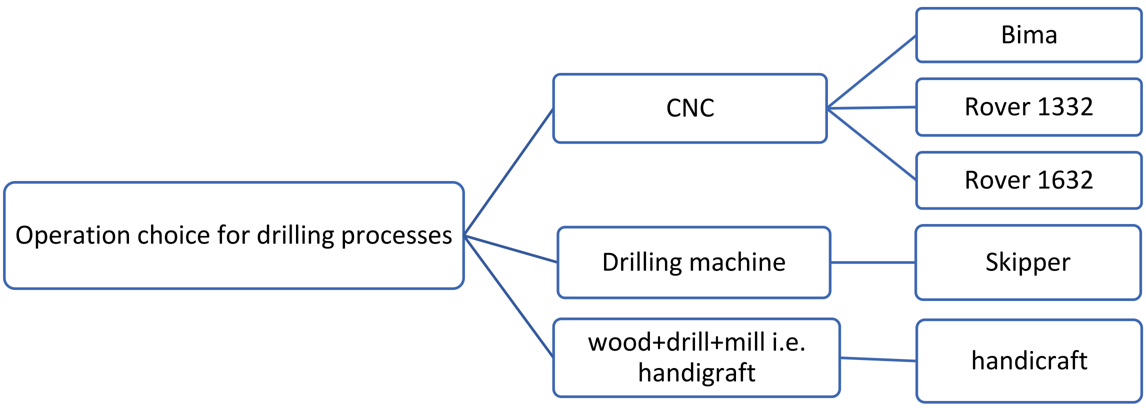


Figure 4.12 Hierarchical distribution of all Standard AS KMV drilling machines and possibilities

For example, it is possible to determine the route map to choose the right machinery for drilling and milling processes (Figure 4.12), based on the following criteria (on "if" principle):

1. If the details are named as "wall bar" ("seinalatt") or "hanging bar" ("riputuslatt") and its width is 60mm, only a resource wood + mill + drill ("puit + frees + puur") will process it.
2. If melamine faced chipboard is under processing, it passes formatting saw Holzma. If it must be edge banded, it moves to edge banging machine Homag 1-poolne. Then after it, goes to drilling. SAF" gives an evaluation, which directs it to the right drilling machine.
3. If the "needs processing" (Puur/frees) field equals with "JAH" (i.e. "yes"), SAF controls the following fields:
   - Tangential edge band (i.e. tan kant) = Y/N (yes/no) – if a specially shaped detail is edge banged or not; does it need Bima processing or not. Bima is a drilling machine that could do all the processing by itself. It could mill detail into a particular shape, edge band it and drill, if needed.
   - Bevelled edge or mitre (i.e. eerung) = Y/N (yes/no) – if the detail should be with a chamfered edge, the processing takes place in five-axis drilling machine Rover 1632.
   - Processed cm^3 difference to choose the drilling machine according to the severity and complexity of the detail processing.
   - A detail has "Erikuju" = Y/N (yes/no), it means that if the part needs special cutting and milling and if it does not need an edge band and there are no chamfers, this detail will be processed in Rover 1332.

Based on the previous criteria can be assessed:

1. If the tangential edge = Y, detail moves to Bima drilling machine;
2. If the tangential edge = N, but mitred edge = Y, detail moves to five-axis drilling machine Rover 1632.
3. If the mitred edge = N, SAF examines the volume of the detail (cm^3).

These, in turn, can conclude:

- Cm^3 difference < 100 $m^{3,}$ i.e. detail has some simple drillings, but the part is not milled. Details that cm^3 difference in less than 100 m^3 are drilled in Skipper, because it can do the simpler drillings, but could not manage with milling.
- Cm^3 difference ≥ 100, i.e. has more difficult drillings and could have some easier milling processing as well. And processing takes place:
  - With Bima, if different shaped edges should be edgebanded.
  - With Rover 1332 if detail is without mitred edges or specially shaped edge bandings and.
  - With Rover 1632, if detail is with mitred edges.

The technological path of each product should end in the default form of assembly and packaging, but there are exceptions: e.g. if there are no production-mounted fittings in the product specification. In this case, the product moves directly from the machine room and finishing to the final operation called packaging.

There are more criteria under Appendix 3 - 5 how the ERP system could find the correct technological path for every needed detail. The idea is to minimise the work of technologists and planners to use their knowledge and skills for more complex activities that the computer could not manage.

4.4.3. Details technological path of one project

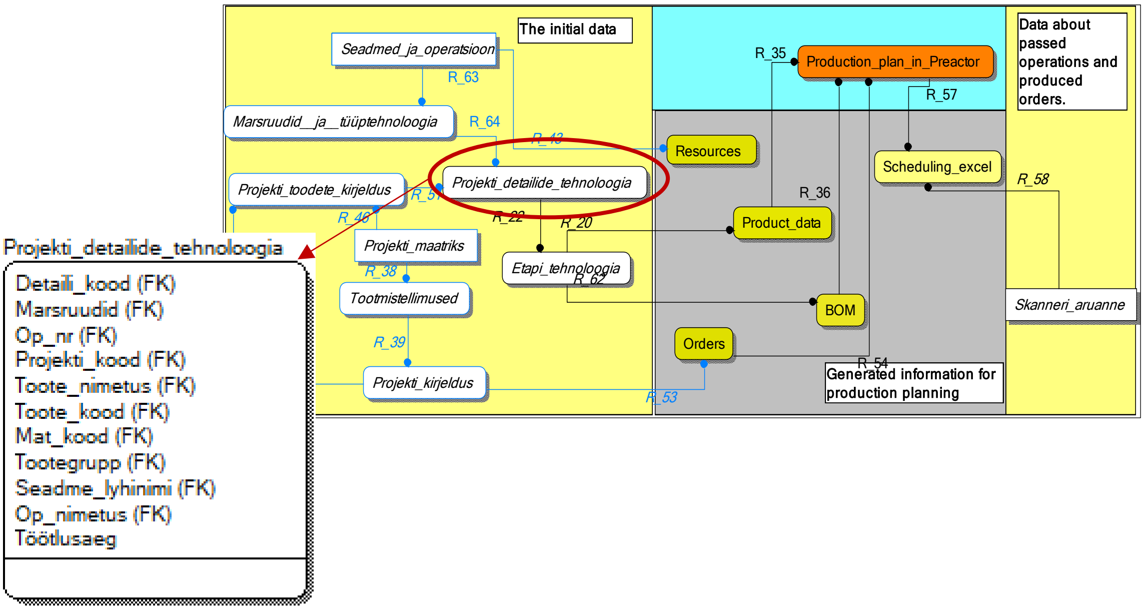


Figure 4.13 IDEF1x diagram closer overview of details technical path creation by using different data inquiry in SAF

Details technological path (in Figure 4.13) describes the routing of every detail of a project. Basis of this is the products specifications and appointment of operations, routings and default technologies that are written in Appendix 3 - 5. Resources, operations and routings were for primary data, but the data in details technology paths' table is derived by SAF.

An idea of the details technological path of one project is drafted (in Estonian) and could be found as an Appendix 6 in the form of a draft and based on the first view of the production planner block. At the top of the table, unfinished projects are listed. The header includes a list of all the details that the product engineer had specified. In addition to technology, routings and operations, the most optimal movements as possible must be achieved. It is possible to do activities of details around the devices: by deleting and writing elsewhere or only by dragging from one device to another. The blank field is automatic "no", and the device is not used for processing. The bottom of the table shows the technological path of precise detail that is currently marked as changeable. Working time is calculated for one part.

4.4.4. Technological path of an order

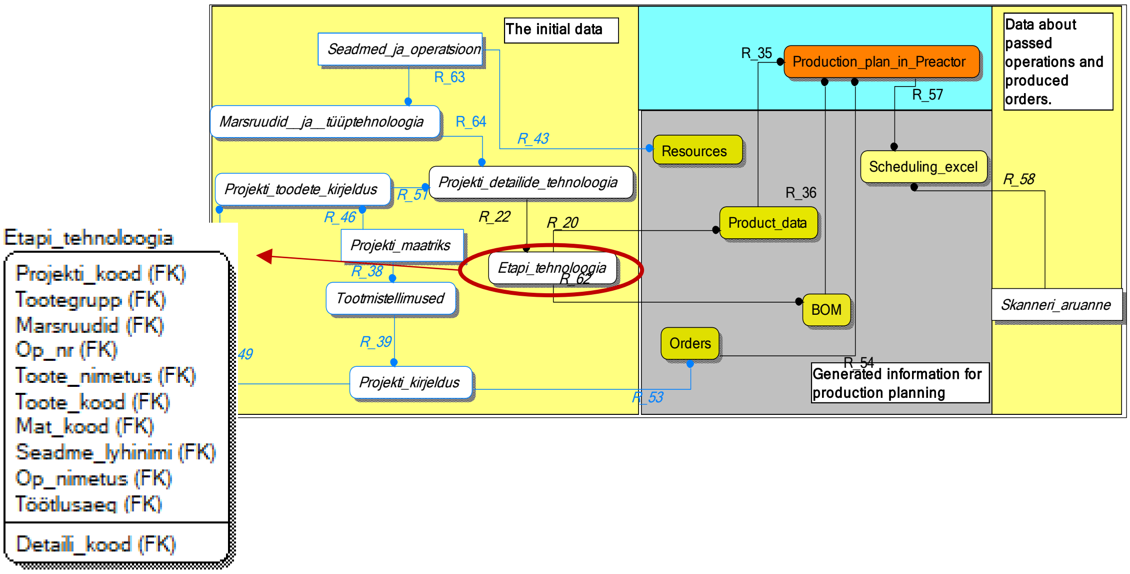


Figure 4.14 IDEF1x diagram closer overview of one stages route map

The order technology or a stage technology (i.e. *Etapi_tehnoloogia*) block in Figure 4.14 is generated from the project details technology. It consists of one orders' all details under product groups, that has a route map in the aggregate. It appears in the form of Product_data (on a grey area in Figure 4.14) as needed data for Microsoft Excel (Appendix 7) and input to Preactor for the production planning.

Route maps are made for product groups (e.g. headboard, writing desk, wardrobe), that gather variations of the product under a single group. SAF assigns product details with the same appearance, material and technology into equal product groups. Therefore, it allows technology to be described for product groups and to create a production plan for larger batches (described more precisely in chapter 4.4.5.).

The work logic and sequence will be for project stage technology, but the technological path will be first described to details separately. In order technology, detailed information is grouped according to the materials and product groups. Production planning is done for materials and product groups because the amount of details is various for convenient planning and information tracking and data management.

4.4.5. BOM file generation

As a next step, SAF has to offer a BOM (bill of material) for all of the materials, products and product groups used for route maps generation. Product's BOM is used to assign required materials to products and will be used in Preactor to calculate required materials for manufacturing orders. (Greiciune, 2017) BOM is a list of components within a project. It visualises the project structure, what materials the products are made of and to which groups the products belong. The program uses BOM, which is imported in an Excel form as in Figure 4.15. Preactor is also able to optimise the details of the project stages to ensure that all by-products are ready for timely material processing. It could secure there is a minimum waiting time between each operation and products in the project are assembled and packaged for delivery according to the delivery date.

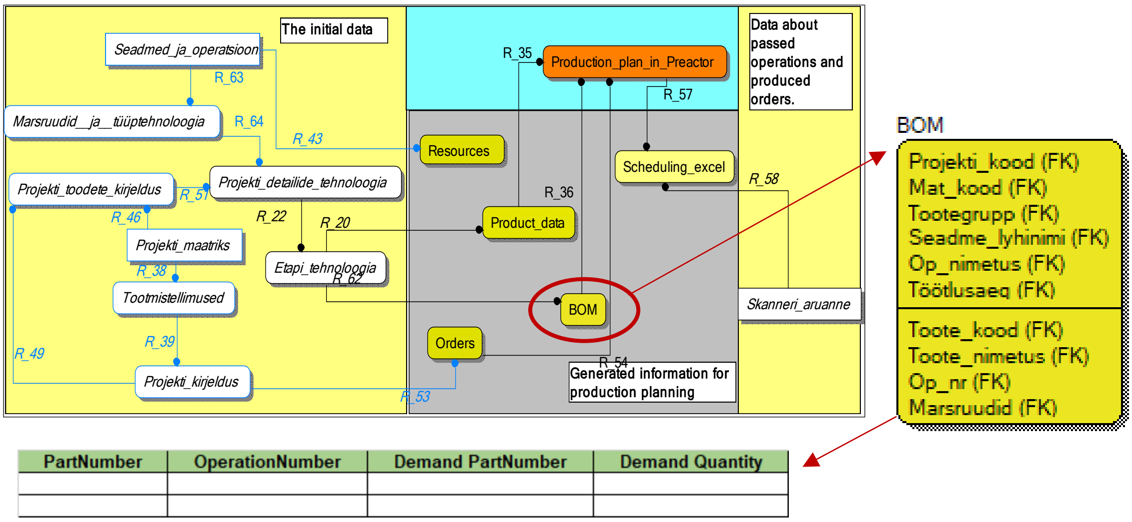


Figure 4.15 IDEF1x diagram overview about data that is used to generate BOM for order and BOM in the form of Excel table

The grouping of materials and products is as described in Figure 4.16. According to this logic will be generated the BOM table, that should mention specifically how the producible batches are distributed and from how many parts it consists. In the beginning, SAF explodes every product of the project into materials. In addition to that, as in Figure 4.16, Project X consists of three different boards and two different coating materials (e.g. laminate). Therefore, as Project X most probably has various products (e.g. five similar closets, four similar beds), SAF groups it into product groups. As a result, there are one group of cabinets (Product group 1) and one for beds (Product group 2). These two groups are now passing the operations in eight batches because, after the panel sawing operations, SAF divides these boards and coating materials for both groups. After the surfacing process (e.g. laminating) Product group 1 includes Board 1, Board 2 and Wafer board 1 under it all together. However, the other group comprises only Board 2 and Wafer board 2. These materials can now be edge banded, drilled, milled and covered with finishing if needed. If these operations are managed, batches move to assembling, and packaging, where SAF calculates them back to the product because products are the ones that are ordered by the customers and results are delivered not sets of products or product groups.

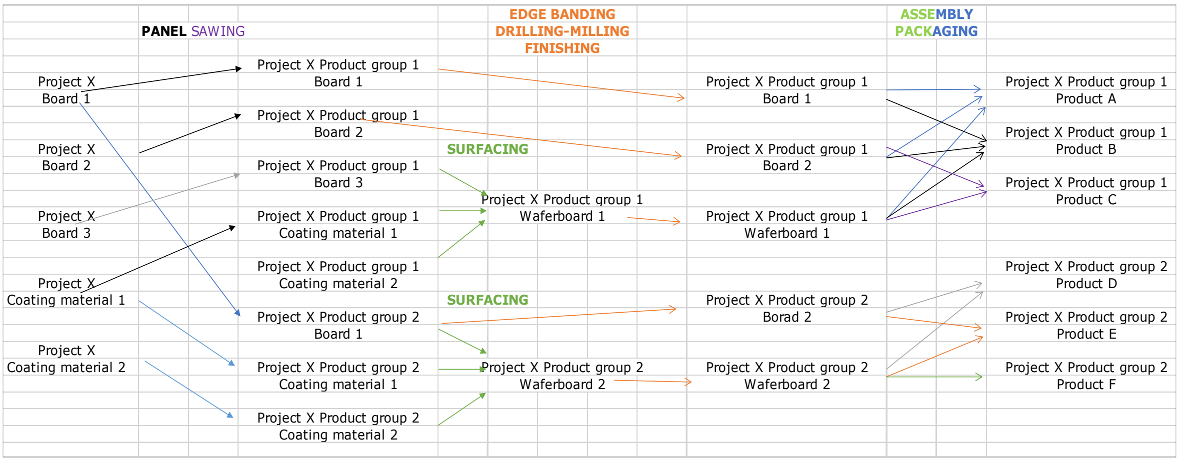


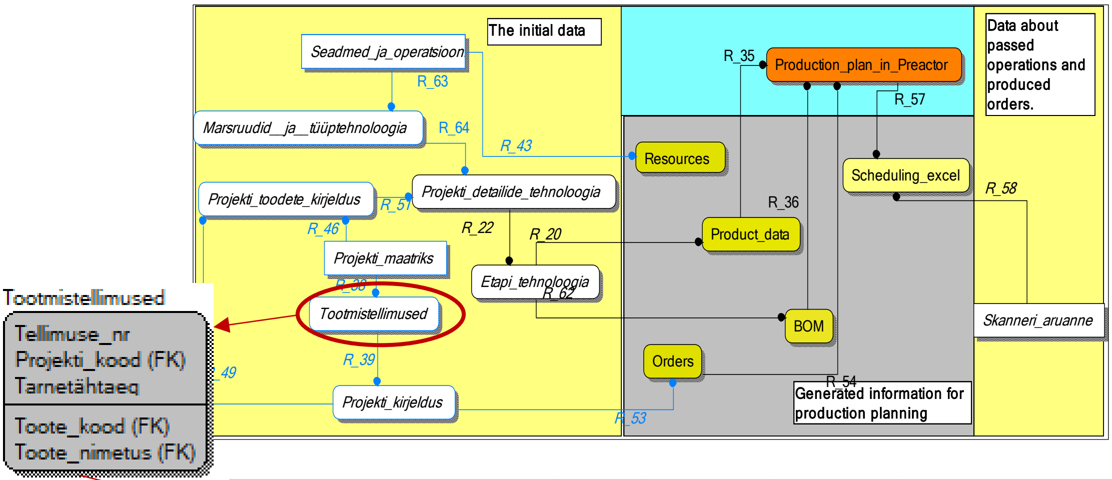
Figure 4.16 General description of processing and overview of the logic of product groups and products formation

Mostly the only operation for which the project has to be separated into different materials is the panel sawing with format sizing machine. Edge banding, drilling and milling take place with the same task in the same product group and with the same material. On the other hand, assembling and packaging take place for the exact project exact product.

4.4.6. Orders

Planning requires a sheet of orders summary, that is based on project manager made-up *Projekti_maatriks* and used via project description *(Projekti_kirjeldus)* to generate an Orders Excel table as done in Figure 4.17 below with greenish headers. This way, it is easier to import new orders into the Preactor. For instance, when the technologist creates an order technology, all data about this order will appear in the list of not imported orders.

Latest starting date is attached from the purchase order as “arriving in the warehouse” date. SAF considers material to be already in a stock if the date is not marked. Hence, the start of assembling is when all of the fittings are in the stock. By deducing that an operations panel sawing for board cutting could start only when raw material has arrived in the warehouse.



Order No.	Part No.	Quantity	Due Date	Earliest Start Date	Notes	Stage

Figure 4.17 IDEF1 diagram of creating Orders Excel (below) from *Projekti_maatriks* and *Projekti_kirjeldus*

The overview of order data Excel should look like visualised in Table 4.17. It is possible to use the same sub-product in different orders/projects, but as Standard AS is planning the production phase, then Order No is the same as Part No. Due date is the delivery date of the exact production order, which the technologist enters under the Project Description on the Stages sheet as a Deadline. The earliest start date is the earliest possible start time, i.e. the time the raw material could be found from the stock. The notes field combines the number of the order entered by the project manager and the production phase of this project.

4.4.7. Process of the road map description

As the projects have more details than a man could handle within a reasonable time, the description of the road map must work based mainly on the recorded routes, on generated data from previous sections, and on "If" function. This process takes place invisibly in *Projekti_detailide_technoloogia (Chapter 4.4.3)*. The technological path is possible to generate individual details or full product. There are three main clicks to delete and create a technical way:

a) Generate technology (i.e. *genereeri tehnoloogia*) – makes technology for a product or selected details.
b) Refresh technology of detail (i.e. *uuenda pos. tehnoloogia*) – deletes previous technology of selected lines and creates a new one.
c) Delete technology (i.e. *kustuta tehnoloogia*) – deletes a whole product technology and enables to start from the beginning.

The work process of defining the path will cover the next steps (visualised by Figure 4.18.):

1. The technologist opens the Project details technology view. He/she searches for the project in progress, selects the line of the detail to which to create the technological path and presses the button "add missing technology". It must be possible to filter details by product, part, material, edge bandings, finishing and notes to create an automatic technological path. Elements with a certain definition predominantly have the same technical route as well.
2. SAF creates a route map according to the details set out from the standard technologies and routings.
3. Technologist or planner can also attach needed operations and resources to all of the details one by one. However, the disadvantage of it is that it takes more time than adding them automatically by a program. Firstly, the worker indicates the details under the process, analyse them and their materials and apply an operation, routing or technology by clicking "add operations" under the actions part.
4. It should be checked that all operations are in the order in which they occur. The number and information in the sequence are easily changeable.
5. Once the technology is described, technologist generates a one stage technological path by selecting this stage or those stages from which details he/she wishes to see the result.

Figure 4.18 The approach of generating the technological path for details in SAF

The rows from stages technologies are frozen afterwards because all the future changes must be implemented on the project details table. It should be noted that even though sets are frozen, the technological path could be changed, but only within that specific stage. Route maps are created for different phases in parallel with orders formalisation.

4.4.8. Production plan update

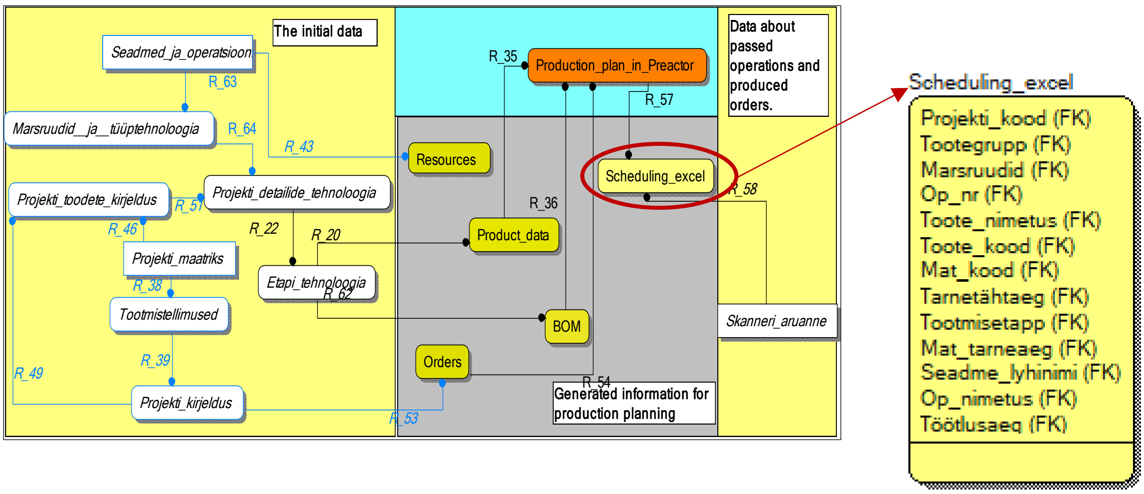


Figure 4.19 IDEF1x diagram visualising the critical attributes of the Scheduling_excel for data comparison between Preactor and SAF live data

Production plan updates take place by importing Schedule Excel (taken out as Appendix 8) to Preactor. Figure 4.19 performs the Scheduling Excel in the middle of Preactor production plan, and SAF scanned orders, i.e. done operations. It includes the data that is left after removing processed functions. The report of all completed operations must work in the same way as the creation of project detail technology: first, the detailed technology is found, which is then aggregated into the stage technology based on product groups and materials. For rescheduling, the number of scanned parts based on the scanner report are subtracted from the original stage quantity leaving a quantity that the Preactor will re-plan. The amount needs to be considered as run time in this context.

To get a new quantity SAF recalculates its times according to the live production data (i.e. *Skanneri aruanne*) and comparing it with the Schedule data deducted time from the previous information and sets OperationFinished FALSE to TRUE or changes the run time accordingly. Only those operations whose initial sum of the stage working hours is equal to the whole of the scanned parts working hours could be changed as TRUE. For Schedule Excel, the following calculation could work: process X pcs subtracted by made Y pcs to get the unprocessed amount X-Y as Z pcs. Therefore, Z is the new quantity to be processed. And after that: if Z is equal with X mark an operation TRUE; if Z is larger than X, recalculate run time.

4.5. Work assignment report for production

Preactor reports on Report Server are available within the local network in Internet Explorer. (Greiciune, 2017) There are two types of reports that are available in Preactor configuration for Standard AS:

- Reports available in Preactor program is for analysing schedule while working in Preactor Sequencer;
- Other departments who need to operate with generated plans and data use Preactor reports from the Report Server (Table 4.20). Every kind of report is exportable to Excel for further analysis.

Route Card for Order No.: 0008garderoob-2C

Product: 0008 garderoob
Part Number: 0008garderoob

Op. No.	Quantity	Operation Name	Resource	Start Time	End Time
10	44	Lihv	Heesemann	10.04.2020 9:53	16.04.2020 13:35
20	44	Krunt	Viimistluskabiin püstol	16.04.2020 13:35	21.04.2020 12:55
30	44	Kuivamine	Kuivamine	21.04.2020 12:55	21.04.2020 20:55
40	44	Lihvimine käsitsi	Lihvimine käsitsi	22.04.2020 7:30	23.04.2020 8:18
40	44	Vahelihv	Vahelihvpink Tagliabue	22.04.2020 7:30	24.04.2020 9:06
50	44	Lõpp	Viimistluskabiin püstol	24.04.2020 9:06	29.04.2020 8:25

Figure 4.20 Route card for the product group "garderoob" from project 0008 visualises the finishing operations

Reports are usable for production supervisors to find out which projects are planned to be producible during the week at that moment. Production plan start time is written by exact day and time and end time is calculated according to the run time.

5. PRACTICAL IMPLEMENTATION

The practical implementation part describes the technological routes generation process through real life examples. It must be bare in mind that these are done only for this thesis and this order would not be produced. In addition, SAF production blocks do not include the final information of the development process.

5.1. Input data description

Input data that is used to generate the road maps of Project 9072 is described in the next two items. The most principal input data through this practical example is the information about the production order and description of this orders' products.

5.1.1. Production orders

TOOTMISTELLIMUS NR. **06018**

Kuupäev:
Saaja ladu: **Marja ladu**
Tarnetähtaeg: **03.06.2020**

Projektijuht:
Projekt: 9072
Tarneaadress:

Saatja ladu: **KMV**
Tellija:
Riik: **Finland**

Pealelaadimise selgitus: 3. korrus

Kliendi tellnr.

Nimetus	Kood	Kogus		Tähtaeg
Projektimööbel Voodiots Headboard Fi40 :- -	PMVORV8HP04664002I-- *Joonise järgi 1 tk; peegelpildis 2 tk*	3,00	tk	03.06.2020
Projektimööbel Voodiots Headboard Fi45 :- -	PMVORV8HP04664004I-- *Joonise järgi 7 tk; peegelpildis 10 tk*	17,00	tk	03.06.2020

Figure 5.1 Standard AS production order of a project 9072

AS Standards' flow of information starts from project managers, who confirms the client order and inserts it to the SAF system. As most of the orders are for projects lasting from one to several months, project managers will first make a project matrix (Projekti_maatriks), where they include the room number, specialities and product amounts. The matrix is one of the primary data that they insert manually. From the data gathered, the production order for manufacturing will be prepared.

For example, in Figure 5.1 is an order number 06018 for the project 9072. It includes a Headboard Fi40 (Fi30) in the amount of three. According to the architectural drawings and received data, product engineers will make drawings and product specifications.

5.1.2. Product description

The product Headboard Fi40 from a project 9072 is chosen as an example product for this thesis. Its assembly drawing could be seen in Figure 5.2 and some of its eighty-five different details are mentioned in Appendix 9. As this headboard has five variations, indifference of measurements it is included in a product group Headboard (HB).

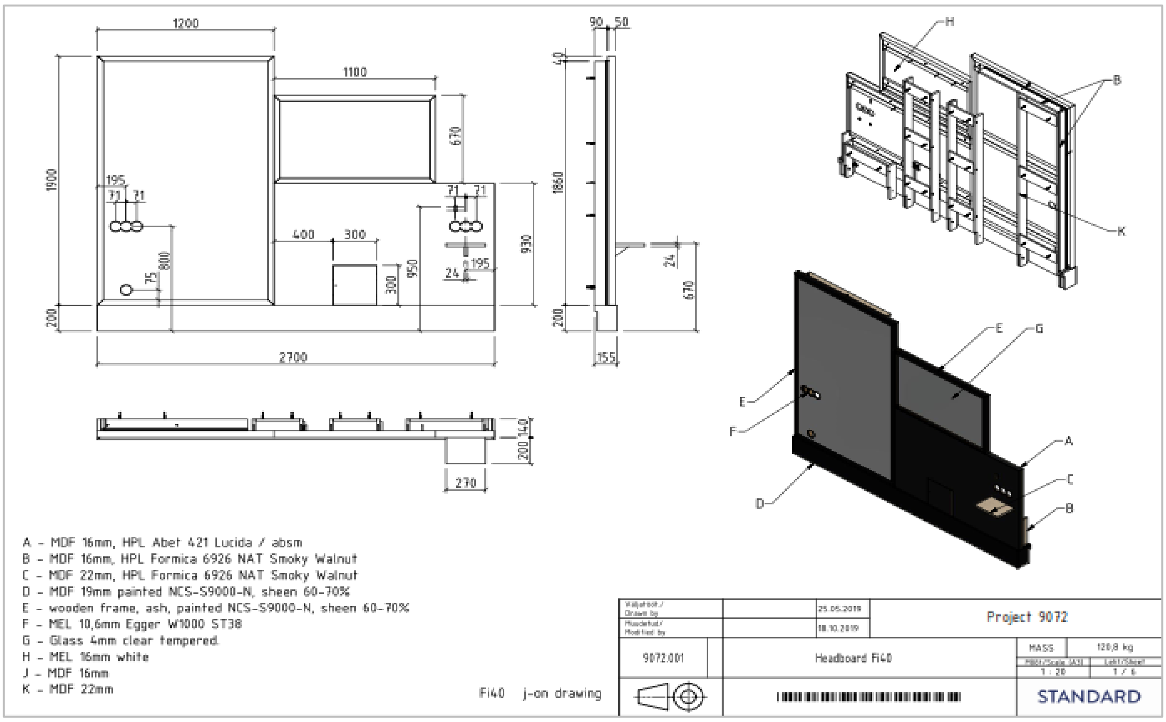


Figure 5.2 Standard AS product Headboard Fi40 from a project 9072 (Standard AS, 2019)

All data about the product could be found from SAF: drawings, product specifications and BOM. If the drawing is ready by a product engineer and inserted to SAF, process engineer checks drawings, specifications, and formalises into a production task.

5.2. Creating the route map

To describe how SAF determines routings and operations, a Headboard Fi40 detail "voodiots" is taken as a sample. Based on Figure 5.3, the laminated board has different drilling and milling processes. Every piece of the detail information from drawing and specification is taken into account by SAF while describing the routing. Every step of this detail routing description will be done by SAF automatically.

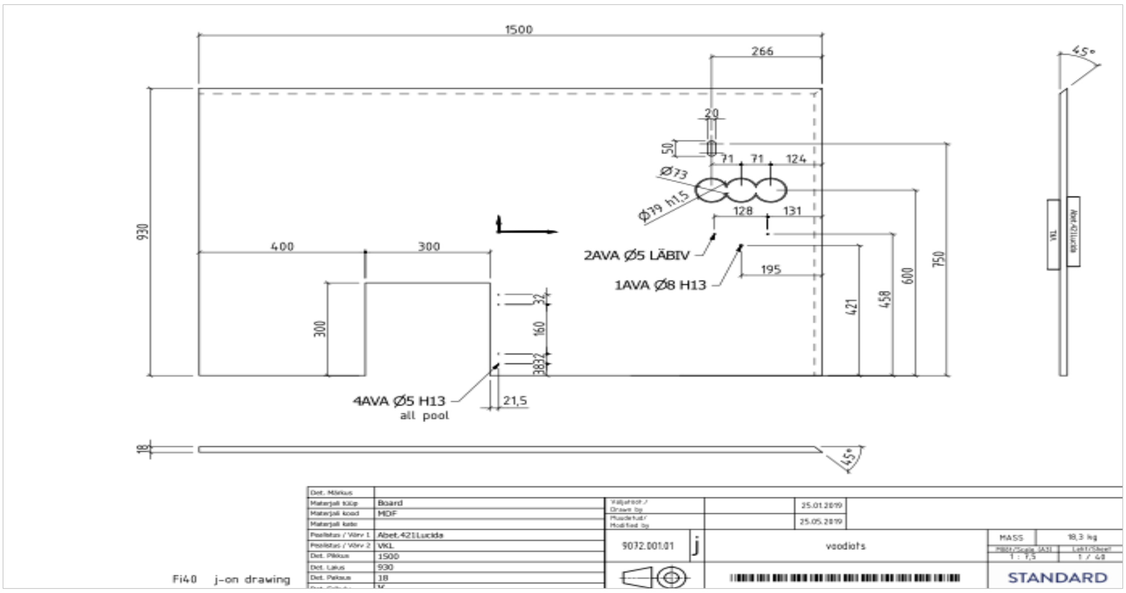


Figure 5.3 Headboard Fi40 (Fi30) detail "*voodiots*" engineered by Standard AS product engineer (Standard AS, 2019)

For example, a Headboard module (Appendix 10) has a detail “voodiots” as described in Figure 5.4. Next will be described the operations and resources determined by SAF for this detail production. As it is a high-pressure laminated board, three different materials should be cut and moved on to the lamination process. The detail does not have edge bandings and goes straight to the next resource for drilling and milling.

!	Projekt	Pos	Toote nimetus	Kogus	Pikkus	Laius	Kõrgus	Tähtaeg	Märkused	Toode SAF
	9072		Headboard Fi40 (Fi30)	1	2700	394	2100	11.10.2019		
	9072		Headbord panel H02R (H02L)	1	2254	145	1680	11.10.2019		

Toote nimetı Headboard Fi40 (F Pikkus 2700 Laius 394
Positsioon Kogus 1 Kõrgus 2100
Toode SAF

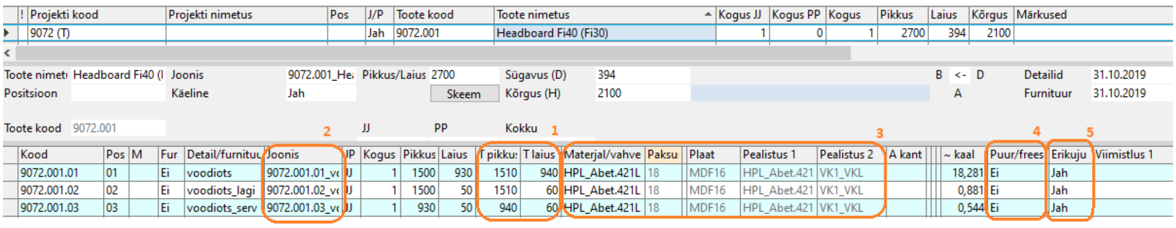
Lisa puuduv tehnoloogia
Uuenda pos. tehnoloogia
Kustuta tehnoloogia
C B D A

Pos	Fur	Detail/furnituur	Pikkus	Laius	Kogus	Materjal/vahve	Paksu	Plaat	Pealistus 1	Pealistus 2	Erik	Holzma	Spooni	Wild	Kalibreer	Italpresse	Ho
01	Ei	voodiots	1500	930	1	HPL_Abet.421L	18	MDF16	HPL_Abet.42	VK1_VKL	Jah						
02	Ei	voodiots_lagi	1500	50	1	HPL_Abet.421L	18	MDF16	HPL_Abet.42	VK1_VKL	Jah						
03	Ei	voodiots_serv	930	50	1	HPL_Abet.421L	18	MDF16	HPL_Abet.42	VK1_VKL	Jah						
04	Ei	riputuslatt	1477	60	1	MDF28	28	MDF28			Ei						

OpNr	Element	Seade	Nimetus	Operatsioon	Op nimetus	Tegevus	Kogus	Ühik
100	Lahtilõikus	7200	Holzma	A72000	Lahtilõikus Schelling	Lahtilõikus - Lahtilõikus Schelling	1,395	m2
210	Pealistus 1	7200	Holzma	A72000	Lahtilõikus Schelling	Pealistus 1 - Lahtilõikus Schelling	1,395	m2
220	Pealistus 2	7200	Holzma	A72000	Lahtilõikus Schelling	Pealistus 2 - Lahtilõikus Schelling	1,395	m2
400	Pealistamine	7211	Wild	A72111	Pealistamine Wild	Pealistamine - Pealistamine Wild	1,395	m2
450	Detaili töötlus pikkus					Detail AC	0	
460	Detaili töötlus laius					Detail BD	0	
610	Detail puurimine	7350	Rover 1332	A73504	Freesimine Rover rosetiava	Detail puurimine - Freesimine Rover rosetiava	0	tk
620	Detail freesimine	7351	Rover 1632	A73502	Puurimine Rover keskmine ava	Detail freesimine - Puurimine Rover keskmine ava	0	tk

Figure 5.4 The example of technological path creation for Headboard Fi40 detail “*voodiots”*

According to an item 4.4.2 (in chapter 4), SAF analyses detail for a drilling machine choice. Figure 5.5. describes specifics of this detail (measurements (1), drawing (2), materials (3)), including its drilling-milling information *(“Puur/Frees”(4) = JAH)*. It also has some special cuttings in it *("Erikuju"(5) = JAH).* In addition, Figure 5.3 confirms that detail "*voodiots*" has three cable holes, a medium-sized opening at the bottom, mitres and some smaller drillings. In consonance with this information, the detail will be drilled and milled by a three-axis machine Rover 1332 and mitres will be done by five-axis machine Rover 1632 as describes in Figure 5.4. As a finishing does not coat this detail, it goes straight to the assembling department.



!	Projekti kood	Projekti nimetus	Pos	J/P	Toote kood	Toote nimetus	Kogus JJ	Kogus PP	Kogus	Pikkus	Laius	Kõrgus	Märkused
	9072 (T)			Jah	9072.001	Headboard Fi40 (Fi30)	1	0	1	2700	394	2100	

Toote nimeti Headboard Fi40 (I Joonis 9072.001_He: Pikkus/Laius 2700 Sügavus (D) 394 B <- D Detailid 31.10.2019
Positsioon Käeline Jah Skeem Kõrgus (H) 2100 A Furnituur 31.10.2019
Toote kood 9072.001 2 JJ PP Kokku 1 3 4 5

Kood	Pos	M	Fur	Detail/furnituu	Joonis	JP	Kogus	Pikkus	Laius	T pikkus	T laius	Materjal/vahve	Paksu	Plaat	Pealistus 1	Pealistus 2	A kant	~ kaal	Puur/frees	Erikuju	Viimistlus 1
9072.001.01	01		Ei	voodiots	9072.001.01_vo	JJ	1	1500	930	1510	940	HPL_Abet.421L	18	MDF16	HPL_Abet.421	VK1_VKL		18,281	Ei	Jah	
9072.001.02	02		Ei	voodiots_lagi	9072.001.02_vo	JJ	1	1500	50	1510	60	HPL_Abet.421L	18	MDF16	HPL_Abet.421	VK1_VKL		0,881	Ei	Jah	
9072.001.03	03		Ei	voodiots_serv	9072.001.03_vo	JJ	1	930	50	940	60	HPL_Abet.421L	18	MDF16	HPL_Abet.421	VK1_VKL		0,544	Ei	Jah	

Figure 5.5 One part of project 9072 product Headboard Fi40 (Fi30) specification in SAF

5.3. Data generation for Preactor import

After routings are generated for every producible detail, Preactor import files must be created for an order 06018. SAF creates an order-based route map, which is imported to an Excel file that could be seen from Appendix 7. The same order from Figure 5.1 is now in a form that could be imported for Preactor scheduling as a product data.

Table 5.1 BOM needed for Preactor of a Headboard group

Part Number	Operation Number	Demand Part Number	Demand Quantity
9072HB_HPL421	10	9072_HPL421	1
9072HB_HPL421	10	9072_MDF16	1
9072HB_HPLF6926	10	9072_HPL6926	1
9072HB_HPLF6926	10	9072_MDF22	1
9072HB_MDF19krunt	10	9072_MDF19krunt	1
9072HB_MDF28	10	9072_MDF28	1
9072HB_MDF16	10	9072_MDF16	1
9072HB_MDF19	10	9072_MDF19	1
9072HB	10	9072HB_HPL421	1
9072HB	10	9072HB_HPLF6926	1
9072HB	10	9072HB_MDF19krunt	1
9072HB	10	9072HB_MDF28	1
9072HB	10	9072HB_MDF16	1
9072HB	10	9072HB_MDF19	1

Product data Excel includes a project BOM describing material distribution in the product group. BOM and its distribution for this Headboard Fi40 product group is described in

Table 5.1. Red lines are the main order product group that do consist the sub-parts in yellow, which in turn contains sub-materials in brown.

Order No.	Part No.	Quantity	Due Date	Earliest Start Date	Notes	Stage
9072HB	9072HB	3	03.06.2020		MK 6018	3
9072Mir	9072Mir	3	03.06.2020		MK 6018	3
9072WD	9072WD	3	03.06.2020		MK 6018	3
9072WR	9072WR	3	03.06.2020		MK 6018	3

Figure 5.6 Orders Excel data including products that order 6018 have

Figure 5.6 expresses the info about importable order: its products, the product quantity (always one, because the whole amount is described in product data as run time), due date (from the order), notes (order number) and stage of the order. The earliest Start Date is not described, because all of the materials could be found from the warehouse.

Info about orders, product routings and BOMs are now ready to be imported to Preactor.

5.4. Production plan generation

According to the four steps stated in Figure 4.1 and visualised in Figure 5.6, data will be imported to Preactor.

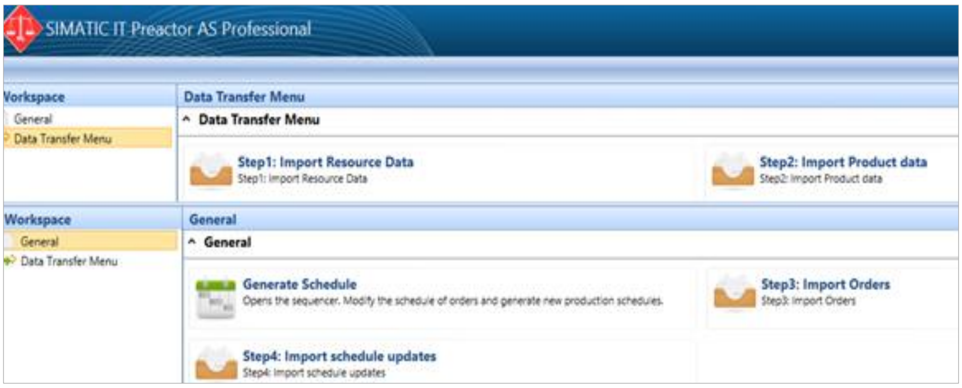


Figure 5.7 Excel tables import to Preactor and generating the schedule

The sample outcome after scheduling the project 9072 order could be seen from Appendix 11. The chosen sample part is included in the greenish batch in Figure 5.8 and passes operations together with other parts of the same batch.

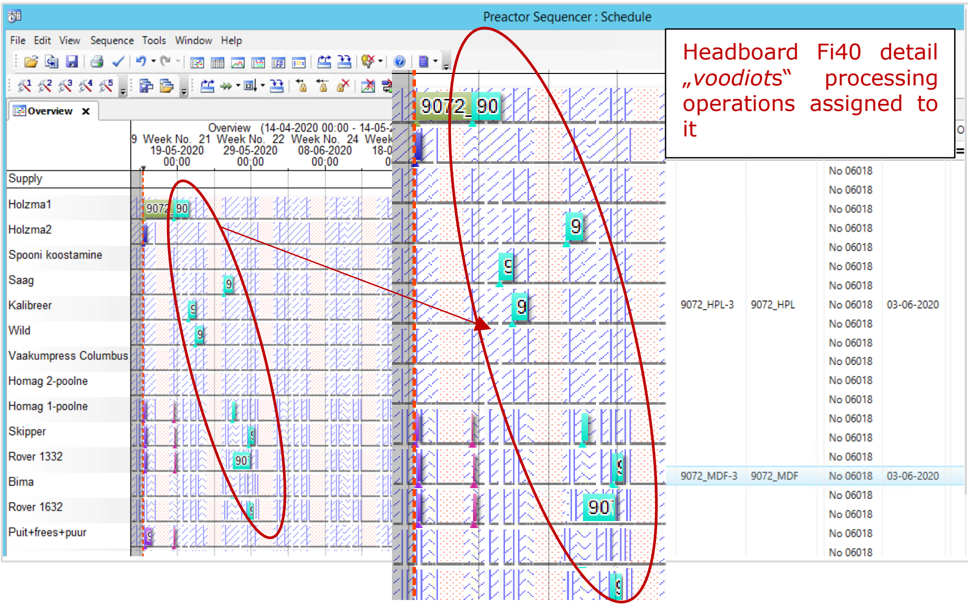


Figure 5.8 The Voodiots detail movement through the production with other HPL details

As pictured in Figure 5.9, the last operations of the sample headboard production are assembling, packaging. The product is ready for the delivery on June 2, 2020. It means that it is prepared according to the due date. It is also confirmed by the report in Figure 5.10 that is used by the production supervisors.

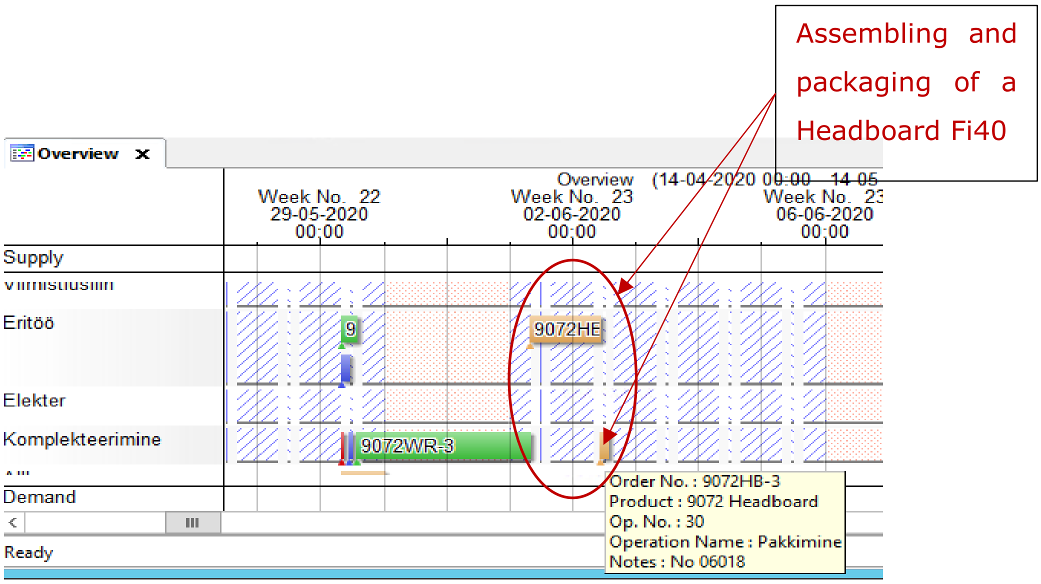


Figure 5.9 Last operations of the Headboard Fi40 production

25.05.2020 - 14.06.2020

Product	Operation Name	Resource	Start Time	End Time	Due Date	Productivity Multiplier	Total Process Time	Notes
9072 Headboard	PMV pealistus	Allhange	29.05.2020	29.05.2020	3.06.2020	1	16,00	No 06018
9072 HPL 421	Servapealistus , freesimine Bima	Bima	26.05.2020	28.05.2020	3.06.2020	1	32,87	No 06018
9072 Writing desk	Montaaz	Eritöö	29.05.2020	29.05.2020	3.06.2020	4	2,94	No 06018
9072 Wardrobe	Montaaz	Eritöö	29.05.2020	29.05.2020	3.06.2020	4	5,39	No 06018
9072 Headboard	Montaaz	Eritöö	1.06.2020	2.06.2020	3.06.2020	8	11,27	No 06018
9072 HPL 421	Servapealistus	Homag 1-poolne	26.05.2020	26.05.2020	3.06.2020	1	7,39	No 06018
9072 Coffee table	Pakkimine	Komplekteerimine	29.05.2020	29.05.2020	3.06.2020	1	0,33	No 06018
9072 Writing desk	Pakkimine	Komplekteerimine	29.05.2020	29.05.2020	3.06.2020	1	0,85	No 06018
9072 Wardrobe	Pakkimine	Komplekteerimine	29.05.2020	1.06.2020	3.06.2020	1	2,30	No 06018
9072 Headboard	Pakkimine	Komplekteerimine	2.06.2020	2.06.2020	3.06.2020	1	2,26	No 06018
9072 HPL 421	Puurimine Rover	Rover 1332	28.05.2020	29.05.2020	3.06.2020	1	8,35	No 06018
9072 HPL 421	Mõõtulõikus	Saag	25.05.2020	26.05.2020	3.06.2020	1	10,83	No 06018
9072 HPL 421	Puurimine Skipper	Skipper	28.05.2020	29.05.2020	3.06.2020	1	8,30	No 06018

Figure 5.10 Project 9072 order 6018 report for production

For now, the order 6018 is produced and could be delivered to the customer with minimal time, with minimal cost for the company, efficiently and what is more, according to the due date.

6. COST OF SAF AND PREACTOR INTEGRATION

It is vital to ascertain the amount that is spent on the development and function of the entire system to obtain. The cost of ERP and APS integration in numbers will be approximately 100 000 € in total. It is only the payment for programs implementation. It is already known that the main revenue lies in the reduction of indirect costs. However, the cost of transportation and delays will be reduced. In addition to that, the Standard AS reputation of being reliable on-time furniture producer and a partner will be improved.

6.1. Cost of SAF technology block generation

The cost of SAF technical route maps development will be approximately 33 300 € and includes the complete engineering process. It involves the preparation of assignment description and specification, whole execution process, implementation of the task and the changes that have occurred during that time.

It is estimated that the entire development process in SAF will take around 83 working days. It means that the work description must be ready by June 2020 so that the implementation process can start from the first week of October in 2020.

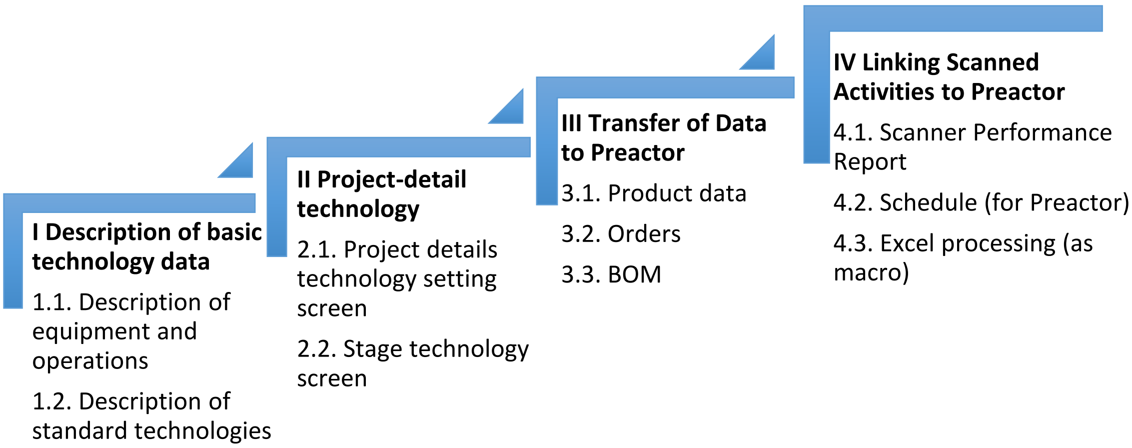


Figure 6.1 Phases of technology block generation by Sysdec AS

According to the quotation of Sysdec AS work includes of four phases: description of the primary technical data, project detail technology, transferring the data from SAF to Preactor and linking scanned activities from SAF *Skanneri_aruanne* to Preactor Scheduling_excel. Figure 6.1 describes these four stages divided into smaller sections.

6.2. Cost of Preactor implementation

The cost for Preactor AS Professional implementation process has been 60 0000 € from the year of 2017 autumn to spring 2019. From summer 2019 and the beginning of 2020 Preactor has not been in use, because it needs a lot of manual information processing and import. This work could not be done manually, and that is the reason the management team of Standard AS decided to stop it for a while. After SAF support is ready to describe the technology route for each detail automatically, it gives more opportunities to plan production with Preactor.

When total Preactor development process cost was 60 000 €, it included different licenses as well. Preactor's licenses for Standard AS cost in total 14 000 €, this was a one-off cost and AS Standard will henceforth be charged for the use of Preactor 167 € per month. It is meant as a maintenance renewal fee, which will be paid once in a month.

It turned out to be an expensive investment to turn it off for a while. Even though Standard AS got excellent implementation training and saw possible data exchange capabilities in Preactor and SAF integration. The company would not know without it what data should be collected to achieve the intended efficiency in APS and ERP collaboration.

6.3. Adaptation

Once both the development of SAF technology blocks and the adaptation of Preactor input and output tables have been regenerated, the implementation of production planning will begin at AS Standards' factories. First, the process will start at AS Standard's Tallinn factory in KMV, where the suitability of Preactor planning and scheduling was already tested once in 2017-2019. If system and logic are working in one factory, it will be implemented in the Kose factory and then in the production of upholstered furniture. During the implementation process, the need to manage the change and skilled people are required.

The estimated due date, when every Standard AS factory are in one production planning and scheduling system will be approximately in the spring of 2024. The expected completion time is after four years, as each production first needs to be re-coordinated and their processes and factories should be first modernized. With the digitisation of Kose factory, will be started in the summer of 2020.

7. RESULTS

The production digitization project in Standard AS started after the team identified that time passed too quickly, and deadlines were overdue. It was not enough to fulfil orders and produce furniture planned accordingly to Excel tables that could not be modifiable nor accurate. They also found out that only moving on with the development processes would keep them in the competition. Digitization allows making existing processes more cost-effective and will increase the profit of the company soon.

The management of Standard AS detected that they could react quickly and intelligently only with functional APS, and it could allow making systematically faster and smarter decisions. It is said that implementing an APS is a long time-consuming effort. Nevertheless, the APS implementation process is also the best way to improve efficiency and competitiveness (MangoGem, 2020).

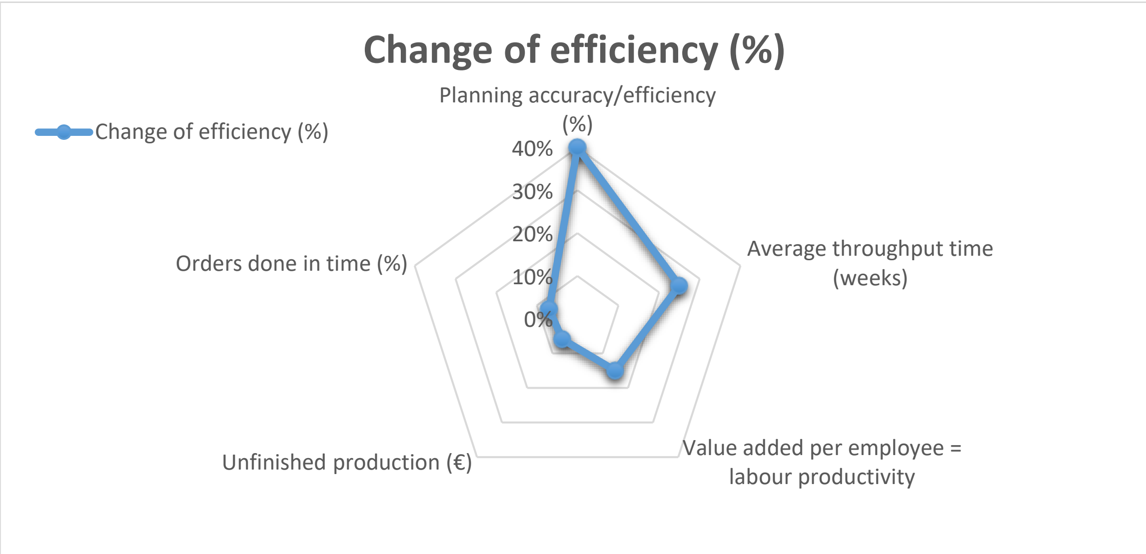


Figure 7.1 Change of efficiency after Preactor and SAF integration

The efficiency estimation of Simatic IT Preactor APS is described in Table 7.1 and drawn out in Figure 7.1. For example, the planning accuracy should increase while production planning is done in cooperation with SAF and Preactor. The AS Standard production development team has determined that integrating ERP and APS system will increase the accuracy and efficiency of production planning from the previous 50% to 80-90% in the future. The efficiency growth could be about 40%, and it means that Standard AS is more able to find additional resources in subcontracting to relieve their bottlenecks and meet the deadlines set for requirements that first felt impossible. It also means that approximately 90% of the orders should be delivered on time. An important indicator is also the value-added by an employee, which could increase by almost 15% through this integration process. Unfortunately, the average output time is unlikely to change.

Table 7.1 Preactor implementations of project efficiency analysis (Standard AS)

Indicator	Before	After	Change of efficiency (%)
Planning accuracy/efficiency (%)	50%	90%	40%
Average throughput time (weeks)	4	3	25%
Value added per employee = labour productivity	23 000	27000	15%
Unfinished production (€)	101000	96700	6%
Orders done in time (%)	83%	90%	7%

In addition to that, the number of raw materials in the warehouse should decrease, because the purchasing will take place according to the production start date. Consequently, the cost in production will be reduced with modern conditions for producing custom-made furniture in small amounts according to clients' preferences.

Table 7.2 Advantages and disadvantages of every step Standard AS gets through arriving to functional production planning and scheduling system

	Advantages	Disadvantages
Production planning with Excel	• possible to plan approximately 3 months ahead (i.e. capacity check)	• no daily production plan either long-term planning
	• derive the approximate project duration	• planning based on experience and predictions
	• find out the production load similarly as Gantt chart	• hard to find bottlenecks and the exact time they occur
		• planning takes ~1,5-2 working days
Production planning after Preactor implementation	• approximately 75-80% of supply efficiency	• a lot of manual work/ inserting orders manually
	• can detect bottlenecks easier and faster	• as input was manual, many mistakes occur
	• convenient overview by a Gantt chart	• challenging to plan in larger batches
	• possible to make a plan for a working week	• planning takes still ~1,5-2 working days
Production planning after Preactor and SAF integration (estimated)	daily production plan	• production scheduling can be complex.
	• timely delivery to customers	• misdirect planning, i.e. dependency on the planner
	• faster product data and order input	• project numbers and materials memorizing
	• variable schedules to use	• planning rigidity
	• increase of supply efficiency to 90 – 95%	
	• bottlenecks detecting and faster outsourcing if needed	

Table 7.2 demonstrates production planning and scheduling integration with SAF reduces disadvantages from previous versions but also highlights a new one. For example could lead to misdirected planning, because the machinery could never be freed of bias and planning is partly a creative activity. In addition to that, production planning and scheduling with APS have still complexity. It stems from the fact that the planner needs to memorize the entire project and product codes, their materials and keep track of them by the schedule. The rigidity comes from the matter that planning has inelasticity and discourages individual experimentation.

The main objectives of this work and production planning system integration were to plan production at least three months to schedule the due dates and product amounts properly for the projects. After the SAF technology and production planning project ends, it should be easier to find the bottlenecks that limit consistent production and by taking it into account, help to reschedule production faster and maximize output to increase the revenue. Solutions should be found to assure timely products delivery. The approach achieved an improved performance regarding crucial key performance indicators such as work-in-progress and machine utilization compared to the real production schedule computed by the company of the industrial application. (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018)

Using production planning and scheduling system will help AS Standard to react to machines breakdowns. The details that were heading to the broken machine are naturally oriented to the next available functional resource to perform the same operation. It is due to the advantages provided by real-time data-exchange and the agility to reschedule. Moreover, much better resource utilization and adaptability to both the production disturbances and changing customer demands may be more beneficial to industrial performance than the individual makespan reduction. Planning and control methods can benefit from data-driven technologies, which allow real-time production monitoring and decision-making. Digitisation and data-exchange should lead to the integration of all its processes enabling industrial performance improvements that are not limited by production and control but can also comprise other tasks and processes such as transport planning and inventory control. (Leusin, Kück, Frazzon, Maldonado, & Freitag, 2018) The last one could also be reduced by synchronizing supply with the demand.

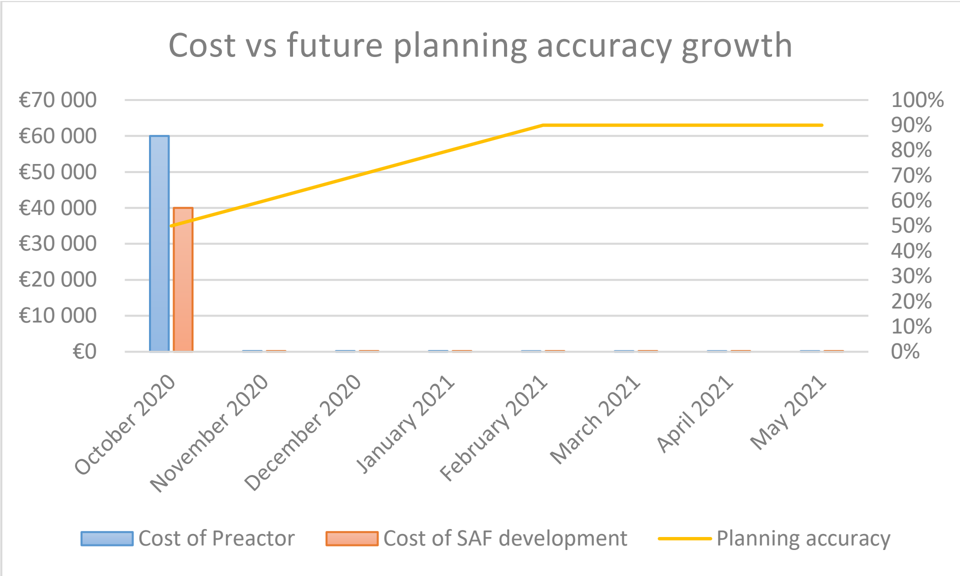


Figure 7.2 Cost and future benefit comparison after SAF and Preactor integration

Even though the development process takes time, money and effort before it could be used, it still could be said that benefits are modern manufactories design and continuous distribution of tasks between workforce and resources for higher performance, adaptability and quality. According to the Chapter 6, that described the total sum that SAF and Preactor integration will cost is formed the Figure 7.2. AS Standard soon would get the profit from accurate production planning and its estimation of its production volumes. The planning accuracy is growing exponentially until it reaches about 90%.

Standard AS hope to increase the product customisation capability and last but not the least get every order ready respectively to the due date. If production planning and scheduling system are entirely usable, the work quality and performance should increase. As orders get prepared accordingly, and production managers and supervisors would not be stressed by late orders, the worker satisfaction would increase. Through a higher acceptance level, AS Standard will strengthen their global position of project management and furniture industry in Europe.

8. FUTURE WORK

The digital diagnostics of Standard AS performed by Columbus Eesti AS found out that the challenges facing the company are improving planning, further digitation of processes and finding digital solutions that support methods, systematic development activities, and more efficient use of existing software. It is also a challenge to manage information (such as interfacing systems) and valuing it so that the necessary data reaches managers' desktops who could quickly get an overview of processes. The goal is to systematically improve the efficiency of processes, effectively manage the supply chain and find an attractive value proposition for the customer. In addition to that, it means that different innovative solutions should be directed to offer to customers.

The nearest goal while digitizing Standard AS factories is to complete the task of production planning and scheduling. If one factory works as planned, other production buildings must be added to the planning and managing system. Thus, it is most optimal to split AS Standards' orders between the three productions. The whole company must operate unambiguously, including optimizing its work based on a unified system. The biggest challenge is probably the co-operation and coherence of all factories.

Production planning should be made as automatic as could, so the time left from production planning and scheduling could be used for other improvement activities. This way, the system supports reaching an objective is automatic handling and analysing the information that has become an essential factor in everyday processes. One type of automatic system can make decisions related to forecasting and production planning. Systems that handle productions and information automatically reduce accidental and systematic errors to minimums and therefore are both faster and more accurate than those dependent upon manual and mental skills and efforts. (E.H.Mac Niece, 1961)

In addition, it could be very progressive and innovative to move increasingly to implement the smart factory of Industry 4.0, including IoT, big data and cloud computing and artificial intelligence technologies. The intelligent machines, conveyors, and products communicate and negotiate with each other to reconfigure themselves for the flexible production of multiple customised products. The industrial network collects massive data from smart objects and transfers them to the cloud. It enables feedback by the whole system and coordination based on big data analytics to optimize production system performance. The self-organized reconfiguration and big-data-based feedback and coordination define the framework and operational mechanism of the smart factory that helps to optimize system performance (Wang, Wan, Zhang, Li, & Zhang, 2016).

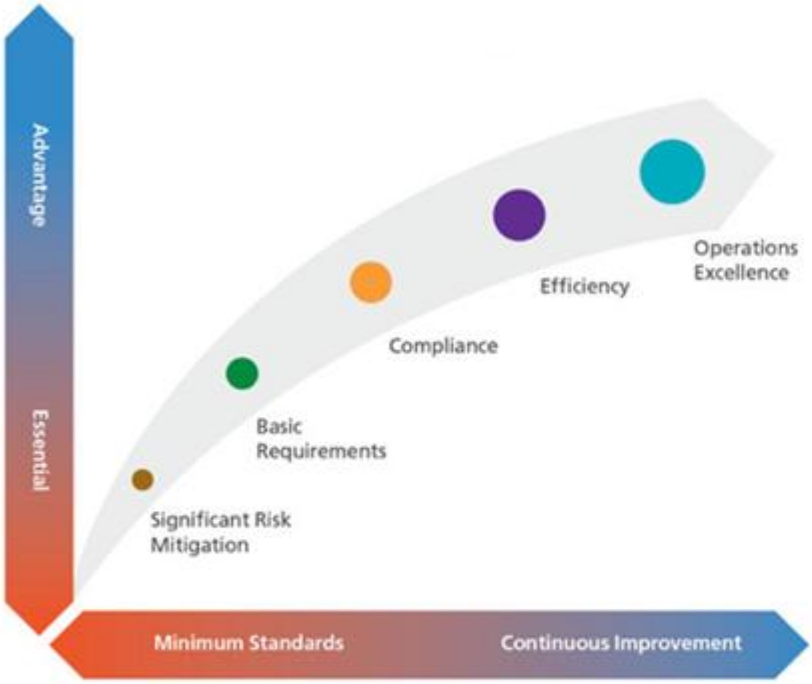


Figure 8.1 Companies better efficiency by continuous improvement (Gilbert, 2017)

Steve Gilbert visualises one company's continuous improvement very well by Figure 8.1. Continuous improvement is the key to production efficiency and the remaining competitiveness. Soon AS Standard would like to include more orders that require possibilities to fulfil highly customised orders for hospitality rooms. In turn, it means further development of production digitalisation and automation is demanded (E.H.Mac Niece, 1961). Furthermore, higher levels of product customisation and varying requirements, call for new adaptive human-centred automation approaches. It should be complementing the cognitive capabilities of humans by advanced sensing and the higher precision of machines. (Cordis, 2020) When the need of automation increases, digital solutions should be improved as well. Individual automatic machines can be highly adaptable and used to perform many different operations on many different products. Completely automatic processes are usually designed to produce a specific product, but they can be modified to produce customised as well. (E.H.Mac Niece, 1961)

AS Standard is ready to contribute by investing in the development of its systems and factories to achieve ever-increasing goals, as increasing the production capabilities to fulfil more orders in less time and according to the due date.

SUMMARY

The master thesis “ERP and Advanced Planning and Scheduling System Integration in Standard AS” is one part of the general development and digitalisation project of Standard AS. It includes production improvement to simplify the system, speed up data management, ensure to meet deadlines and to increase turnover as well as production throughput capacity via more effective production planning and scheduling.

Master student Kristiin Bauer brought out the difficulties and possibilities, what should be carried out while integrating an advanced planning and scheduling system Preactor with an ERP system called SAF. Whole work is based on an Estonian furniture production company Standard AS, who have spent some years for searching and implementing a coherent and efficient planning system for its three production plants. Through years, they have lost a large part of their profit and growth due to the lack of it. For now Estonian furniture producer Standard AS production volumes and turnover is increasing every year. They face difficulties that require a very accurate assessment of production volumes and optimal production planning capabilities.

While writing this master thesis, the author worked out the capabilities and possibilities to integrate the considered ERP and APS system and brought out many advantages and disadvantages of the process results. In addition, worked through the general structure for data exchange by using IDEF1x method and made a task description and comparison of production planning in Standard AS at different points in time. The author managed a case study using DFD method about the new approach and described what could change after successful integration of SAF and Preactor. Finally yet importantly, the financial estimation of the new approach was outlined.

Integration of SAF, i.e. ERP and. Preactor, i.e. APS will allow

- To plan production at least three months ahead;
- To plan possible deadlines and quantities for potential incoming orders;
- To prognosis the possible delivery of outsourced products and raw materials;
- To find the bottlenecks that limit consistent production flow;
- To allow quick rescheduling;
- To plan the time and resources;
- To find out solutions to untimely delivery of products.

In 2020, Standard AS have a possibility to give a push to the development process part in the SAF system and integrate it with Preactor Scheduling. It is possible to produce

similar products simultaneously and process the same materials in one procedure by developing SAF production planner, i.e. technology module and integrating its result with Preactor. Through this, it is possible to reduce the amount of energy required for processing details than without an optimal planning program, which also reduces the harmful impact on our environment and people. APS integrated with ERP will help to save time while providing flexibility in updating ever-changing priorities and refreshing production plans.

SAF system developer confirmed the authors' vision and the work with SAF improvement and integration with Preactor APS could start in early summer of 2020 and will be finished in October 2020.

After this project is over, the development team would like to synchronize Preactor with a program that collects data about the resources for easier managing and more precise production plan. The show could get instant notifications when interruptions and downtimes occur, and it could give real-time information on production capacity to get more profit with the same Standard AS production effectiveness. In addition to that, there are many more things to develop and improve during the digitalisation project in Standard AS.

KOKKUVÕTE

Antud magistritöö pealkirjaga "ERP ja tootmise planeerimise süsteemi integreerimine ettevõttes Standard AS" kuulub ühe osana AS Standardi tootmise arendamise ja digitaliseerimise projekti alla. Selle tulemuseks on tootmise parendamise eesmärgil süsteemi lihtsustamine, andmevahetuse kiirendamine ja tähtaegadest kinnipidamise tagamine. Sealjuures ka käibe ja tootmisvõimekuse suurendamine planeerimisprogrammi Simatic IT Preactor APS by Siemens kasutuselevõtuga. Töö idee on lisada ERP süsteemile sobiv moodul tootmises kasutatavate teekonna kaartide kirjeldamiseks ning tootmise efektiivseks planeerimiseks läbi Preactori.

Magistrantuuri üliõpilane ning Standard AS tootmiste planeerimisjuht Kristiin Bauer, tõi oma töös välja, millised keerukad, kuid samas ka positiivsed küljed, peituvad ERP süsteemi ja tootmise planeerimise (APS) süsteemi omavahelises integreerimises. Kogu protsess viiakse läbi Eesti ühe suurima mööblitootja ehk Standard AS tehases. Tänaseks on kõnealune ettevõte püüdnud omale sobivat APS süsteemi juurutada ja rakendada juba enam kui kolm aastat, kuid ebaõnnestunult ning nad on läbi aastate toimiva programmi puudumise tõttu kaotanud suuri summasid. Standard AS seisab silmitsi keeruliste projektidega, mis nõuavad tootmismahtude väga täpset hindamist ja optimaalseima tootmise kavandamise suutlikkust.

Selle magistritöö raames tõi autor välja ERP ja APS süsteemi ühendamise tulemusena avalduvad positiivsed ja negatiivsed omadused. Sealjuures analüüsis konkreetselt läbi ning kirjeldas IDEF1x ja DFD meetodite abil üldise süsteemi struktuuri ja andmete voo. Saadud diagrammide põhjal loodi ülesande kirjeldus SAF süsteemi arendajale Sysdec AS. Muu hulgas tõi töö autor välja erinevatel hetkedel tootmise planeerimiseks kasutatavate süsteemide ehk SAFi ja Preactori plussid ja miinused. Olemasolevate andmete põhjal sooritas autor juhtumianalüüsi (ehk inglise keeles *case study*). Peale käsitluse, tõi autor olulise osana välja SAFi ja Preactori arendustele kuluva rahalise kulu, mille abil on võimalik hinnata töömahtu ja ressurssi.

SAFi ja Preactori ühildamise tulemusena loodetakse:

- tootmist planeerida vähemalt kolm kuud ette;
- planeerida tootmisvõimekustest lähtuvalt tarnetähtaegasid ja hinnata toodete keerukust;
- prognoosida sisse ostetavate toodete ja tooraine võimalikku tarneaega;
- leida pudelikaelad tootmistehastes, mis piiravad järjepidevat ja ühtlast tootmisvoogu;
- võimaldada kiiret tootmisplaani ümbermuutmist/-korraldamist;

- saada reaalajas ülevaade tootmises olevatest projektidest, nende seisukorrast ja võimalikust tarnekuupäevast;
- planeerida olemasolevad ressursse ja aegasid;
- leida lahendused mitte tähtaegsele tootmisele.

Aasta 2020 on AS Standardi jaoks kui suur arenduste läbiviimise aasta. Standard AS on jõudnud selle hetkeni, mil on võimalik alustada SAFi tehnoloogia arendamiseg, mida siis mõne aja pärast on võimalik SAFist Preactorisse ümber importida ning saadud andmeid tootmise planeerimiseks ära kasutada. Tootmise planeerija ehk tehnoloogia mooduli integreemisel APS süsteemiga on võimalik sarnaseid tooteid, sarnaste materjalidega toota samaaegselt. Selle tulemusena väheneb detailide töötlemisele kuluv energiakogus, mis vähendab kaudselt ka kahjulikku mõju meie keskkonnale ja inimestele. Loodud tulemus hoiab kokku aega, pakkudes paindlikkust pidevalt muutuvate prioriteetite taustal tootmisplaani reaalsena hoida.

SAFi arendajad ettevõttest Sysdec AS kinnitasid autori visiooni ning projekt läheb töösse aasta 2020 suvel ning valmib umbes neli kuud hiljem, ehk hilissügisel.

Pärast selle projekti lõppemist soovib tootmisese arendustiim süsteemi ühildada ka programmiga, mis koguks andmeid ressursside hõlpsamaks haldamiseks ja täpsemaks tootmisplaaniks. Selle tulemusena on võimalik Preactor „varustada" vastava teabega samaaegsete katkestuste ja seisakute kohta, et saada praeguse tootmisvõimekuse kohta maksimaalselt kasumit.

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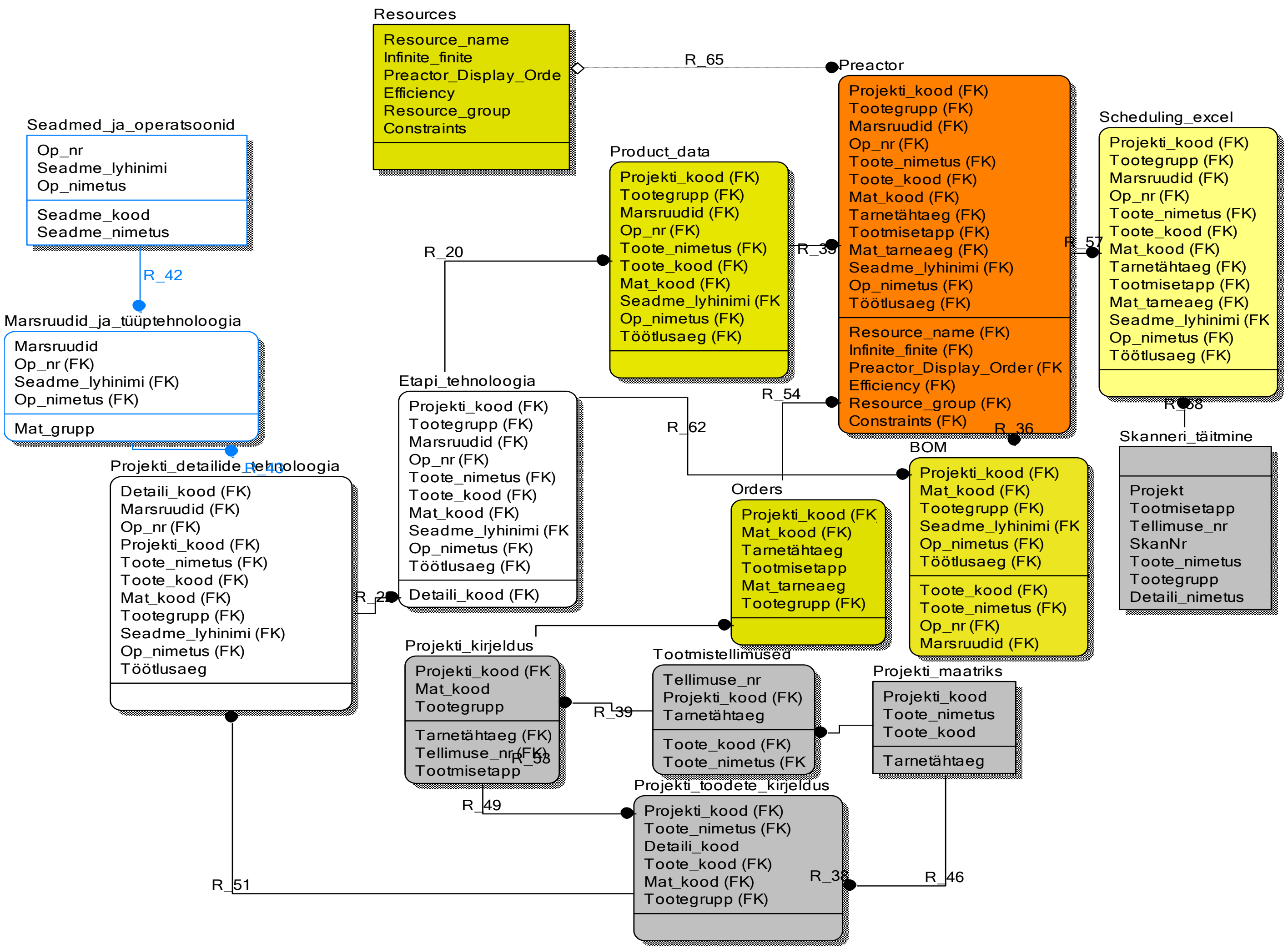
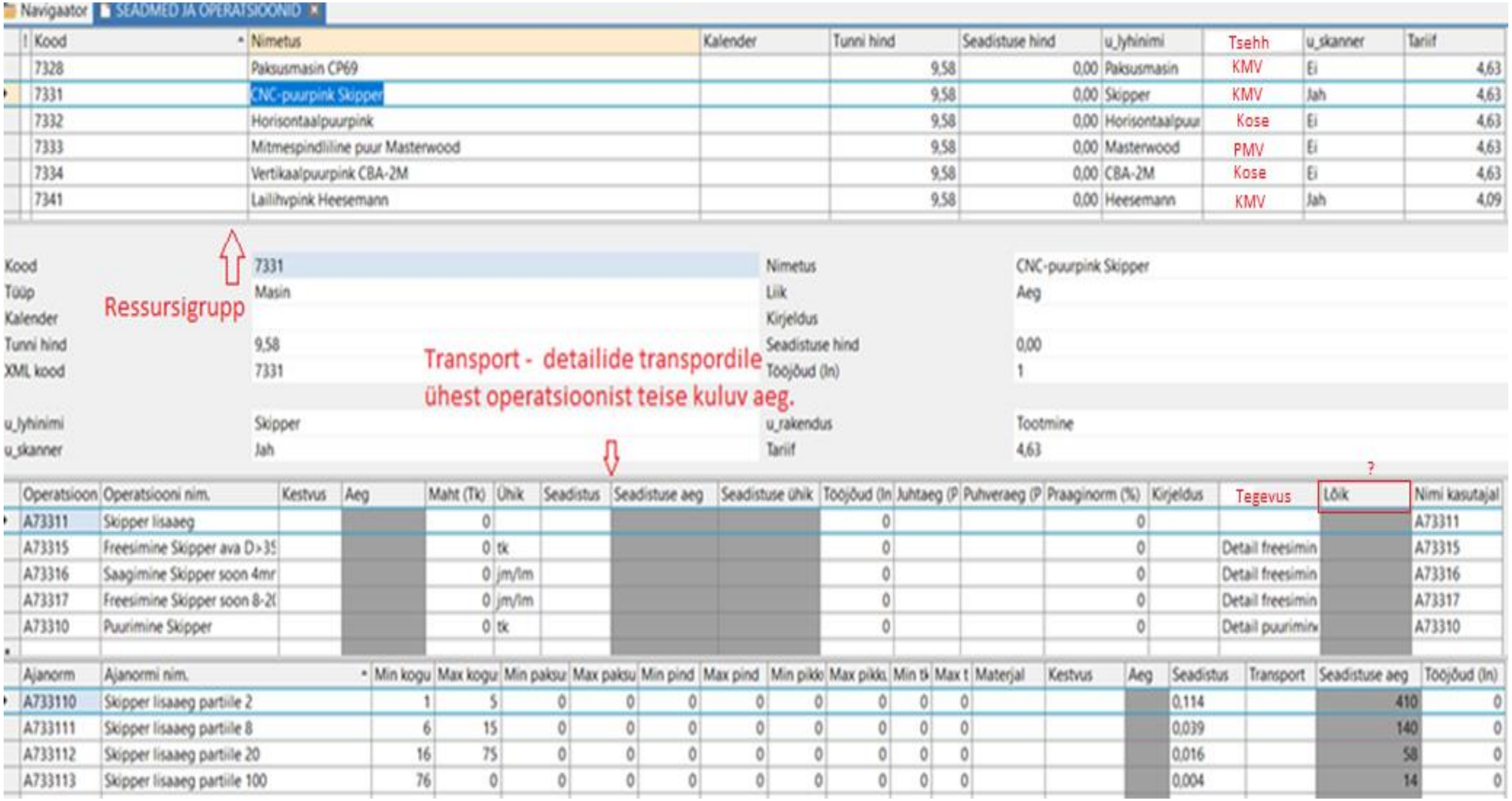
APPENDICES

Appendix 1 IDEF1 diagram of SAF blocks relationship with the Preactor importable data



Appendix 2 SAF production submodule of technology block resources and operations



Navigaator | SEADMED JA OPERATSIOONID

Kood	Nimetus	Kalender	Tunni hind	Seadistuse hind	u_lyhinimi	Tsehh	u_skanner	Tariif
7328	Paksusmasin CP69		9,58	0,00	Paksusmasin	KMV	Ei	4,63
7331	CNC-puurpink Skipper		9,58	0,00	Skipper	KMV	Jah	4,63
7332	Horisontaalpuurpink		9,58	0,00	Horisontaalpuu	Kose	Ei	4,63
7333	Mitmespindliline puur Masterwood		9,58	0,00	Masterwood	PMV	Ei	4,63
7334	Vertikaalpuurpink CBA-2M		9,58	0,00	CBA-2M	Kose	Ei	4,63
7341	Lailihvpink Heesemann		9,58	0,00	Heesemann	KMV	Jah	4,09

Ressursigrupp

Kood	7331	Nimetus	CNC-puurpink Skipper
Tüüp	Masin	Liik	Aeg
Kalender		Kirjeldus	
Tunni hind	9,58	Seadistuse hind	0,00
XML kood	7331	Tööjõud (In)	1
u_lyhinimi	Skipper	u_rakendus	Tootmine
u_skanner	Jah	Tariif	4,63

Transport - detailide transpordile ühest operatsioonist teise kuluv aeg.

?

Operatsioon	Operatsiooni nim.	Kestvus	Aeg	Maht (Tk)	Ühik	Seadistus	Seadistuse aeg	Seadistuse ühik	Tööjõud (In	Juhtaeg (P	Puhveraeg (P	Praaginorm (%)	Kirjeldus	Tegevus	Lõik	Nimi kasutajal
A73311	Skipper lisaaeg			0					0			0				A73311
A73315	Freesimine Skipper ava D>35			0	tk				0			0		Detail freesimin		A73315
A73316	Saagimine Skipper soon 4mr			0	jm/lm				0			0		Detail freesimin		A73316
A73317	Freesimine Skipper soon 8-2(			0	jm/lm				0			0		Detail freesimin		A73317
A73310	Puurimine Skipper			0	tk				0			0		Detail puurimin		A73310

Ajanorm	Ajanormi nim.	Min kogu	Max kogu	Min paksu	Max paksu	Min pind	Max pind	Min pikk	Max pikk	Min t	Max t	Materjal	Kestvus	Aeg	Seadistus	Transport	Seadistuse aeg	Tööjõud (In)
A733110	Skipper lisaaeg partiile 2	1	5	0	0	0	0	0	0	0	0				0,114		410	0
A733111	Skipper lisaaeg partiile 8	6	15	0	0	0	0	0	0	0	0				0,039		140	0
A733112	Skipper lisaaeg partiile 20	16	75	0	0	0	0	0	0	0	0				0,016		58	0
A733113	Skipper lisaaeg partiile 100	76	0	0	0	0	0	0	0	0	0				0,004		14	0

Appendix 3 Operations list for technological path selection

Operatsiooni nimetus	Kood	Ressursigrupp	Ressurss	Ressurss (täisnimi)	Märkused
Lahtilõikus	7200	Holzma	Holzma1	Formaatsaag Holzma	Esimene operatsioon on lahtilõikus, mida teostab Holzma (I vahetus).
Lahtilõikus	7200	Holzma	Holzma2	Formaatsaag Holzma	Esimene operatsioon on lahtilõikus, mida teostab Holzma (II vahetus).
Pealistamine	7211	Press	Wild1	Pressiliin Wild	soe press
Pealistamine	7211	Press	Wild2	Pressiliin Wild	külm press
Pealistamine	7212	Press	Italpresse	Press Italpresse	
Kalibreerimine	7222	Kalibreer	Kalibreerpink	Kalibreerpink Tagliabue	
Puurimine , freesimine	7280	CNC	Bima	Töötlemiskeskus Bima	
Spooni koostamine	7290	Spooni koostamine	Spooni koostamine	Spooni koostamine	
Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne	Servapealsitusliin Homag (kahene)	
Kreppimine	7312	Servapealistus	Homag 1-poolne	Servapealistusliin Homag (ühene)	Kui servakandiks on kant algusega "KR", mille x/y mõõtudest y<=10.
Servapealistus	7312	Servapealistus	Homag 1-poolne	Servapealistusliin Homag (ühene)	Detailid liiguvad kantimisse, kui spetsi lahtrites on täidetud vähemalt üks ABCD kant JA kant on "ABS" või "nat".
Puit+frees+puur	7320	Puit+frees+puur	Puit+frees+puur	Puidutöötlemine koos freesimise ja puurimisega	Kui detaili nimetuses on "seinalatt" või "riputuslatt" ning mille laius = 60mm.
Kreppliistu valmistamine	7320	Puit+frees+puur	Puit+frees+puur	Puidutöötlemine koos freesimise ja puurimisega	Kui detaili nimetuses on "kreppliist", läbib detail ainult seadme puit+frees+puur.
Lahtilõikus	7321	Saag	Ketassaag	Ketassaag SCM SI	
Lahtilõikus	7322	Saag	Ketassaag	Mitmekettaline saag	
Lahtilõikus	7323	Saag	Lintsaag	Lintsaag Meber	
Paksusmasin	7328	Paksusmasin	Paksusmasin	Paksusmasin CP69	
Puurimine	7331	Puurimine	Skipper	CNC-puurpink Skipper	
Pinnalihv	7341	Pinnalihv	Heesemann	Lailihvpink Heesemann	
Servalihvimine	7342	Servalihv	servalihvpink Tagliabue	Kahepoolne servalihvpink Tagliabue	

Pinna käsilihv	7345	Pinnalihv	Lihvimine käsitsi	Lihvimine käsitsi töökoht	
Serva käsilihv	7346	Servalihv	Lihvimine käsitsi	Lihvimine serv käsitsi töökoht	
Puurimine , freesimine	7350	CNC	Rover 1332	CNC-puurpink Rover A 1332	
Puurimine , freesimine	7351	CNC	Rover 1632	CNC-puurpink Rover A 1632	
Kruntimine lakk	7401	Viimistluskabiin	Viimistluskabiin püstol	Viimistluskabiin - püstolviimistluse töökoht	
Kruntimine värv	7401	Viimistluskabiin	Viimistluskabiin püstol	Viimistluskabiin - püstolviimistluse töökoht	
Lakkimine	7401	Viimistluskabiin	Viimistluskabiin püstol	Viimistluskabiin - püstolviimistluse töökoht	
Värvimine	7401	Viimistluskabiin	Viimistluskabiin püstol	Viimistluskabiin - püstolviimistluse töökoht	
Peitsimine	7403	Peitsimine	Peitsikabiin püstol	Peitsikabiin	
Servade peitsimine	7403	Peitsimine	Peitsikabiin püstol	Peitsikabiin	
Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue	Vahelihvpink Tagliabue	
Vahelihv käsi	7405	Vahelihv	Lihvimine käsitsi	Vahelihv - käsitsi töökoht	
Lahtilõikus	7501	Saag	Altendorf	Ketassaag Altendorf	
Montaaz	7509	Montaaz	Montaaz käsi	Montaaz käsitsi töökoht	Kui toote küljes esineb T-furn.
Kreppimine	7509	Servapealistus	Montaaz käsi	Montaaz käsitsi töökoht	Kui servakandiks on kant algusega "KR", mille järel x/y mõõtudest y>10.
Komplekteerimine	7515	Komplekteerimine	Komplekt käsi	Komplekteerimine käsitsi töökoht	
Pakkimine	7517	Pakkimine	Pakkimine	Pakkimine käsitsi töökoht	Iga detaili teekond lõpeb pakkimisega.
Allhange	7518	Allhange	Allhange	Allhange	
Jahtumine	7213	Jahtumine	Jahtumine	Jahtumine	
Kuivamine	7406	Kuivamine	Kuivamine	Kuivamine	
Pealistamine	7285	Vaakumpress	Vaakumpress		
Elekter	7335	Elekter	Elekter	Elekter	
Pahteldamine	7214	Käsiviimistlus	Käsiviimistlus	Viimistlus käsitsi	
Õlitamine	7214	Käsiviimistlus	Käsiviimistlus	Viimistlus käsitsi	
Teipimine	7214	Käsiviimistlus	Käsiviimistlus	Viimistlus käsitsi	

Appendix 4 Routings for technological path selection

Nimetus	Op.Nr	Operatsiooni nimetus	Ressursikood	Ressursigrupp	Ressurss
Puurimine, freesimine	30	Puurimine, freesimine	7280	CNC	Bima
	30	Puurimine, freesimine	7350	CNC	Rover 1332
	30	Puurimine, freesimine	7351	CNC	Rover 1632
	30	Puurimine	7331	Puurimine	Skipper
	30	Puit + frees + puur	7320	Puit + frees + puur	Puit + frees + puur
Viimistlus	Värvimine	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
		Pinnalihv	7341	Pinnalihv	Heesemann
		Kruntimine värv	7401	Viimistluskabiin	Viimistluskabiin püstol
		Kuivamine	7406	Kuivamine	Kuivamine
		Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue
		Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
		Värvimine	7401	Viimistluskabiin	Viimistluskabiin püstol
		Kuivamine	7406	Kuivamine	Kuivamine
		Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
		Pinnalihv	7341	Pinnalihv	Heesemann
		Värvimine	7401	Viimistluskabiin	Viimistluskabiin püstol
		Kuivamine	7406	Kuivamine	Kuivamine
	Peitsimine	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
		Pinnalihv	7341	Pinnalihv	Heesemann
		Peitsimine	7403	Peitsimine	Peitsikabiin püstol
		Kuivamine	7406	Kuivamine	Kuivamine
		Kruntimine lakk	7401	Viimistluskabiin	Viimistluskabiin püstol
		Kuivamine	7406	Kuivamine	Kuivamine
		Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
		Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue
		Lakkimine	7401	Viimistluskabiin	Viimistluskabiin püstol

	Kuivamine	7406	Kuivamine	Kuivamine
Lakkimine	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
	Pinnalihv	7341	Pinnalihv	Heesemann
	Kruntimine lakk	7401	Viimistluskabiin	Viimistluskabiin püstol
	Kuivamine	7406	Kuivamine	Kuivamine
	Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
	Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue
	Lakkimine	7401	Viimistluskabiin	Viimistluskabiin püstol
	Kuivamine	7406	Kuivamine	Kuivamine
Õlitamine	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
	Pinnalihv	7341	Pinnalihv	Heesemann
	Õlitamine	7214	Käsiviimistlus	Käsiviimistlus
	Kuivamine	7406	Kuivamine	Kuivamine
	Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
	Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue
	Õlitamine	7214	Käsiviimistlus	Käsiviimistlus
	Kuivamine	7406	Kuivamine	Kuivamine
	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
	Pinnalihv	7341	Pinnalihv	Heesemann
	Õlitamine	7214	Käsiviimistlus	Käsiviimistlus
	Kuivamine	7406	Kuivamine	Kuivamine
	Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
	Vahelihv	7404	Vahelihv	Vahelihvpink Tagliabue
	Õlitamine	7214	Käsiviimistlus	Käsiviimistlus
	Kuivamine	7406	Kuivamine	Kuivamine
	Servalihvimine	7342	Servalihv	servalihvpink Tagliabue
sp kandi ja krepi viimistlus	Kruntimine lakk	7401	Viimistluskabiin	Viimistluskabiin püstol
	Kuivamine	7406	Kuivamine	Kuivamine
	Serva käsilihv	7346	Servalihv	Lihvimine käsitsi
	Lakkimine	7401	Viimistluskabiin	Viimistluskabiin püstol
	Kuivamine	7406	Kuivamine	Kuivamine

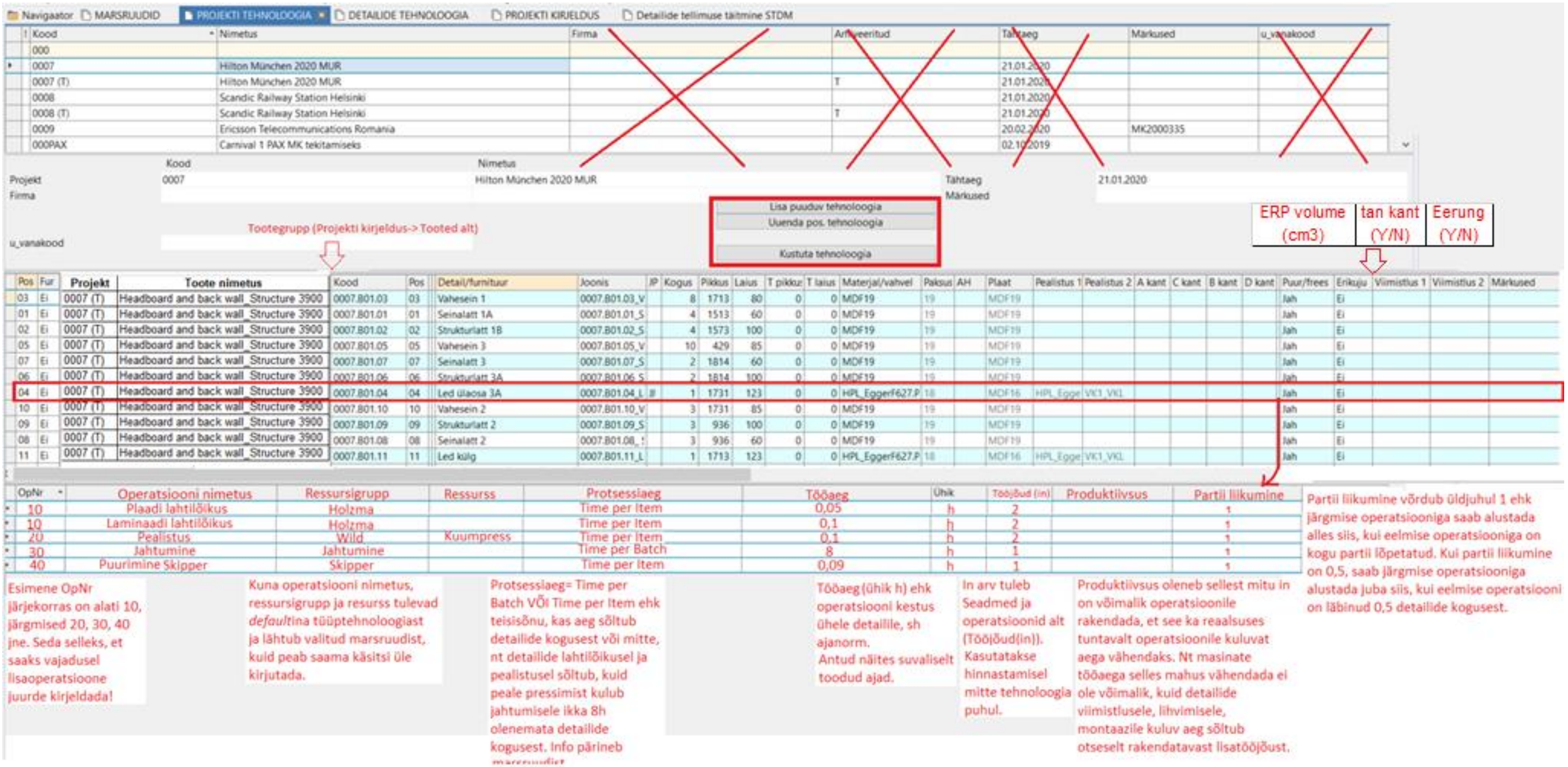
Appendix 5 Standard technology for technological path selection

Nimetus	Op.Nr	Operatsiooni nimetus	Ressursikood	Ressursigrupp	Ressurss
Tüüptehnoloogiad:					
MPLP/PLP/MDF/HDF/vineer	10	plaadi lahtilõikus	7200	Holzma	Holzma
	20	Servapealistus	7312	Servapealistus	Homag 1-poolne
	30	marsruut puurimine , freesimine			
	...	marsruut viimistlus			
sp vahvel	10	plaadi lahtilõikus	7200	Holzma	Holzma
(kui materjali vahvli vähemalt ühe komponendi toode on "Spoon, tasakaalupaber".)	10	Spooni koostamine	7290	Spooni koostamine	Spooni koostamine
	20	Pealistus	7211	Press	Wild1
	30	Jahtumine	7213	Jahtumine	Jahtumine
	40	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
	50	Servapealistus	7312	Servapealistus	Homag 1-poolne
	60	marsruut puurimine , freesimine			
	...	marsruut viimistlus			
lam vahvel	10	plaadi lahtilõikus	7200	Holzma	Holzma
(kui materjali vahvli vähemalt ühe komponendi toode on "Laminaat, Linoleum, Kork, Tapeet, Dek.Kile, Vaip.")	20	laminaadi lahtilõikus	7200	Holzma	Holzma
	20	Kalibreerimine	7222	Kalibreer	Kalibreerpink
	30	Pealistus	7211	Press	Wild2
	40	Jahtumine	7213	Jahtumine	Jahtumine
	50	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
	50	Servapealistus	7312	Servapealistus	Homag 1-poolne
	60	marsruut puurimine , freesimine			
Tüüptehnoloogia erisused:					

Kantimistoorik					
x,y TOORIK (detailI	10	plaadi lahtilõikus	7200	Holzma	Holzma
x,y TOORIK (detailI	20	Servapealistus	7312	Servapealistus	Homag 1-poolne
x,y TOORIK (detailI	30a	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
x (detail) *y (detail)*	40	marsruut puurimine , freesimine			
x (detail) *y (detail*	...	marsruut viimistlus			
x,y TOORIK (detailI	30	marsruut puurimine , freesimine			
x,y TOORIK (detailI	40b	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
x (detail) *y (detail)*	...	marsruut viimistlus			
Pealistustoorik					
x,y,z TOORIK (detail)	10	plaadi lahtilõikus	7200	Holzma	Holzma
x,y,z TOORIK (detail)	20	laminaadi lahtilõikus	7200	Holzma	Holzma
x,y,z TOORIK (detail)	30	Pealistus	7211	Press	Wild2
x,y,z TOORIK (detail)	40	Jahtumine	7213	Jahtumine	Jahtumine
x,y,z TOORIK (detail)	50	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
x (detail) *y (detail)* *z (detail)*	50	Servapealistus	7312	Servapealistus	Homag 1-poolne
x (detail) *y (detail)* *z (detail)*	60	marsruut puurimine , freesimine			
Krepitud detailid					

x.1 (detail) toorik	10	plaadi lahtilõikus	7200	Holzma	Holzma
x.1 (detail) toorik	20a	Spooni koostamine	7290	Spooni koostamine	Spooni koostamine
x (detail)	20b	laminaadi lahtilõikus	7200	Holzma	Holzma
x (detail)	10	Kreppliistu valmistamine	7320	Puit+frees+puur	Puit+frees+puu r
x.2 (detaili) kreppliist	30	Kreppimine	7509	Servapealistus	Montaaz käsi
x.1 (detail) toorik	40	Kalibreerimine	7222	Kalibreer	Kalibreerpink
x (detail)	50	Pealistus	7211	Press	Wild2
x (detail)	60	Jahtumine	7213	Jahtumine	Jahtumine
x (detail)	70	Mõõtulõikus	7311	Mõõtulõikus	Homag 2-poolne
x (detail)	80	Servapealistus	7312	Servapealistus	Homag 1-poolne
x (detail)	80+	marsruut puurimine , freesimine			
x (detail)	...	Teipimine	7214	Käsiviimistlus	Käsiviimistlus
x (detail)	...a	marsruut viimistlus			
x (detail)	...b	marsruut sp kandi ja kr (krepi) viimistlus			
KOOST					
x.1 (detail)	10	plaadi lahtilõikus	7200	Holzma	Holzma
x.2 (detail)	10	plaadi lahtilõikus	7200	Holzma	Holzma
x.3 (detail)	10	plaadi lahtilõikus	7200	Holzma	Holzma
x.4 (detail)	10	plaadi lahtilõikus	7200	Holzma	Holzma
x (detail)	20	koostamine	7509	Montaaz	Montaaz käsi
x (detail)	30	Servapealistus	7312	Servapealistus	Homag 1-poolne
x (detail)	40+	marsruut puurimine , freesimine			
x (detail)	...+	marsruut viimistlus			

Appendix 6 A draft of the detail technological path of one project table



Appendix 7 A draft of the product data table in Microsoft Excel table for Preactor import

Project	Part Number	Product Name	Operation Number	Operation Name	Resource Group	Resource	Process Time Type	Setup time, h	Run Time, h	Productivity multiplier
Scandic Marsk 9072	9072_MDF8	9072 MDF8	10	Lahtilõikus	Holzma	Holzma1	Time Per Batch	0,08		1
Scandic Marsk 9072	9072_MPLP106	9072 MPLP10,6 valge	10	Lahtilõikus	Holzma	Holzma2	Time Per Batch	2,08		1
Scandic Marsk 9072	9072_HPL0693	9072 HPL 0693	10	HPLi ja VKL lahtilõikus	Holzma	Holzma2	Time Per Batch	3		1
Scandic Marsk 9072	9072_HPL2006	9072 HPL 2006	10	HPLi ja VKL lahtilõikus	Holzma	Holzma1	Time Per Batch	1,35		1
Scandic Marsk 9072	9072HB_HPLF6926	9072 Headboard HPL F6926	20	Pealistus	Wild		Time Per Batch	0,48		1
Scandic Marsk 9072	9072HB_HPLF6926	9072 Headboard HPL F6926	30	Jahtumine	Jahtumine		Time Per Batch	0,6		1
Scandic Marsk 9072	9072HB_HPLF6926	9072 Headboard HPL F6926	40	Mõõtulõikus	Saag		Time Per Batch	0,12		1
Scandic Marsk 9072	9072HB_HPLF6926	9072 Headboard HPL F6926	50	Puurimine, freesimine	Puit+frees+puur		Time Per Batch	0,54		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	20	Servapealistus	Homag 1-poolne		Time Per Batch	0,18		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	30	Eerungi saagimine	Eritöö		Time Per Batch	0,06		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	40	Servalihv	servalihvpink Tagliabue		Time Per Batch	0,24		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	50	Pinnalihv	Heesemann		Time Per Batch	0,54		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	60	Värvimine	Viimistluskabiin		Time Per Batch	0,36		1
Scandic Marsk 9072	9072HB_MDF19krunt	9072 Headboard MDF19 krunditud	70	Kuivamine	Kuivamine		Time Per Batch	0,12		1
Scandic Marsk 9072	9072HB_MDF28	9072 Headboard MDF28	20	Puurimine, freesimine	Puit+frees+puur		Time Per Batch	0,12		1
Scandic Marsk 9072	9072HB_MDF16	9072 Headboard MDF16	20	Puurimine Skipper	Skipper		Time Per Batch	0,84		0,5
Scandic Marsk 9072	9072HB_MDF16	9072 Headboard MDF16	20	Puurimine Rover	CNC	Rover 1632	Time Per Batch	2,64		0,5
Scandic Marsk 9072	9072HB_MDF16+MDF19	9072 Headboard MDF16+MDF19	20	Plaatide kokkupressimine	Wild		Time Per Batch	0,78		1
Scandic Marsk 9072	9072HB_MDF16+MDF19	9072 Headboard MDF16+MDF19	30	Puurimine, freesimine	Puit+frees+puur		Time Per Batch	0,42		1
Scandic Marsk 9072	9072HB_MDF19	9072 Headboard MDF19	20	Puurimine, freesimine	Puit+frees+puur		Time Per Batch	0,48		1
Scandic Marsk 9072	9072HB_MDF22	9072 Headboard MDF22	20	Puurimine, freesimine	Puit+frees+puur		Time Per Batch	0,72		0,5
Scandic Marsk 9072	9072HB_MDF22	9072 Headboard MDF22	20	Puurimine Rover	CNC	Rover 1332	Time Per Batch	0,72		0,5
Scandic Marsk 9072	9072HB_MPLP106	9072 Headboard MPLP10,6 valge	20	Puurimine Rover	CNC	Rover 1332	Time Per Batch	0,84		1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	10	Lihvimine käsitsi	Lihvimine käsitsi		Time Per Batch	0,78	2	1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	20	Peitsimine	Peitsimiskabiin		Time Per Batch	0,84		1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	30	Kuivamine	Kuivamine		Time Per Batch	4,8		1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	40	Kruntlakk	Viimistluskabiin		Time Per Batch	0,9		1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	50	Kuivamine	Kuivamine		Time Per Batch	0,3		1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	60	Vahelihv	Lihvimine käsitsi		Time Per Batch	0,42	2	1
Scandic Marsk 9072	9072HB_TP	9072 Headboard saar	70	Lõpulakk	Viimistluskabiin		Time Per Batch	0,48		1

Appendix 8 An overview of Schedule Excel table

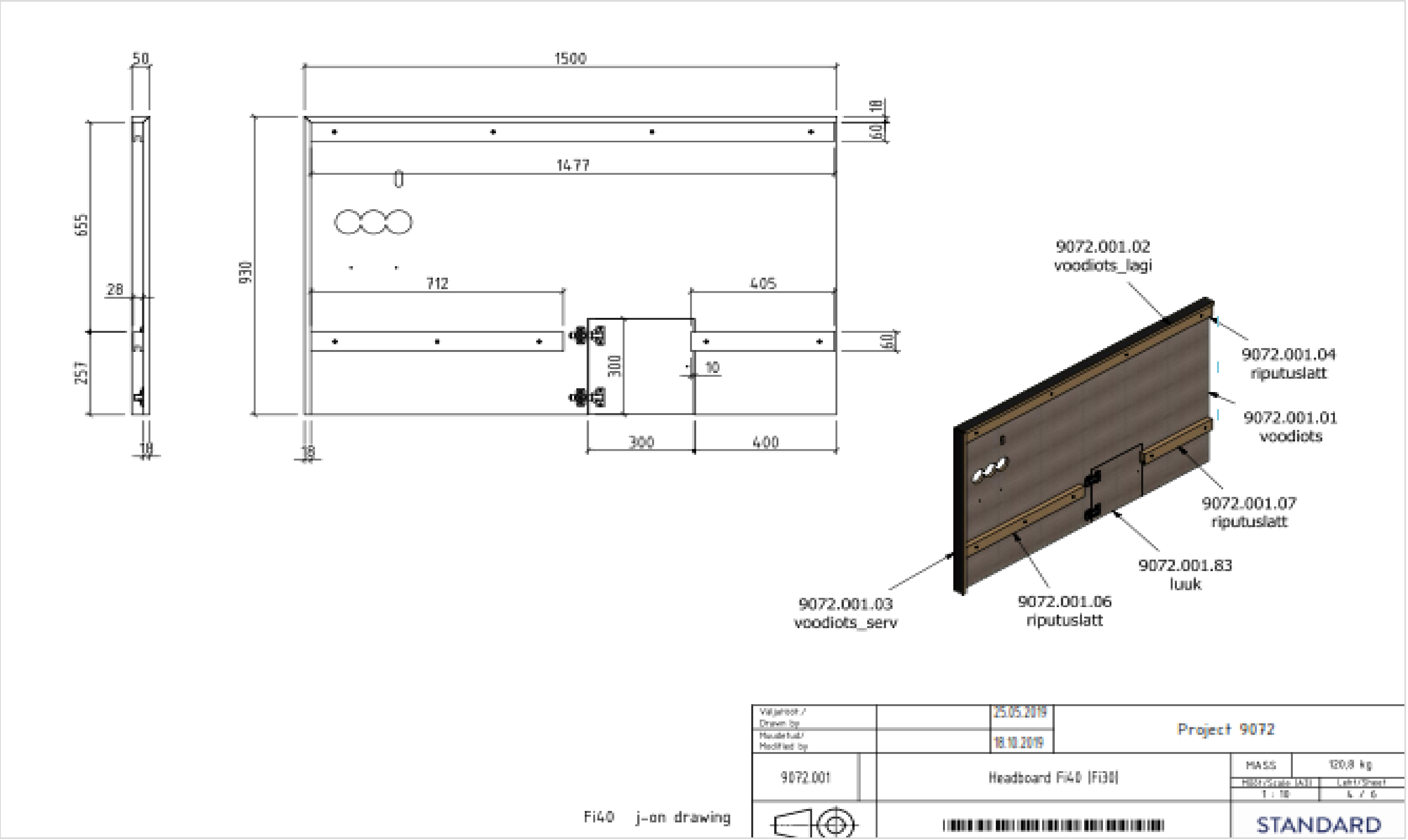
Production PlanSchedule	ProductionPlan ResourceName	Project	ProductionPlan OrderNo	ProductionPlan Product	OrderNotes	Production PlanOpNo	ProductionPlan OperationName	ProductionPlan StartTime	ProductionPlan EndTime	ProductionPlan TotalProcess Time	Operation Finished	Resource group	Productivity Multiplier	PartNo	Quantity	Project Stage
Schedule	Holzma2	Marriott Hote	RIGhent_Vin15	Residence Inn	2.tarne,2.k MK	10	Lahtilõikus	23.08.2019	23.08.2019	0,2	TRUE	Holzma	1	RIGhent_Vin15BBBB	20	2
Schedule	Holzma2	Marriott Hote	RIGhent_Vin12	Residence Inn	2.tarne,2.k MK	10	Lahtilõikus	23.08.2019	23.08.2019	0,24	TRUE	Holzma	1	RIGhent_Vin12C	24	2
Schedule	Wild	Marriott Hote	RIGhentWRShe	Residence Inn	2.tarne,2.k MK	20	Pealistus	14.08.2019	14.08.2019	0,465384615	TRUE	Wild	1	RIGhentWRShelf_HPLf2253	11	2
Schedule	Jahtumine	Marriott Hote	RIGhentWRShe	Residence Inn	2.tarne,2.k MK	30	Jahtumine	14.08.2019	14.08.2019	0,21	FALSE	Jahtumine	1	RIGhentWRShelf_HPLf2253	11	2
Schedule	Homag 2-pooln	Marriott Hote	RIGhentWRShe	Residence Inn	2.tarne,2.k MK	40	Mõõtulõikus	14.08.2019	14.08.2019	0,320833333	FALSE	Homag 2-po	1	RIGhentWRShelf_HPLf2253	11	2
Schedule	Homag 1-pooln	Marriott Hote	RIGhentWRShe	Residence Inn	2.tarne,2.k MK	50	Servapealistus	14.08.2019	14.08.2019	0,385	FALSE	Homag 1-po	1	RIGhentWRShelf_HPLf2253	11	2
Schedule	Komplekteerin	Marriott Hote	RIGhentWRShe	Residence Inn	2.tarne,2.k MK	10	Pakkimine	12.08.2019	12.08.2019	0,171875	FALSE	(Ctrl)	2	RIGhentWRShelf	11	2
Schedule	Puit+frees+puu	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	10	kreppliistu valn	12.08.2019	12.08.2019	0,75	TRUE	Puit+frees+p	2	RIGhentWRSafe_KR	30	2
Schedule	Wild	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	20	Pealistus	14.08.2019	14.08.2019	0,807692308	FALSE	Wild	1	RIGhentWRSafe_HPLmust	15	2
Schedule	Jahtumine	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	30	Jahtumine	14.08.2019	14.08.2019	0,11	TRUE	Jahtumine	1	RIGhentWRSafe_HPLmust	15	2
Schedule	Homag 2-pooln	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	40	Mõõtulõikus	14.08.2019	14.08.2019	0,8125	TRUE	Homag 2-po	1	RIGhentWRSafe_HPLmust	15	2
Schedule	Homag 1-pooln	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	50	Servapealistus	14.08.2019	14.08.2019	0,3	FALSE	Homag 1-po	1	RIGhentWRSafe_HPLmust	15	2
Schedule	Rover 1332	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	60	Puurimine Rove	14.08.2019	14.08.2019	0,9375	FALSE	CNC	1	RIGhentWRSafe_HPLmust	15	2
Schedule	Eritöö	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	20	Kreppimine	12.08.2019	12.08.2019	0,3	TRUE	Eritöö	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Kalibreer	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	30	Kalibreerimine	13.08.2019	13.08.2019	0,75	TRUE	Kalibreer	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Wild	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	40	Pealistus	14.08.2019	14.08.2019	1,557692308	FALSE	Wild	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Jahtumine	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	50	Jahtumine	14.08.2019	14.08.2019	0,0015	FALSE	Jahtumine	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Homag 2-pooln	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	60	Mõõtulõikus	14.08.2019	14.08.2019	0,5625	FALSE	Homag 2-po	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Homag 1-pooln	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	70	Servapealistus	14.08.2019	14.08.2019	0,375	FALSE	Homag 1-po	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Rover 1632	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	80	Puurimine Rove	14.08.2019	14.08.2019	0,375	FALSE	CNC	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Lihvimine käsi	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	90	Servalihv	15.08.2019	15.08.2019	0,1875	FALSE	Lihvimine kä	2	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Heesemann	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	100	Teipimine	15.08.2019	16.08.2019	3	FALSE	Heesemann	1	RIGhentWRSafe_HPLf2253KR	15	2
Schedule	Viimistluskabi	Marriott Hote	RIGhentWRSaf	Residence Inn	2.tarne,2.k MK	110	Kruntvärv	16.08.2019	16.08.2019	1,425	FALSE	Viimistluska	2	RIGhentWRSafe_HPLf2253KR	15	2

Appendix 9 product Headboard Fi40 (Fi30) list of details

Kood 9072.001 **Headboard Fi40 (Fi30)**

Kood	DETAIL	KOGUS TOOTELE	KANDID PIKKUS	KANDID LAIUS	PAKSUS	PLAAT	AH	PEALISTUS	VIIMISTLUS	MÄRKUSED
.01	**voodiots**	1	1500	930	18	MDF 16mm		Laminaat Abet 0,9mm 421 Lucida Must-Läikiv		2 serva eerungis
								Laminaat tasakaal (pruun)		
.02	**voodiots_lagi**	1	1500	50	18	MDF 16mm		Laminaat Abet 0,9mm 421 Lucida Must-Läikiv		2 serva eerungis
								Laminaat tasakaal (pruun)		
.03	**voodiots_serv**	1	930	50	18	MDF 16mm		Laminaat Abet 0,9mm 421 Lucida Must-Läikiv		2 serva eerungis
								Laminaat tasakaal (pruun)		
.11	**liist**	2	670	50	40	Saar			NCS.S9000-N.60-70% MUST	2 serva eerungis
									NCS.S9000-N.60-70% MUST	
.13	**liist**	2	1100	50	40	Saar			NCS.S9000-N.60-70% MUST	2 serva eerungis
									NCS.S9000-N.60-70% MUST	
.06	**riputuslatt**	1	712	60	28	MDF 28mm				
.07	**riputuslatt**	1	405	60	28	MDF 28mm				
.08	**seinalatt**	1	712	60	19	MDF19				
.09	**seinalatt**	1	395	60	19	MDF19				
.04	**riputuslatt**	1	1477	60	28	MDF 28mm				
.05	**seinalatt**	1	1477	60	19	MDF19				

Appendix 10 Project 9072 Headboard Fi40 module



Appendix 11 Project 9072 order no 06018 production plan in Preactor