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PRODUCTION DIGITALISATION IN FURNITURE INDUSTRY

TOOTMISE DIGITALISEERIMINE MÖÖBLITÖÖSTUSETTEVÕTETES

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare, that I have written this thesis independently.
No academic degree has been applied for based on this material.
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Introduction

Production companies today are facing major challenges – customers are expecting something new, something personal, better quality and shorter deliveries. In the same time producers must think on how to be more environmentally friendly, how to use less resources and produce less waste. Doing so, the price should stay the same or even lower.

That puts production companies to a position, where something new and innovative has to be done. As the clients can use mobiles and Internet wherever they are and place their orders, the companies must fit with the needs and look for a mobile technology themselves. The area where clients look for the goods is spreading so every company needs to adapt with faster production and delivery.

Formerly companies used to build their components in various locations and brought them together to make the final product for the customer. Today the companies are expected to centralize their production so all the operations can be simultaneously controlled and are changeable.

To meet these requirements companies must look for to digitalization their manufacturing, which means bringing to use smartphones, tablets, sensors, programs that are connected with one another. This creates the way for the future in production – Industry 4.0.

The main aim of the thesis is to take closer look into different ways of production digitalization and Industry 4.0. In the thesis will be mapped the situation in Estonian furniture industry: are there any companies digitalizing their productions and what are the thoughts towards digitalizing. For that a survey was carried out and the results of the questionnaire were analyzed. Another aim of the thesis is to study the digitalization progress in a company named Plaat Detail OÜ to see what are the benefits gained from, what are the risks and difficulties by implementing new technology and analyze the situation where the company is today and what are the next steps needed to execute.

1 Production digitalization

1.1 Industry 4.0

The proliferation of cyber-physical systems introduces the fourth stage of industrialization, commonly known as Industry 4.0. The term „Industry 4.0“ is not just a slogan, it brings together trends and technologies to turn around the way things are made. [3]

The need for the fourth industrial revolution is driven in one hand by changes in production strategies and also by the new needs of the society. The main needs that started Industry 4.0 are:

- lowering the cost;
- simplicity;
- high flexibility and easy handling;
- chance for small and medium size companies;
- easy shifted;
- customer oriented production;
- smart, robotics oriented production for small and medium size companies. [4]

The reality that came at the beginning while applying the Industry 4.0 we're:

- automated production unit's too high cost;
- complexity;
- high competence requirement;
- availability for only big companies;
- to get the efficiency large production output is needed;
- production by series. [4]

The importance of robots in everyday life and in production is growing rapidly. Today there are robots all around us; in agriculture milking machines, in household vacuum cleaners, bomb robots to make dangerous tasks etc. Robots are even able to play musical instruments. [4]

Service robotics market size is expected to reach 21.7 billion USD by 2022. The main need for robotics is in defense service along with healthcare, transport, production. [5]

Robotized production may bring the rise of small and medium size companies, because the cost of robots is decreasing and changes in the idea of robotics. People are getting used to robots. As the robots were programmed to do some simple tasks and were rounded by a safe barrier.

The workplaces were strictly positioned. The robots are getting more and more intelligent and that gives a chance to let them free to the production next to other workers and make flexible workstations. That gives the opportunity to easily change workstations and change the products or details to be produced. That could be very important to small factories which are producing small quantities of different products. The developments are moving towards robotized workstations, where there is no need for production units and all necessary operations can be done by robots. [4]

1.2 Changes with Industry 4.0

The Industry 4.0 can be defined as the next phase in the digitization of manufacturing driven by four disruptions:

- the rise in data volumes, computational power and connectivity;
- the emergence of analytics and business-intelligence capabilities;
- new forms of human-machine interactions;
- improvements in transferring digital instructions to the physical world.

The name Industry 4.0 is not based on these four trends, rather being the fourth major upheaval in modern manufacturing after the lean revolution in 1970s, outsourcing phenomenon in the 1990s and the automation in the 2000s (see Figure. 1). [3]

The changes that come with Industry 4.0 will affect the whole factory and the supply chain. The speed of changes will probably be smaller than what has been seen in the consumer sector. The earlier big changes in industry brought changing the equipment up to 80-90 percent, coming of steam power and the rise of robotics, which meant large capital investments. With Industry 4.0 changes like that are not expected, but still are expected that 40-50 percent of machines need upgrading or replacing. [6]

Industry 4.0 creates a so called smart factory. In structured smart factories cyber-physical systems are monitoring physical processes, creating a virtual copy of them and make decentralized decisions. Via Internet of Things (IoT) these systems communicate with one another and cooperate with humans in real time and via Internet of Services (IoS). [6]

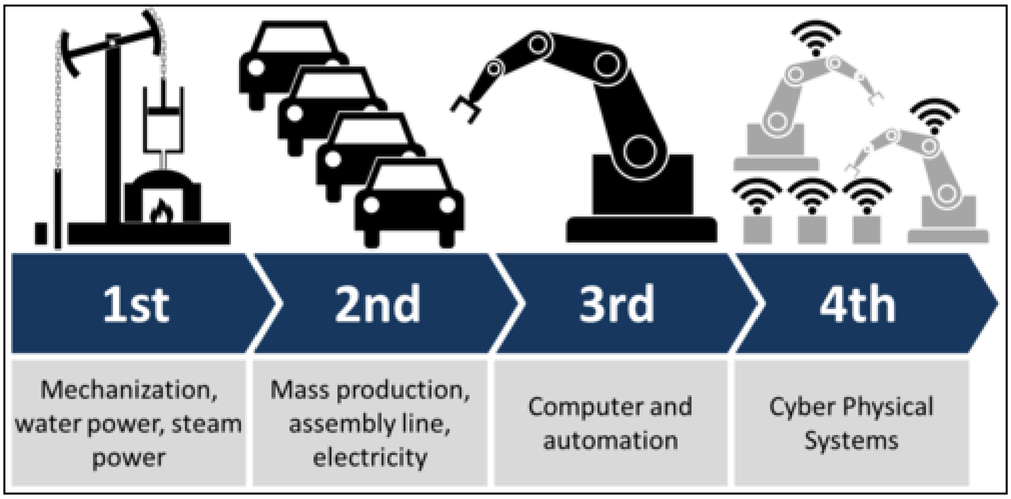


Figure 1. History of industrialization

To consider developing Industry 4.0 in a factory or system it must include:

- interoperability - machines, devices, sensors and people that connect and communicate with one another;
- information transparency - the systems create a virtual copy of the physical world through sensor data in order to contextualize information;
- technical assistance - both the ability of the systems to support humans in making decisions and solving problems and the ability to assist humans with tasks that are too difficult or unsafe for humans;
- decentralized decision-making - the ability of cyber-physical systems to make simple decisions on their own and become as autonomous as possible. [6]

As there are risks with any big changes in productions there are also risks and challenges in adopting an Industry 4.0 model:

- data security issues are greatly increased by integrating new systems and more access to those systems. Additionally, proprietary production knowledge becomes an IT security problem as well;
- a high degree of reliability and stability are needed for successful cyber-physical communication that can be difficult to achieve and maintain;
- maintaining the integrity of the production process with less human oversight could become a barrier;
- loss of high-paying human jobs is always a concern when new automations are introduced;

- avoiding technical problems that could cause expensive production outages. [6]

To create and execute these systems the company has to invest heavily, because at the moment there is lack of experience and manpower for these operations. Still Industry 4.0 has lots of benefits to make the investment worthwhile. In dangerous working environment the workers health and safety can be improved, supply chains could be more readily controlled when there is data for every manufacturing process, more reliable and consistent productivity and output can be produced by computer control. [6]

The Industry 4.0 is used for three mutually interconnected factors:

- digitization and integration of any simple technical – economical relation to complex technical – economical complex networks;
- digitalization of products and services offer;
- new market models.

All these activities are connected with different communication systems - Internet of things, Internet of services and Internet of people. These technologies help entities to communicate with each other and reclaim information from the production owner during the all life cycle of systems without respect to border among enterprises and countries. All divisions of the production, market network is also able to have relevant data. That will help all the parties, while production can work out systems featuring very modern components which will be even in the design and testing phase. [7]

1.3 Enterprise resource planning

Enterprise resource planning (ERP) systems are the heart of every firm. Making people use this expensive time-consuming investment is one of the most important problems to work with.
In an increasingly competitive globalized market, the key to organization's success is the ability to maintain and increase that competitive advantage.
Organizations cannot compete by their own, advantage can be achieved through cooperation with other organizations forming integrated and flexible supply chains. [10]
ERP is an evolution of the 1980s manufacturing resource planning (MRP II), succeeding the concepts and theories that go back to the 1960s with first attempts to improve lead times and possession stock costs. ERP became quickly the standard enhancing operational efficiency with the integration of business processes throughout all organization.

In the last decades the usage numbers of ERP system users have increased remarkably and the worldwide ERP market is summed 22.4 billion euro by 2013. The competition is heated and the top five companies represent half of the market (SAP 24%, Oracle 12%, Sage 6%, Infor 6%, Microsoft 5%). [10]

ERP is a process by which a company (often a manufacturer) manages and integrates the important parts of its business. An ERP management information system integrates areas such as planning, purchasing, inventory, sales, marketing, finance and human resources. [11]

It refers to the systems and software packages used by organizations to manage day-to-day business activities, such as accounting, procurement, project management and manufacturing. ERP systems tie together and define a wealth of business processes and enable the flow of data between them. ERP software integrates all facets of an operation — including product planning, development, manufacturing, sales and marketing — in a single database, application and user interface. By collecting an organization's shared transactional data from multiple sources, ERP systems eliminate data duplication and provide data integrity with a "single source of truth." [11]

ERP software typically consists of multiple enterprise software modules that are individually purchased, based on what best meets the specific needs and technical capabilities of the organization. [11]

Some of the most common ERP modules include those for product planning, material purchasing, inventory control, distribution, accounting, marketing, finance and human resources. A business will typically use a combination of different modules to manage back-office activities and tasks including the following:

- distribution of process management;
- supply chain management;
- facilitate better project planning;
- standardize critical business procedures;
- reduce redundant tasks;
- assess business needs;
- accounting and financial applications;
- lower purchasing costs;
- manage human resources and wages fund. [12]

A key ERP principle is the central collection of data for wide distribution. Instead of several standalone databases with an endless inventory of disconnected spreadsheets, ERP systems bring order to the chaos so that all users, from the CEO to accounts payable clerks, create, store, and use the same data derived through common processes. With a secure and centralized data repository, everyone in the organization can be confident that data is correct, up to date, and complete. Data integrity is assured for every task performed throughout the organization, from a quarterly financial statement to a single outstanding receivables report, without deploying error-prone spreadsheets. [13]

1.3.1 The Business value of ERP

It is difficult to ignore the impact of ERP in today's business world. As enterprise data and processes are corralled into ERP systems, businesses are able to align separate departments and improve workflow, resulting in significant bottom-line savings. Examples of specific business benefits include:

- improved business insight – from real-time information generated by reports;
- lower operational costs – through defined and more streamlined business processes;
- enhanced collaboration – from users sharing data in contracts, requisitions and purchase orders;
- improved efficiency – through a common user experience across many business functions and managed business processes;
- consistent infrastructure – from the back office to the front office , all business activities have the same look and feel;
- high user-adaption rates – from a common user experience and design;
- reduced risk – through improved data integrity and financial controls;
- lower management and operational costs through uniform and integrated systems. [13]

1.3.2 History of ERP

The history of ERP is longer than 100 years. In 1913 engineer Ford Whitman Harris developed a paper-based manufacturing system for production planning - now known as the economic order quantity (EOQ) model. EOQ was the standard for manufacturing for decades. It was changed by company Black and Decker in 1964 while being the first company to adopt a material requirements planning (MRP) solution that combined EOQ concepts with a mainframe computer. [13]

Until manufacturing resource planning (called MRP II) was developed in 1983, MRP was the manufacturing standard. MRP II featured modules as a key software architectural component and integrated main manufacturing components like purchasing, bill of materials, scheduling and contract management. The different manufacturing tasks were for the first time integrated into a common system. The new system also provided imperative vision of how organizations could leverage software to share and integrate enterprise data and boost operational efficiency with better production planning, reduced inventory and less waste. [13]

1.3.3 Warehouse management and ERP integration

A warehouse management system (WMS) is to support all other aspects of controlling the inventory in the digitizing process. It helps to lower costs and order fulfillment times with reducing the movement in warehouse. To get the maximum accuracy and productivity it needs to be connected with other business processes. [24]

By controlling the movement and material storage in the warehouse and processing operations related to companies WMS is an important part of their supply chain. The computer programs continually follow the process of products as they move through production to warehouse and makes sure that the receipt, storage and movement of goods are all steadily under control. [24]

Key process support usually consists of the standardization of shipment receipt, optimization of stock levels to prevent needless money being tied up or businesses failing to deliver, modeling and administrating warehouse locations for optimal order production time, data communication with order and logistics management, keeping track on the products location and shelf-times to use the space smart and in maximum capacity and to be ready for irregular demands. [24]

In WMS data capture technology and auto-ID often work as a tandem to maximize efficiency. Using barcode scanners, RFID or voice recognition systems to simplify keeping track on the product flow. This information will be sent to database and can be synced to support real time reporting and to increase efficiency in different positions. [24]

Integrating warehouse systems with ERP ensures that warehouse will not operate as a stand-alone entity. To make better decisions the real-time data from warehouse system can quickly be used in customer service and manufacturing departments. Project managers with process managers can better organize production plans on the basis of real-time material availability.

And customer service can then give more precise answers and deadlines for customers based on the feedback getting to them from the warehouse. [24]

With complete integration it would be possible for warehouses to move one step forward – automatic electronic notifications. Purchasing department can be informed of what has or has not been delivered and customer service can inform the clients on changes in delivery times. All information from freight manifest systems and carriers can be closely linked with the sales order system to speed up and raise the accuracy of billing when online sales portals are available. [24]

Adding in more mobile technology it would be possible to low the barriers between manufacturing and warehouse. Minimizing information leakage and correctly unifying production with inventory, RF and bar code activities can be carried out in either location. [24]

Fulfilled correctly, a system like that would cover all the bases – goods receipt, location management, order pool management, picking, replenishment, reporting on physical and cycle counts and vendor returns to stock-keeping-unit (SKU) management. It does not matter whether the goods are used in production or sold directly to customer, this system gives well organized and smartly used space in warehouse and saves employee time. [24]

WMS-ERP integration creates one system for all - customer service, production and warehouse, everyone works with the same information and paperless work environment can become a reality. [24]

1.4 Material requirements planning

Material requirements planning (MRP) system is a software-based solution that works backwards from customer orders to determine when materials will be needed for production and then initiates their purchase to have delivery coincide with upcoming manufacturing runs and scheduled product delivery dates. It plans production, schedules raw material purchase and delivery, and manages completed inventory levels. [14]

An MRP system is designed to do three main things:

- make sure raw materials and component parts are always on-hand for production, to keep the production schedule running smoothly;
- support just-in-time (JIT) production by enabling the lowest level of materials and inventory to be available and still keep production on track;
- plan production schedules to meet customer demand for products in a timely manner.[15]

The first MRP systems of inventory management developed in the 1940s and 1950s. In use were mainframe computers to explode information from a bill of materials for a certain finished product into a production and purchasing plan for components. Soon MRP was escaladed to include information feedback loops so that production personnel could update and change the inputs into the system as needed. [15]

There are three questions that MRP is meant to answer:

1. What is needed?
2. How much is needed?
3. When is it needed?

MRP distributes inventory requirements into planning periods so that production can be completed in a timely manner while inventory levels - and related carrying costs - are kept to a minimum. Implemented and used properly, it can help production manager's plan for capacity needs and allocate production time. But MRP systems can be time consuming and costly to implement, which may put them out of range for some small businesses. In addition, the information that comes out of an MRP system is only as good as the information that goes into it. Companies must maintain current and accurate bills of materials, part numbers, and inventory records if they are to realize the potential benefits of MRP. [15]

1.4.1 MRP inputs

There are three main sources of information input into MRP systems: a bill of materials, a master schedule and an inventory records file. The bill of materials consists of a listing of all the raw materials, component parts, subassemblies and assemblies that are required to produce one unit of specific finished product. Its own separate bill of materials is made for every different product. The bill of materials is arranged in a hierarchy, so that managers can see what materials are needed to complete each level of production. [15]

MRP uses the bill of materials to determine the quantity of each component that is needed to produce a certain number of finished products. [15]

The master schedule brings out the predicted production activities of the factory. It is developed by using both internal and external orders, it points out the quantity of each product that will be manufactured and the time frame in which they will be needed. The master schedule divides the planning horizon into time „buckets“, usually calendar weeks. The schedule has to cover a time frame long enough to produce final product. [15]

The inventory records file provides an accounting of how much inventory is already on hand or on order, and thus should be subtracted from the material requirements. The inventory records file is used to track information on the status of each item by time period. This includes gross requirements, scheduled receipts, and the expected amount on hand. It includes other details for each item as well - like the supplier, the lead-time and the lot size. [15]

1.4.2 MRP processing

Using information gathered from the bill of materials, master schedule and inventory records file, an MRP system sets the net requirements for raw materials, component parts and subassemblies for each period on the planning horizon. Firstly the MRP processing determines gross material requirements and then divides out the inventory in hand and adds back in the safety stock in order to calculate the net requirements. [16]

The three main outputs from MRP contain three primary reports and three secondary reports. The primary reports consist of:

1) planned order schedules, which explain the quantity and timing of future material orders;
2) order releases, which allow orders to be made;
3) changes to planned orders, which could involve cancellations or revisions of the quantity or time frame.

The secondary reports consist of:

1) performance control reports – used to trace problems like missed delivery dates and stock outs in order to evaluate system performance;
2) planning reports – used in forecasting future inventory requirements;
3) exception reports – require manager’s attention to vital problems like late orders and excessive scrap rates.

To determine the requirements for components by working backwards from the production plan for a final product might seem like an easy task, in reality it could be very difficult as some type of raw materials could be used in different products. The other aspects that make it difficult are frequent changes in product design, changes in order quantities, changes in production schedule. The importance of IT power is obvious while considering the number of material schedules that must be tracked. [16]

1.4.3 The advantages and disadvantages of MRP system

MRP has been around for around 30 years, as material requirements planning (MRP) or manufacturing resource planning (MRP II) and still as one of the predominant methodologies in inventory organizing and production planning it has its pros and cons. To get the most out of an MRP system, it is important to consistently follow it. [16]

The advantages of using MRP come mainly from the basic idea of it:

- on time availability of the right required materials for production;
- little, if any, excess inventory;
- in time delivery of goods to customers;
- optimal use of manufacturing resources;
- decrease in capital cost due to decreased inventory levels and optimal use of production resources;
- collecting the business data for analysis and therefore better planning. [16]

MRP systems give production companies a number of potential benefits. Some of the main benefits include help to production managers for minimizing inventory levels and the associated carrying costs, track material requirements, determine the most economical lot sizes for orders, compute quantities needed as safety stock, separate production time among various products and plan for future capacity needs. The information generated by MRP systems is also useful in other areas. Production planners and production managers are obvious users of the MRP system, they must find balance between workloads across departments and make decisions about scheduling work. Other users include customer service representatives, who need to be able to provide projected delivery dates, purchasing managers and inventory managers. [15]

First drawback of MRP is that it relies upon input information accuracy. If a business has not maintained good inventory records or has not updated its bills of materials with all relevant changes, it may encounter serious problems with the outputs of its MRP system. These problems can be missing parts or excessive order quantities, in worst scenarios schedule delays and missed delivery dates. [15]

Second potential drawback connected with MRP is that the systems might be difficult, take a lot of time, expensive to implement. Many businesses have found opposition from own employees when trying to implement MRP. [15]

MRP is an excellent methodology in general, but it gives you the benefits when applied under appropriate circumstances. Especially when talking about the material requirements planning flavor of it, MRP is definitely suitable for make-to-stock manufacturers. Make-to-order and mixed mode manufacturers also benefit from MRP, but only to the extent that their production lots are medium to large and the product does not change much. When the company is engineer-to-order or project based manufacturer, it may be enough to use the common sense approach of ordering and manufacturing what is needed and MRP gives you just a framework how to not miss the important bits. [16]

With MRP, it is needed to keep records and enter data. Together with the ability to suggest what, how much and when to buy or manufacture, comes the need to keep stock and production records. For the production planning to be correct, is needed to record finished operations and manufacturing orders as soon as production gets completed. [16]

Training and education for all affected workers are the key factors to make MRP implementation work. It is important in early stages to identify the key personnel who will be mostly effected by new MRP system. They have to be the first ones to be convinced of the merits of the new system so they may buy into the plan. The personnel had to be convinced that the new system will personally serve them better than any alternative system. To adjust a reward system to reflect production and inventory management goals is one way to improve employee acceptance of MRP system. [15]

1.5 Manufacturing execution system

Before computer systems a manufacturing execution system (MES) consisted of hand-drawn charts and managers with clipboards checking inventory level. Essentially MES tracks the manufacturing process from the raw materials phase through the finished product. It provides the right information at the right time to show the floor manager how to optimize current conditions to improve production output. [17]

MES consists of the computer systems used to manage production and daily operations within a process facility, above the level of automatic control. MES are computerized systems used in manufacturing, to track and document the transformation of raw materials to finished goods. MES operates in real-time to enable the control of multiple elements of the production process. A MES guides, initiates, responds to and reports on plant activities as they occur, based on accurate data. [18]

The extensive data and analysis that formerly was unattainable through traditional methods, is now in most factories mapped by computers with MES. Manufacturing execution system gives various advantages to manufacturers. [19]

Firstly MES helps to capture costs more accurately. With MES several costs like labor, scrap, downtime and maintenance are recorded in real-time from the shop floor. This data is in turn used by management teams to evaluate unprofitable business models and in pricing new work. As other systems also share this data, MES enables the company to increase productivity in all its production facilities. [20]

Secondly using MES helps to reduce waste, scrap and overages. MES analyzes accurately production lines and finished products. Thus this system discovers all inconsistencies or deviations on these lines, straight halting them to limit the number of defected parts and wasted material. [20]

Thirdly MES decreases downtime. Through using MES the system can generate realistic production schedules. MES reaches that by tracking raw materials and parts inventory. This removes time spent from re-configuring schedules while parts are in work. It then becomes possible to add employee scheduling into this program and making efficient use of applicable staff. [20]

Fourthly MES helps to decrease costs. It is possible to accelerate operations logically once there is a better handle on the product, the material, time and labor required to complete the job. The process makes it possible to cut back on ordering or to release personnel from operating production lines and controlling inventory. [20]

MES assists to reduce inventory. Keeping extra inventory costs money. Next to overage production costs, transportation, storing and monitoring these goods gets expensive. A good manufacturing execution system will continuously update the inventory records with new production, scrap material, undue product. That gives knowledge to purchasing, shipping and scheduling departments what is available in each facility and what has to be ordered. [20]

1.5.1 Manufacturing execution system as an investment

Manufacturing execution system (MES) is a fundamental example of an investment that can really make the business better. Whether the business change is great or not can vary on how brave, committed and visionary the company is. These manufacturers who come out on top in the struggle for competitive advantage see macro opportunities for transformation over and above micro successes from a single plant. [21]

More and more manufacturing enterprises are looking for ways to streamline, increase promptness and become more data smart. As it is a big investment for a company it brings with expectation of return of investment (ROI). MES gives a wide range of hard and soft benefits that increase over time. Nevertheless, businesses are pre-occupied with usual targets revolving around short-term cost cutting on a local scale. [21]

The temptation to hurry development to meet an average ROI target of three times investment is vital. A quick and easy return could be politically alluring, but it is eventually short sighted. Companies like the encouragement of seeing a dollar saved, but who stop there might risk with missing out on the larger savings that could impact strategic business outcomes in the future. [21]

The first phase of MES lays the foundation for even more cost reductions and performance benefits over time. If an MES is rolled out over multiple plants and embraced as a companywide initiative, an ROI way beyond the average three times is possible. The cumulative effects of near-real-time visibility of production processes, as well as an understanding of them, will surface the less easily quantified, but equally significant benefits.

An industry analyst research suggests a list of following potential benefits for those companies who do not expect great changes in nearest future. [21]

Potential benefits in 3-12 months:

- efficiency gaining;
- cost reductions;
- improved quality.

Potential benefits 12-36 months from implementation:

- process improvements;
- shortened cycles / work flows;
- reduced inventory costs.

Potential benefits 3+ years from implementation:

- accelerated new product introduction;
- reduced indirect labor costs;
- better managerial decision support;
- increased organizational agility;
- improved asset utilization. [21]

Manufacturers are increasingly operating in an information-driven environment. Increased visibility of processes across multiple sites offer manufacturers the tools needed to recognize and seize new opportunities that might not have been previously even considered. It is important not to let business invest in MES, and then fail to look beyond the first phase of benefits. One has to be patient, learn from the information generated, act upon the insights and reap ROI in the long-term. MES is truly the hidden weapon of manufacturing. It is up to the management to enable it to transform the business for the better in a continuous improvement philosophy. [21]

1.5.2 Mistakes by ordering IT-services

The biggest mistake that productions make by ordering IT solutions is buying it with fixed price without previous thorough analysis. There is no IT project that does not change while in process. [22]

The first thing is to visualize the benefits of digitalization. The question is, what are the benefits for the company if it is known exactly when the delivery is to the customer and all deliveries are on time, if the inventory is reduced by half, if to use production resources 30% more efficiently, what are the benefits of shortening the delivery times by half? [22]

All this is possible by digitalizing the production without changing the current production processes to a greater extent.

The second thing is to create possibility of digitalization as possibility to order IT services.

Estonian factories are full of IT mistakes that no one is known of because it is the topic that nobody is willing to speak. [22]

One aspect is that IT companies do not know production really well. The IT systems in production are very different from other IT sectors. In production the value comes from using the data, rather than saving and keeping the data. For example the tax return can be sent digitally and the value for the user is time that the person gains from not going to the office or collecting the different data needed. [22]

In factory it is precisely important to know how to use the gathered data. How does the final step of the process know, when it is the right time to start, in view of previous process data, availability of materials, order delivery times. To use all the data correctly and usefully, one has to know the production very good. [22]

On the other side, factories do not know how and do not have the experience of ordering IT services. The knowledge of making a factory work, does not give the knowledge of how to run IT services. It needs very good project management and a well stated IT assignment. [22]

Third important thing to do before starting to digitalize the production is to familiarize with already existing ready-made solutions. It may save lots of time and money. In other hand the ready-made solutions may have made to solve only one specific problems and situations. That

would be a problem, because every factory has its own ideas and rules and are unique with their manufacturing processes. What works nicely for one, can be useless for the other. [22]
It is important to exactly find out what the factory needs and learn from others mistakes, so the digitalization process would be fast and expenditures made wisely. [22]

1.6 Digitalisation opportunities in production

There is probably no industrial sector that is not influenced by digitalisation. The world’s largest advertising companies are Facebook and Google, all larger stores have self-serving cash registers and according to Forbes 72% of purchases in Amazon are made with smartphones. [23]
Digital development breaks current communication channels, competitors are moving faster and partners are waiting for more automated communication. Cloud-services give companies endless computing performance with data processing software. It is possible to integrate effective and flexible intelligent systems to products that can change the production, communication and development. [23]

There are three possibilities to earn additional income:

- increase offered value and raise the price;
- decrease manufacturing cost;
- decrease manufacturing input cost.

From digitalising manufacturing process, different departments gain benefits. The sales department will have better overview of products completion and can prioritise their actions based on that. Purchase department can see the raw material inventory in real-time and know exactly when is needed to order new materials. Quality control department will see the deflection from normal immediately as they appear. [23]

1.7 Smart warehouse

The most important part of any factory is often the warehouse. Questions “What is that?” and “Where is this?” are the commonly asked questions in the warehouse. The time spent in the warehouse to look for right materials for production and the right products for clients is often the key to smooth production. The idea of a “smart warehouse” could find answers to these questions and help significantly the customer service and production.

Over the past two decades the perception of a warehouse has significantly changed. It is not just four walls anymore, a fixed stationary force that works well for any distribution network.

Today these descriptions are highly outdated as the warehouses are lead by cloud-computing, e-commerce, big data and last-mile logistics. The warehouse itself is still the core but technology and innovation by materials handling have become important catalysts in the development of smarter warehouse. [25]

The term “Smart warehouse” has been in use for years now. It has represented variable ideas from the use of RFID tags and software to quality certainty. [26]

A real smart warehouse is not just a buzzword or manufacturing jargon, when putting into practice effectively it will be a systematic strategy that takes traditional operations to a next level. [26]

With integration of automated technology a smart warehouse is expected to fulfill day-to-day operations. The elements of a smart warehouse may contain utilization of conveyor systems, automatic guided vehicles (AGV), automatic trailer loading (ATL) vehicles, automatic guided cars (AGC), automated storage and retrieval systems (AS/RS) and warehouse management system (WMS). These are the components to make a very productive warehouse. [26]

1.7.1 Solutions for a smart warehouse

Track and trace solutions assist organisations to keep an eye on company assets and product shipments, improve effectiveness, decrease costs, optimize inventory, find and improve weaknesses in the supply chain and fallow regulatory requirements. To find quickly right orders or materials are in use known technologies like GPS, GPRS, RFID, bar codes and stickers. Heavy investments are made in data collection and analytics to execute these implementations. [27]

Warehouse managers have applied track and trace solutions across the organization. By introducing RFID antennas within the warehouse and supplementing it with wearable technology like Google glasses and intelligent gloves, efficiency can easily be increased. At the same time can be tracked products, shipments, forklifts and workers. [27]

1.7.2 Measurable benefits and advantages

A company making necessary changes and reorganization to invest and develop its warehouse and distribution centers will gain multiple benefits:

- improving productivity by automating perpetual time and investigating work;
- optimizing routes within warehouse to increase efficiency;
- cut down errors with picking and placing and reduce associated costs;
- accurate products identification by individual elements not only by pallets or containers;
- increase safety and security with reading the RFID tag of each worker and shipment through the day. [27]

A smart warehouse operation will help a warehouse manager to ascertain the ideas of raising client's satisfaction and lessen operating costs. Smart warehouses observe the basic point of "lean" warehousing, in the same time creating a safer work environment by decreasing the probability of human error. [26]

For improving security and reducing manpower smart warehouses use robotics, guided vehicles, surveillance cameras. Automation and robotics provide accuracy and predictability. As more homogenous the environment and tasks are, the higher the predictability and accuracy. [27]

Smart warehouses that are interested in gaining productivity and security need to change their approach. It is needed to look for a more comprehensive approach when planning production floor, warehouse and final destination. [27]

Smart warehouses allow companies to add to the processes reliability and dependability, accomplish sought results and most importantly, predictability. In that case a smart warehouse can operate "lights out" all day if necessary. Companies that had lots of manpower in warehouse, can now reassign their personnel to other important areas. [27]

1.7.3 Smart warehouse technologies

The SmartCart Automatic Guided Cart (AGC) is a magnetic tape-guided automatic guided vehicle (AGV) with low cost. It is an AGV that is able to transport finished pallets from film wrapping area to AS/RS, warehouse shelves or to another adjacent area in the warehouse.

To change the route of an AGV it is needed to adjust the tape on the warehouse floor and change a little the software. This makes the system very flexible and easy to modify. [26]

A SmartCart AGC is very suitable for transporting pallets from production to warehouse, because it is able to deliver pallets onto a conveyor. As the pallet is set to the conveyor it can be taken to a high-rise storage, AS/RS or to the dock for trailers to pick it up. [26]

An ATL vehicle can pile up pallets accurately and efficiently. It can be even more accurate than traditional forklift operations. That is because an ATL vehicle is very flexible, its movement is not depended on fixed rail-guided AS/RS machines that can only move within one aisle. An ATL vehicle uses inertial or laser guidance and thus is a free-ranging device that can move freely within a warehouse. [26]

An ATL vehicle can move finished pallets directly into trailers and it does not need any trailer or plate modifications and automatically adjusts to trailer skew. [26]

An ATL vehicle improves company's productivity and efficiency because it gives a special combination of stacking and loading skills. [26]

Conveyors are the centre part of any manufacturing, warehousing or distribution operations, because they give high reliability in very demanding environments. They can be used for moving pallets, products or details from point-to-point. Conveyors are widely used because of their simplicity, low price and are easy to handle. Gravity roller conveyors can be used push-lines or graded lines using the force of gravity. For heavy, bulky or unitized loads are in use modular-designed pallet accumulation conveyors with powered zones. [26]

AS/RS deposits and retrieves loads automatically from fixed storage locations. By that the system improves transportation efficiency, ranking and searching of standard or non-standard loads. It withdraws the unreasonable and repeated handling of materials, increases productivity, reduces inventory, frees more space in the warehouse and increases product loss. [26]

Rack system is a good choice if available room is an issue. Rack systems are easier to set up and control and are also more cost-effective than AS/RS. Racks give possibility to make higher stacking than storing on floor and give extra space on floors. [26]

To handle two pallets at a time, drive-in or drive-through rack can be designed (cutting labour is half). This would be the most cost-effective way. [26]

1.8 Robotics in manufacturing processes

The robots are mostly used by tasks where they give the most benefit and can easily replace human labour. These tasks can be placing different items, packing, drilling and milling, lifting heavy items, testing. The robots must benefit the production, speed processes and make workers job safer, simple and easier.

Industrial robot as defined by ISO 8373:2012: “An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.” [31]

To be reprogrammable, means that a robot is designed so that the programmed motions or additional features are changeable without physical alteration. [31]

Being multipurpose, means to be capable of adaption to various applications with physical alteration. [31]

Traditional industrial robots are classified by different criteria like type of movement (degrees of freedom), architecture (serial or parallel), application (production process) and brand. [32]

Robots can also be classified by mechanical structure:

- linear robots;
- SCARA robots;
- articulated robots;
- parallel robots;
- cylindrical robots;
- others;
- not classified. [31]

1.8.1 Selection of industrial robots

Finding the best robot for a specific industrial application is one of the most complex problems in real time manufacturing. Due to increased complexity, advanced equipment and functions being included to the robots it has become more and more complicated. The mostly affecting factors that influent the selection of robots are manufacturing environment, product design, production system and cost. Personnel responsible need to find the best suited robot to accomplish needed outcome with minimum price and with specific applications available. [28]

An industrial robot is a reprogrammable, automatically controlled, multifunction programmable in more than three axes. The most important part of a robot is its mechanical arm. Its ability of decision-making, responding to different sensory inputs and communicating with other machines are the other important features. While selecting an industrial robot is also needed to take into consideration its programming flexibility, accuracy, memory capacity, repeatability, ability of man-machine interfacing. These attributes classify the robot selection as objective and subjective or beneficial and non-beneficial. In one hand objective characteristics are numerically defined, like cost and load carrying potency. On the other hand programming flexibility and service quality are defined as subjective characteristics. The beneficial attributes are those in which higher values are always advisable, like capacity of load carrying and flexibility of programming. Non-beneficial properties are those with lower values are preferable, for example cost and repeatability. [29]

While the election of industrial robot for a given application, the one deciding needs to consider all these attributes. [28]

1.8.2 Industrial robots with different types of movement

Cartesian robots are the simplest of stationary robots. Regular Cartesian robots (see Figure 6 and Figure 7) have a freedom to move in 3 linear axes that are oriented to each other perpendicularly. This movement will ensure working in a form of a rectangular box. Cartesian robots have a high level of precision and repeatability and are easy to program. Due to their simplicity these robots are cheaper than their analogues. Nevertheless it has its cons – firstly the work envelope that is not near to ideal. Very limited are the options for tool orientation and compared to other similar task executing robots they have a quite big footprint. However a typical Cartesian type robot can be the cheapest option for easy operations like pick and place tasks. [33]

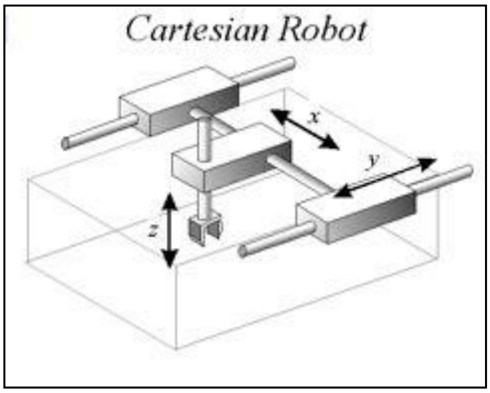


Figure 2. Plan of Cartesian robot

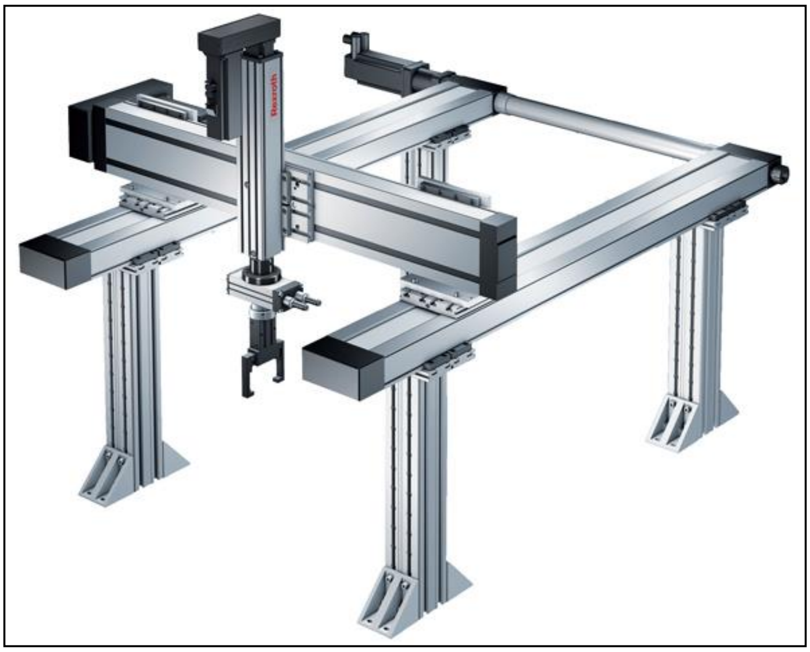


Figure 3. Cartesian robot

The acronym SCARA comes from Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm. SCARA robot (see Figure 8 and Figure 9) is based on a 4-axis design. Tasks that are ideal for SCARA robots are kitting, packaging, high-speed assembly and different material handling applications. They are very accurate, work fast and are easy to program. [34]

Their main shortage is the lack of end-effectors degrees of freedom. They cannot pitch or yaw, the end-effector can only roll and rotate around the vertical axis. For that reason they can only be used with parts that lay flat on the workspace. [34]

Because of their design, SCARA robots are usually rather small. It would be hard to design a SCARA robot that could lift and move very heavy items. [34]

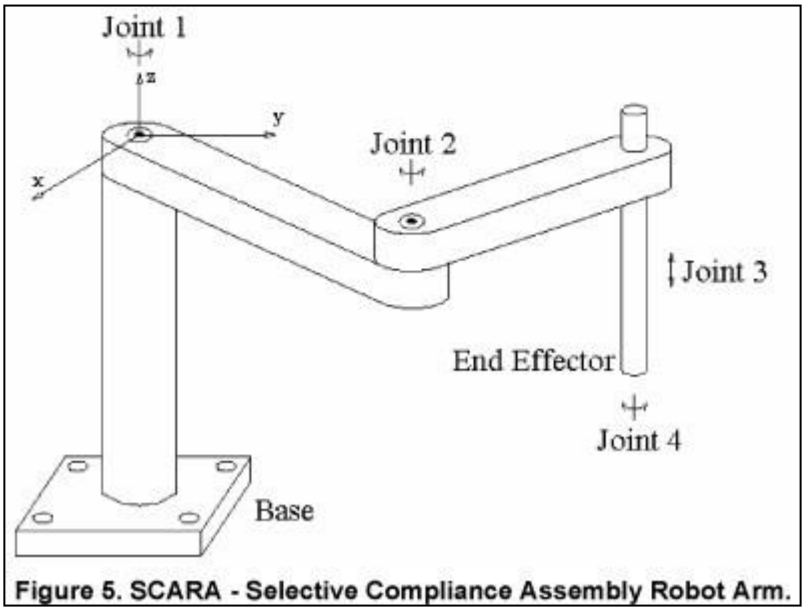


Figure 5. SCARA - Selective Compliance Assembly Robot Arm.

Figure 4. Plan of SCARA robot

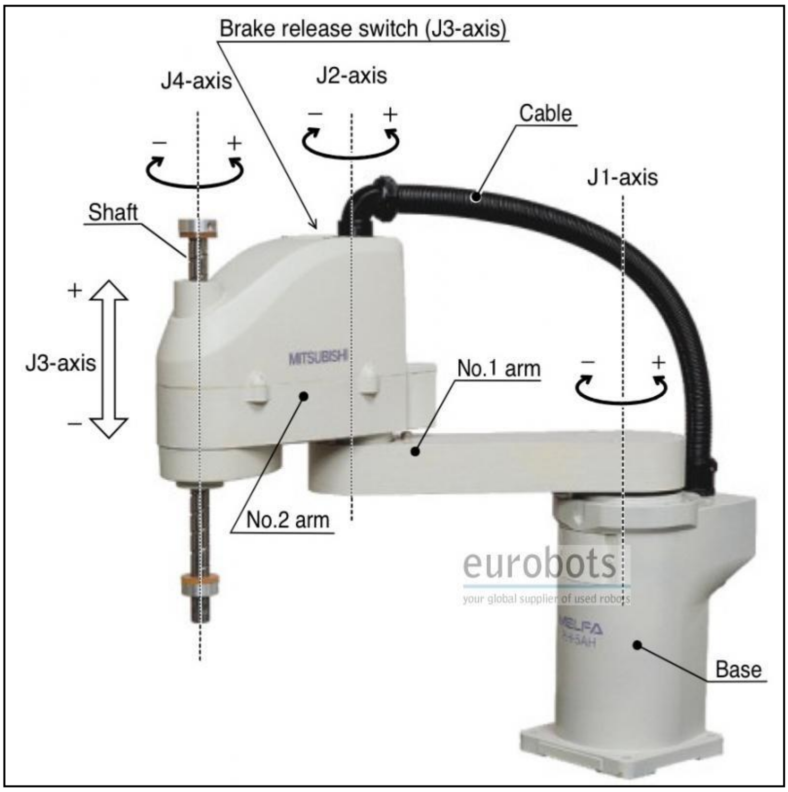


Figure 5. Photo of SCARA robot with markings

Universal 6-axis collaborative robot (see Figure 10 and Figure 11) is a highly developed equipment that can automate and accelerate repeated production processes. They can fully position their tool in a given position and orientation. 6-axis robots can be fast and easily deployed to new applications. They are very compact and space-saving and do not need a safety guarding. They are easily removable in the factory from one workstation to another. [35]

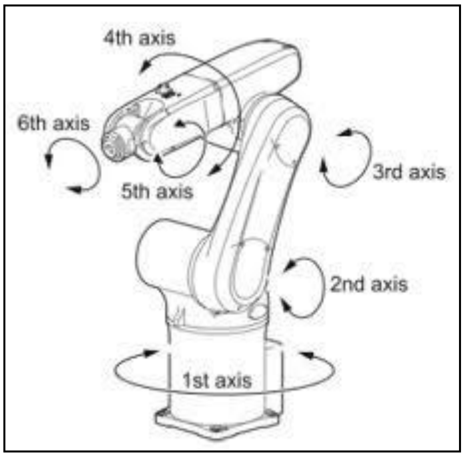


Figure 6. Scheme of 6-axis robot

Figure 7. Real pictures of 6-axis robots

Redundant robots (see Figure 12) can completely place their tool in a given position like 6-axis robots. Not like 6-axis robots that can only have one posture of a predetermined position, redundant robots can hold a specific tool position under different frames. It can be looked like a human arm, that can move elbow and shoulder joints while in the same time holding something fixed. [32]

Figure 8. Redundant robot

Dual-arm robots consist of two together working arms on a given workplace. A dual-arm robot (see Figure 13) can complete tasks and make decisions in the process. This robot recognizes objects with both arms simultaneously and is able itself to adjust the applied force on the objects by the end-effectors (hands). [36]

Figure 9. Dual-arm robot

1.8.3 Collaborative industrial robots

Collaborative robots are robots that are designed to physically interact with humans in a collaborative environment. In human-robot collaboration (see Figure 14) the human operator is assisted by the robot. Human is not replaced by a robot, it complements human with its abilities to ease severe tasks like heavy lifting and overhead work. The operator controls and monitors the production, the robots fulfil the commandments. Both support their specific abilities, the crucial principle of Industry 4.0. [37]

Increasingly more robotic systems are entering the field used to be occupied only by humans. To get the full advantage of both humans and robots, there is a growing need to combine robots to manufacturing operations. [37]

A robot that works in pair with a human worker is called “cobot”. A cobot is usually designed for one detailed task where human worker gives the power of movement and the cobot gives guidance, using servomotors. [37]

Figure 10. Collaborative robot

From a technical point of view, a cobot can limit its force and discover substandard activity in their work environment. This lets humans and cobots to work closely without physical isolation. For safety, in case of an impact, all cobots have force sensors that stop their movement. That permits to work at full speed, without troubling of human injuries. [38]

Due to their light weight cobots can easily be moved from one work task to another, as they are easy to program with a tablet or a smartphone. Collaborative robots are usually easier than more traditional robots and that makes them cheaper to buy, maintain and operate. [38]

2 Industry 4.0 in Estonian furniture industry

In Estonia the Industry 4.0 is not yet really working. Industry 3.0 gives today in Estonia higher value than Industry 4.0 probably would. [9]

Around 150 Estonian companies were asked what kind of Industry 4.0 projects they have run and how they see their future with it. Typical answer was that nothing has been made and the reason was that they value highly the personnel who have helped to build up the company. Only three companies reported that they have run Industry 4.0 projects. [9]

What also came out of the survey is that many companies do not really get the meaning of Industry 4.0. They have made that kind of projects but are not sure whether it is a project that could be classified as an Industry 4.0 project. [9]

Majority of companies said that they are at the moment not moving towards Industry 4.0. Only every 4-5 said that they have it in plans, but the tendency is showing it takes a long time to get it work properly. [9]

The survey also showed that most Estonian companies are far from Industry 4.0 and prior to it needs to made Industry 3.0. From a realistic point of view Industry 3.0 with automation could bring higher value to companies, because it has lower costs and is easier to deploy.

Every company has to precisely figure out the meaning of Industry 4.0 and what benefits it has in the production. [9]

2.1 Manufacture digitalization in Estonian furniture companies

For getting better understanding about the situation in Estonian furniture producing companies was ran through a survey with the help of Estonian Furniture Industry Association. The questionnaire was sent to around 300 companies. The questionnaire consisted of 11 questions, main questions about company size and questions about the thoughts of digitalizing. The questionnaire can be seen in appendix 3.

Unfortunately the interest in answering the questionnaire was not as expected, was gotten only 20 answers. It was expecting at least 50 to make better conclusions. Still some conclusions can be made already on the fact that that few companies were interested in the survey.

It was asked about Industry 4.0 and how much have the companies heard about that phrase and do they have ran some Industry 4.0 projects in their production. The most popular answer by 47.1 % was that the company has not heard about that phrase. 23.5 % answered that they have heard about it and know superficially about it. Around 12 % of the respondents said that they have heard about Industry 4.0 and led themselves on course with the topic. These answers were quite surprising for me because I thought that most of the companies should have at least heard about it for now, it has been often in the news and it is supported by Estonian government. The results can be seen in Figure 2.

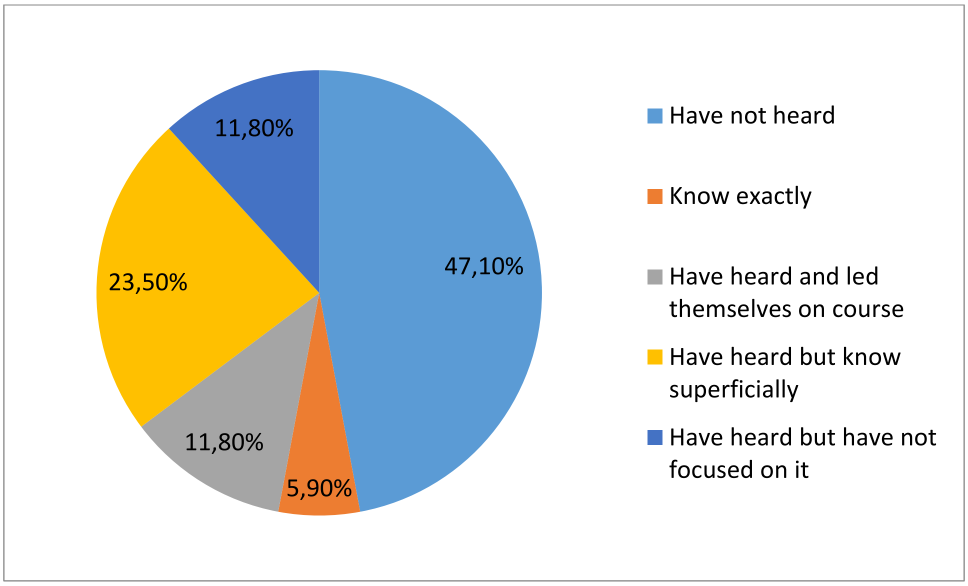


Figure 11. "What says the phrase Industry 4.0?"

In continuation for the last question was also asked from the companies about Industry 4.0 projects, using robotics in manufacturing processes. Answers to these question are firmly connected as the most, 61.1 %, answered that they have not ran any Industry 4.0 projects. Only one company said that they have already ran some projects and one company is going to run any Industry 4.0 project in the near future. A quarter of answered companies said that they do not see enough sufficient benefits on these investments, although they are not very small factories, having over 20 workers in the factory. The answers can be seen on Figure 3.

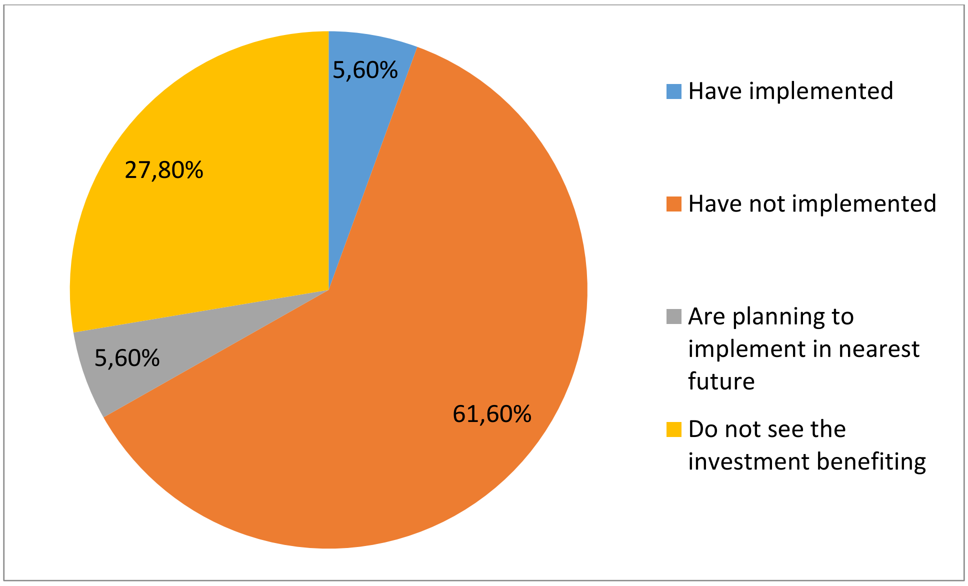


Figure 12. „Have any Industry 4.0 projects been run in the factory? “

Beside of Industry 4.0 project it was asked about other IT-services that companies use in their everyday work. The answers can be seen on Figure 4. Most answered option was unspecified “other” where can be different accounting systems. Other options - material accounting, production planning, warehouse systems, work time accounting were answered practically equally and one or many of them are today in use every manufacturing company.

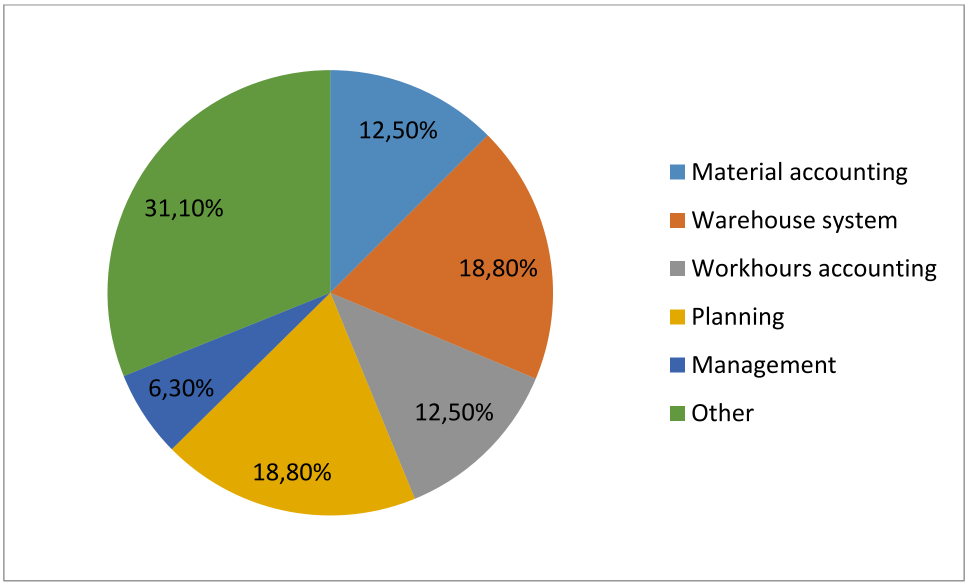


Figure 13. “What IT systems are used in everyday work? “

These all are very important fields for fast and high-quality production and need to be currently developed. Here can be drawn a parallel with Plaat Detail OÜ where at the moment are these sectors in development to make the production smoother and get better overview of current real-time situation.

As today all different purchasing processes are going to the Internet and people are getting used to buying everything directly from web, the same applies to furniture companies. On the basis of that was asked whether companies already have their own e-services in use or are they using any other web shops by retailers. The answers can be seen on Figure 5.

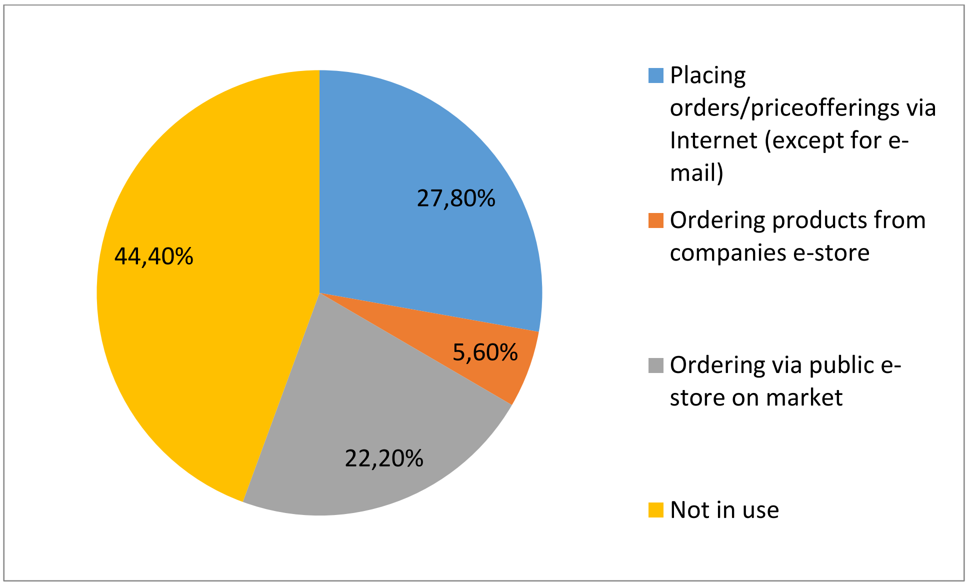


Figure 14. „Which client oriented e-services are in use? "

The majority answered that they do not have any e-services in use. Half of the other respondents said that they are using web shops already on market, like ON24.ee or Kaup24.ee, who are selling their products. The other half answered that their customers can place orders or biddings directly from their homepage. This saves a lot of time for the customer for not having to go to the office and also for the producer, they do not have to keep so many workers in the office to place different orders or biddings. Direct communication in the office with clients is one of the most time-consuming operations the workers have. To make it possible for customers to place orders or offerings via Internet, would raise the productivity of project managers.

The last part of the survey was to find out what is the perspective in the next 5 years for Estonian furniture companies in connection with digitalizing. Several companies said that they do not have any plans on digitalizing their manufacturing, but other options also were:

- better connection between sales and production;
- equipment management;
- to introduce any manufacturing program;
- continue to concentrate all the production steps to one production software;
- developments towards accounting and warehouse management;

develop processes to a level where the need for papers in production could be minimized.

3 Digitalisation in Plaat Detail OÜ

3.1 Warehouse digitalisation in Plaat Detail OÜ

At the moment in Plaat Detail OÜ is in use business software SAF for warehouse, production and financial calculations. The main idea of the digitalisation process is to address all the goods in the warehouse to save time in the look for materials and goods. In everyday use there are around 1000 different products in the warehouse and missing is the total overview of the location of the goods. In collaboration with KMA OÜ was found a possible way how to digitalize the warehouse processes in Plaat Detail OÜ.

To resolve the primary needs in warehouse 5 main points are brought out.

1. All warehouse operations will be made through mobile workstation in software “Laomees”. The mobile workstation can be a warehouse scanner or a tablet based on Android software. Additional needed data will be held separately in “Laomees” database.
2. All data will be preserved in SAF as today.
3. The registration of incoming materials will be done like it is now, based on the bill of delivery. All materials need to be checked that they are in accordance with the bill of delivery. The information about the incoming material will reach the “Laomees” database as the material articles are entered to SAF.

   The incoming goods are at first placed to the system address “Income area”. Next all the goods are registered with warehouse scanners and placed to shelves. Scanning and placing will create to the system a correct warehouse placement. As long as the goods are not relocated from the “Income area”, their address will remain the same. Depending on the amount of goods arriving simultaneously, there may be multiple areas.

4. To outfit the goods the main document will be read from SAF to “Laomees” database and afterwards it will be written back to SAF database. All the information between addresses in warehouse layout will stay in “Laomees” database.

   To get the materials for production, the material requirement is read from SAF based on the production order, where project managers enter the need based on calculations. From that the system will generate a pick order in “Laomees”. As the materials are completed the system will rewrite the entered quantities to SAF according to the actually used quantity and the materials will be written off.

To outfit the materials for selling directly to customer the sales order is read from SAF. After completing the materials with mobile workplace an output document is generated and uploaded back to SAF, with real quantities that were given, not anymore those that a project manager entered.

For moving the materials between different warehouses the material movement document is read from SAF to “Laomees” program and on the basis of that the warehouse worker can perform the job. It will be written back to SAF for between the warehouses entry (it would be wise to use an intermediate storage, because after writing the materials off from one warehouse they will not immediately be available momentarily in the other warehouse).

5. An additional material dispensing from warehouse during production will immediately be registered in warehouse scanner and the system will make the right cost of entry to SAF.

Essentially the inventory will be held parallel in two systems:

1. SAF – all information about prices and quantities
2. “Laomees” – knowledge of the inventory in time and the placement of goods and materials in warehouse addresses

At every moment can be seen from the scanner placement of any material or the amount of stock in any warehouse address and it can be adjusted if needed.

Since the system knows exactly in which addresses are which goods and in which amount, the materials can be placed randomly in the warehouse.

Moving the materials between warehouse addresses within one warehouse, the movement is registered with the scanner. That information is not provided in SAF.

Systematically is “Laomees” going to keep every material income as a separate batch. That gives the chance to have an overview by batches, which gives the chance, if needed, in later stages of production if detecting problems to get the overview, when the defected material has arrived in warehouse and submit reclamation to the supplier.

Main risks with “Laomees” software are:

- human acts, for example if changes in material inventory are made only in SAF. The chance of these acts should be minimized;

- technically are needed equipment that support Wi-Fi or 3G/4G;
- systematically it is needed to compare the inventory between SAF and “Laomees” and make adjustments if needed.

3.1.1 Situation today and benefits for Plaat Detail OÜ

Today in Plaat Detail OÜ there are 4 workers in warehouse, who are responsible for finding and bringing materials out for production and for customers, who only have bought raw materials. The warehouse cannot manage all the tasks given and time that customers and production need to wait for warehouse is too long.

The time wasted just for looking for laminates from high shelves is too high. Usually as the worker goes to warehouse to look for a specific laminate, the time spent for looking could be around 10-12 minutes. The worker has to find the right shelf column and after that look for the right laminate from 20 or more pallets. All the pallets are marked with signs but still is needed to read all the signs and then lift the pallets on the warehouse floor and sort out the right laminate.

With the “Laomees” software the time could be at least halved. The information about the laminate location will be shown in the scanner and so the worker will know exactly from which column the laminate should be looked for. If the laminate is located in different shelves, that information is also visible in the tablet or scanner. It is needed to go to the right shelf and scan the code from the shelf. From tablet can be seen, on which pallet the right laminate is and how many sheets are there.

There is also possible to calculate and optimize the most preferable route in the warehouse to pick up the materials. For example as the worker gets an assignment to bring out different materials for one project – multiple laminates, particleboards in different width, MDF, the software will calculate the most optimal route and order in which to look for the materials. Today usually a worker starts from the top of the list and brings out materials one by one, meaning that the time looking and driving with the lift in the warehouse would be remarkably shorter. The information would appear in the scanner in already right order and the unnecessary back-and-forth driving would be eliminated.

The situation today is that the company is close to hiring at least one new worker. The companies costs for one extra worker in warehouse is around 16000 € per year (monthly salary 800 € net). The investments to new software are around 8500-12000 € / net (Appendix 1). That would be one-time cost and the time to get the system in work would be around 1 year. The company would benefit from that investment already on second year.

Another great benefit from the software would be the inventory accuracy and the ease of stocktaking. Last year it was needed 14 workers for 2 whole workdays to make the stocktaking. With new software I think would be enough for only 4 workers from warehouse to make the inventory.

Price offer for “Laomees” software is in appendix 1.

3.2 Process digitalisation in automated production in Plaat Detail OÜ

Plaat Detail OÜ has two separate production buildings, one is located in Tallinn, Suur-Paala, and the other in Tabasalu. Tabasalu factory is semi-automated with only 5-6 workers. In this factory are produced semi-manufactured articles, that go to after-treatment – whether in Suur-Paala factory by Plaat Detail OÜ, directly to furniture companies is Estonia or in Europe or to resellers like Bauhaus or Espak.

Five different articles are produced:

- worktops with leading edge R5 in standard width 600 mm;
- worktops with leading edge U5 in standard width 600 mm;
- door modules, both long edges milled, in width 295 mm, 395 mm, 495 mm;
- laminated shield in dimensions 3045x1290 mm;
- worktops with both edges R5.

The idea of digitalising the factory came from problems and reclamations by customers. As the factory is automated, it is difficult to discover defected products (see Figure 15). Typical defects are scratches on the surfaces, broken laminate, damaged sides that cannot be seen before the client gets the product. The reason is that the products come from production line and are staffed automatically on a pallet. No worker needs to lift the worktops or shields themselves. As for that it is difficult afterwards to say that the defect did not come already in the factory, but during the transportation outside of factory or by post processing in customers factory.

Figure 15. Picture of a defected worktop

From that came the idea of labelling all products with unique labels and adding cameras near the production line to see afterwards, whether the defects came to products in our factory or later on. From the labels is possible to determine what product it is, the exact time, when the product came from the certain stage of production and who from the workers is responsible for the defected product. Based on the information read from the label can then look for pictures from server made in the exact time and stage and see, whether the defect was already made in the factory or not.

3.3 Production stages

3.3.1 Lifting and cleaning the boards

The first operation is to load the particleboard, MDF or plywood to the line. For that there are vacuum lifting devices that lift the board on the production line. From there the board is moved through cleaning section, where it is cleaned with brushes so there will be no little pieces of wood or anything else on that could later on get under the laminate and leave lumps on the laminated product.

From there on are two possibilities:

1) the board goes directly to gluing;

2) the longer edges of the board are milled to radiuses and goes to gluing.

In the adhesive coating phase is the first label printer. The board comes from coating and is covered with laminate. If laminated shields are produced, the label is printed and glued on the laminate. From there the shields are moved under pressure for 37 seconds. The upper plate of the press is 81°C and the lower plate is 79°C. Coming from press there would be a scanner that reads the label and sends information to computer that one shield is produced. From there the shield moves on rollers to cutting, where both long edges are trimmed so the customer will get a laminated board that they do not need to cut extra in width, it is already done in our factory. At the end of the first line would be cameras that take two photos of the shield, one from upper side and one from back side and the shields are stacked on a pallet and are ready to be moved to warehouse.

3.3.2 Processing the boards

If in the production are other products than shields, the second step before cleaning the boards is milling. The both long edges are milled to profile and after that the board is cleaned. From there it goes on to gluing and under press like shields. The difference is that this time the laminate is not labelled before the press but after the press. The board is likewise under press and is labelled afterwards. The standard worktops in width 600mm are produced in pairs so after the press the board is cut in half and then both halves are labelled separately. After that the labels are scanned the system gets information that two blanks for worktops are produced. Both blanks are also pictured from both sides and pictures are uploaded to server.

The blanks are automatically moved by vacuum lifting device to the beginning of next phase and are piled to stack. From the stack the blanks are lifted to the line. As they are moving on the line, there would be a scanner that reads from the label what product is produced and the information is sent to the operator who can then make the right adjustments on the production line.

As the blanks get to postforming area, they have one long edge cut clean, but on the other edge the laminate is over the board. The first operation in the line is heating up the overlay laminate to make it possible to bend. The postforming adhesive is applied on in temperature 190°C and the heating lamps heat the laminate up to 200°C. After the laminate is bended on the board the cooling rollers in temperature 4°C cool the edge down. At the end of the line automated vacuum lifters lift the postformed worktop and place it on rollers, upper side down. That is where another picture would be taken, this time only from the upper side.

After postforming operation the details are moved on rollers to the start of next operation, edgebanding. There would be a scanner that reads information from the label. The information will be sent to the edgebanding operator's computer, where the worker can make adjustments on the detail thickness. In that line both ends of the worktop are covered simultaneously with strips of the same laminate as the worktop is. At the end of this line would be another camera that takes pictures of the worktops ends and a scanner that reads the label. At this point the product is ready and the information is sent to the main computer, where the factory manager can see, what has been made, from whom it has been made and whether there were any interruptions or complications.

The label installation system consists from different parts - front applicator, scanner and stand.

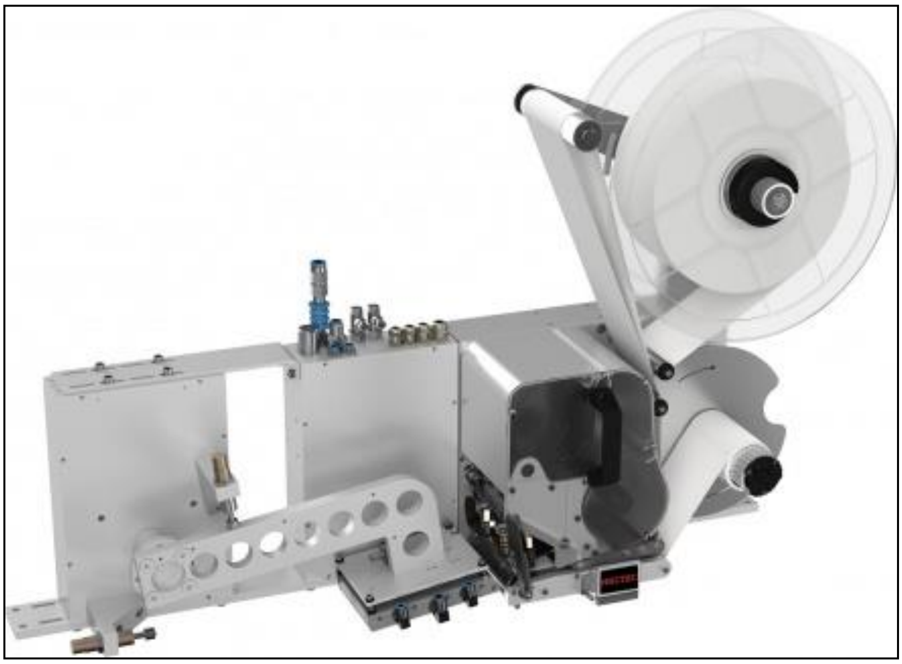


Figure 16. MECTEC F100/12 label installation system

Front applicator MECTEC F100/12 characteristics:

- thermal transfer printer (300dpi);
- start/stop photosensor;
- PCU IV (RS232, USB, Ethernet);
- print width 108 mm;
- mounting pad 110 mm x 110 mm.

Price offer for label installation system is in appendix 2.

3.4 Production planning mobile application in Plaat Detail OÜ

To make the production more effective and faster in Plaat Detail OÜ there is in use a mobile application. This application is created specifically for Plaat Detail OÜ taking into consideration the specificities of the factory and production. The application came in use from 1st September 2015 but the developing started at the end of 2014.

The idea of the application is:

- to get better control and overview of the production;
- keep time accounting over hours of labor;
- to see whether the pricing is correct;
- find the bottlenecks of the production.

The idea of creating an application seemed the easiest way because everyone is using a smartphone and it is the most convenient tool for that.

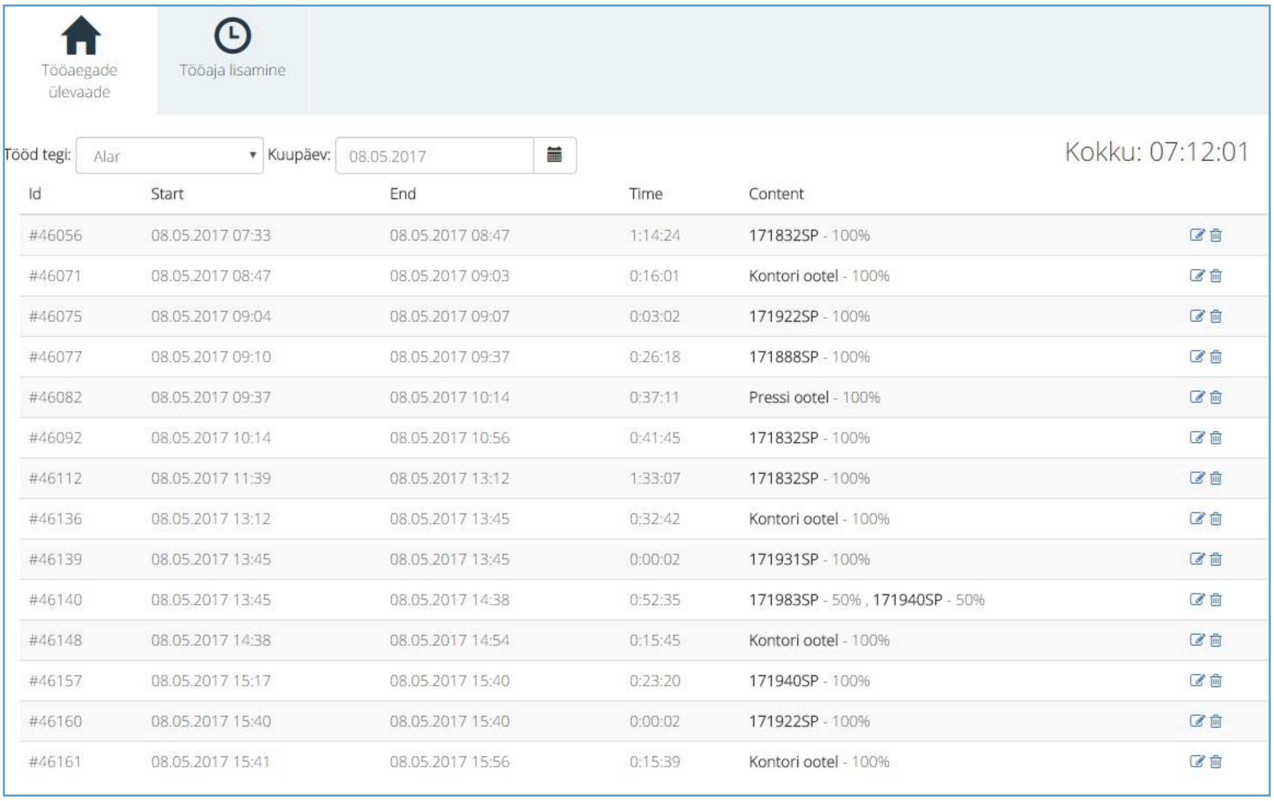
The main measure that needs to come out of the system is working hours. Previously in Plaat Detail OÜ the workers got paid by piecework. The time for different operations was calculated and the workers got paid for exactly for how many details they had made. As the company developed different operations were added, the work got more complicated and it was more difficult to calculate the production times for products. All the workers were then paid monthly an exact salary. That lead to a situation where 8 hours of work was done but the outcome was not exactly what was expected. It created a lack of an overview, what was made and where was the time spent. The productivity was decreased.

From there came the idea to go to hours-work and all the workers needed to write down the tasks and projects they did. Usually the timesheets were filled after work or even at the end of the week, so the times were not accurate, smaller projects were forgotten to write down and that gave wrong information about products own-price. It was not possible to make price calculations or conclusions about projects profitability based on that. It also took a lot of time from workers to fill the papers and extra time for accountants to enter all this data to computer. From that need was created the application.

3.4.1 Situation today and benefits of the application

In Plaat Detail OÜ is WiFi in the whole factory and all the workers are given smartphones by the company just as a regular working tool. The application works on Android 5.0 or newer operational system and it works just like another application - every worker has a user ID and has to log in with it before starting to work. The application works only in Plaat Detail OÜ local WiFi.

As there formerly were different papers that the workers had to fill in the morning before starting to work and in the evening after work, now it can all be done with the application and the calculation of time is more precise. Also the workers do not have to fill the papers as they come to work, as they start a new project, when they are working overtime etc. It all can be done via the application and it all can be seen in the computer by the production manager. From Figure 17 can be seen exactly all the projects that a worker was dealing with on a specific day. It is easily seen what time the work had started, what time ended and how much time used for each project. Also are correctly marked the waiting times for press, “Pressi ootel”, and waiting for the office, “Kontori ootel”. This gives the production manager quick overview about the work done and how we’re the working hours used. Formerly all the information was written on paper with accuracy of 0,5 hours and the production manager had to type all the information from papers to computer and then was able to calculate the times used on various projects.



Id	Start	End	Time	Content
#46056	08.05.2017 07:33	08.05.2017 08:47	1:14:24	171832SP - 100%
#46071	08.05.2017 08:47	08.05.2017 09:03	0:16:01	Kontori ootel - 100%
#46075	08.05.2017 09:04	08.05.2017 09:07	0:03:02	171922SP - 100%
#46077	08.05.2017 09:10	08.05.2017 09:37	0:26:18	171888SP - 100%
#46082	08.05.2017 09:37	08.05.2017 10:14	0:37:11	Pressi ootel - 100%
#46092	08.05.2017 10:14	08.05.2017 10:56	0:41:45	171832SP - 100%
#46112	08.05.2017 11:39	08.05.2017 13:12	1:33:07	171832SP - 100%
#46136	08.05.2017 13:12	08.05.2017 13:45	0:32:42	Kontori ootel - 100%
#46139	08.05.2017 13:45	08.05.2017 13:45	0:00:02	171931SP - 100%
#46140	08.05.2017 13:45	08.05.2017 14:38	0:52:35	171983SP - 50% , 171940SP - 50%
#46148	08.05.2017 14:38	08.05.2017 14:54	0:15:45	Kontori ootel - 100%
#46157	08.05.2017 15:17	08.05.2017 15:40	0:23:20	171940SP - 100%
#46160	08.05.2017 15:40	08.05.2017 15:40	0:00:02	171922SP - 100%
#46161	08.05.2017 15:41	08.05.2017 15:56	0:15:39	Kontori ootel - 100%

Figure 17. View from web about workers day, synced with the app

The app is in use by every operation in the factory – carpenters, CNC center, sawing center, edgebanding and packing unit. All the operations have to be added to the application by project manager. If one is not added, the worker will not see that the project is meant for him to work.

There are also other possibilities for workers to mark:

- waiting for the office;
- having a break;
- on a meeting;
- waiting for warehouse;
- maintenance of equipment.

Table 1. Report about time usage for carpenters while not working on a specific project

Report 15.05.2017 - 18.05.2017	Carpenters				Project in sum (hours)
	Worker 1	Worker 2	Worker 3	Worker 4	
CNC assistance	0	0	0	1,41	**1,41**
Edgebanding assistance	0	0	0	0,33	**0,33**
Waiting for office	11,62	5,11	7,49	17,18	**41,4**
Meeting	0	0,68	0,36	0,44	**1,48**
Waiting for warehouse	0,27	0,57	0	0	**0,83**
Maintenance of equipment	0	0,97	0	0,63	**1,6**
Other	0	0	3,36	0,37	**3,73**
Waiting for press	1,94	2,21	0	0,48	**4,84**
Waiting for saw	0	0,39	0,19	0	**0,68**
Carpenter in sum	**13,83**	**9,92**	**11,4**	**20,86**	**68**

From table 1 can be seen all the different options the workers can choose between while not being able to work on a project. It can be seen that during the time period 15.05 – 18.05 the mostly used option was "waiting for the office". This shows that at this time period there was not enough work given to the carpenters by the office that they just had to wait for new projects (waiting for office 41.4 h). The same option is also used while waiting instructions or drawings or etc from office. This shows the production manager and project managers directly how much work is needed for the carpenters.

Options "CNC assistance" or "edgebanding assistance" are used when there are too large details to process that the operator is not able to lift and place the details by himself. Usually is the help given by the same carpenter that has already prepared the details.

The main conclusion that can be made by this report is that during this time period the factory was lacking for projects that are meant to be for carpenters. It does not show that at the same time other operations like saw, CNC and edgebanding could have been under great pressure and had plenty of work.

In table 2 are shown all workers in the factory, their possibilities to choose between operations while not working on a project and time spent on these operations. As in table 1 are only carpenters and the main selection was “waiting for the office”, in table 2 can be seen that edgebanding machinery was in maintenance, so both of the workers had chosen “maintenance of equipment” for all chosen time period. This also creates a link with carpenters wait. They had chosen “waiting for the office” because they were waiting for new projects, but in the same time multiple projects were waiting for the edgebanding machinery. This means that these projects that were waiting for edgebanding machinery were put on pause and new projects were asked.

Another option that shows out is that Holzma saw was waiting for the warehouse 6 hours (see Table 2). This is one of the biggest issues that the production is dealing with today. If the warehouse cannot bring materials in time for saw, it creates a sequence for all other operations as well – edgebanding, CNC, carpenters. That is the reason why digitalizing the warehouse could have a great impact on other processes.

To compare the two Holzma shifts to one another, can be seen that the second shift has only been waiting for the warehouse 0.12 h. The second shift comes to work at 15.00, this means the office will be then open for only two hours and after that the warehouse does not have to deal with customers and can focus on bringing right materials from warehouse for the night shift. For that reason the night shift is often more productive than the day shift. Another reason for being productive is that in the evening there are no other distractions, nobody is going to interrupt the work with their rapid problems.

Table 2. Report about waiting/assisting times by all workers in the factory (hours)

	Workers											
Report 15.05 - 18.05	Worker1	Worker 2	CNC 1	CNC 2	Holzma 1	Holzma 2	Edgebanding 1 shift	Edgebanding 2 shift	Postform 1 shift	Postform 2 shift	Worker 3	Worker 4	Sum (hours)
CNC assistance	0	0	0,25	0	0	0	0	0	0	0	0	1,41	**1,66**
Holzma saw assistance	0	0	0	0	0,3	1,79	0	0	0	0	0	0	**2,09**
Edgebanding assistance	0	0	0	0	0	0	0	0,83	0	0	0	0,33	**1,16**
Waiting for office	11,62	5,11	0	0,28	0	0,35	0	0	1,37	0	7,49	17,18	**43,4**
Meeting	0	0,68	0	0,31	0,08	0	0	0	0,24	0	0,36	0,44	**2,11**
Waiting for warehouse	0,27	0,57	0	0	6	0,12	0	0	2,38	0	0	0	**9,34**
Maintenance of equipment	0	0,97	4,72	2,23	2,56	1,21	19,37	23,42	0,52	0	0	0,63	**55,63**
Other	0	0	0,37	0,2	1,51	0,11	0	0,62	0	0	3,36	0,37	**6,54**
Postform assistance	0	0	0	0	0	0	0	0	0	31,28	0	0	**31,28**
Waiting for press	1,94	2,21	0	0	0	0	0	0	0	0	0	0,48	**4,63**
Waiting for saw	0	0,39	0	0	0	0	0	0	0,77	0	0,19	0	**1,35**
Working position in sum	**13,83**	**9,92**	**5,34**	**3,02**	**10,44**	**3,58**	**19,37**	**24,87**	**5,28**	**31,28**	**11,4**	**20,85**	**159,19**

This shows where the bottlenecks are in the production – are they waiting too long for materials from the warehouse, does it lack from information and projects given by project managers, is the machinery failing etc. (see Figure 18).

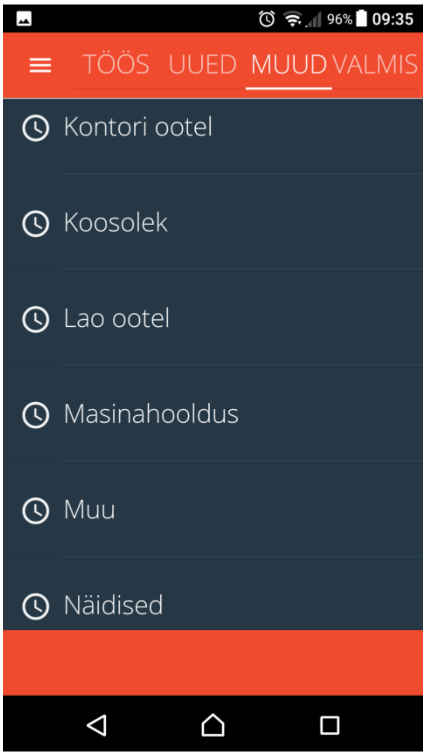


Figure 18. View from smartphone, options to choose while not working on a project

The application is connected to MRP/MES program, so all the information inserted in the application becomes available in computer and vice versa. All the projects in work are added from the computer to the application, so the production manager and project managers have real-time online overview of how one or another project is going and how much time has been spent with different operations. That way project managers can give customers precise information of their products estimated delivery time.

It works also the other way around. In the MRP program the project managers add estimated work time for every project for every worker. So if there are any issues with the project and the estimated work hours are crossed it can be seen from the web and then later be discussed with the worker.

It happens quite often that multiple projects are simultaneously in work by carpenters.

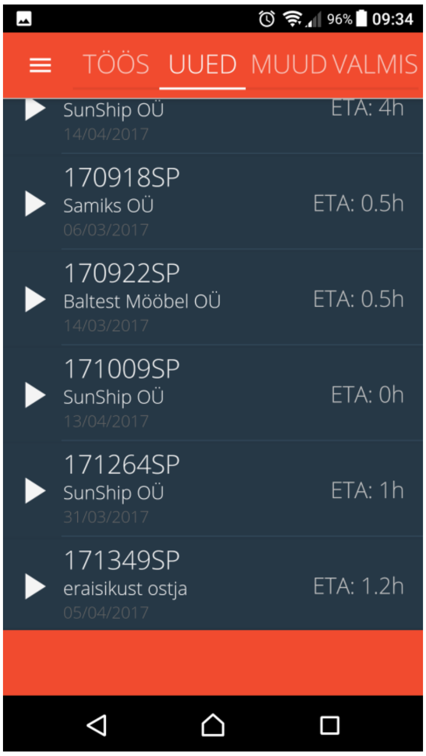


Figure 19. View from smartphone for choosing new project

So if they have to go to the warehouse to get the materials for another project, they can just pause in the application one project and start working with the other (see Figure 19). As well they can see how much of the estimated time they have used and what they need to do to stay within the time.

This gives to project managers and process manager precise information about the project - were the times calculated correctly, is there enough time for the worker, are there been any complications in the production. All that information gained works for the future and helps to make more accurate biddings, see if the project was lucrative, see whether the prices need to be raised to stay competitive with other manufacturers.

The application works really well with projects where only a specific service is offered, for example edgebanding or CNC-operations. Sometimes it can be difficult to calculate at the beginning the time for these operations. The information given is that it is needed to process 200 details, but the level of complexity is not specified and therefore there is a great possibility to price the project wrongly, overpricing or low-pricing.

With these projects is an agreement made with the customer that we can give them the price after the work is done. Of course it could be also done with paper and pencil and the worker marks all the hours spent on a paper, but it would be more complicated when the project lasts for days and it is needed to process other projects in between. In the application is possible to pause and start the project over and over again (see Figure 20) and the final time spent would be more accurate and the worker does not need to look for the papers where the hours are marked.

Figure 20. View from smartphone about projects in work

3.4.2 Disadvantages of application

This application still has some problems. The first and probably the biggest problem is the Wifi connection. If there are some interruptions or the Wi-Fi does not work properly, so will not the application. This means no information is given to the system and the workers cannot start or end projects in the app. So it happens that the information finally running in the computer is not true and needs to be manually checked and fixed. As well it confuses employees, whether to work on without registering to the app or reporting the problem and waiting for the solution.
The other issue is that many projects are connected with different users. If the project is finished by edgebanding it goes on to CNC machinery. If the edgebanding operator accidentally marks in the app that project finished, it will be not visible anymore for other workers who are also connected with it. To make the project again visible for other users, the status of the project has to be marked to work in the computer. It means that the worker has to come from one end of

the factory to the other and tell project managers that he cannot start this project in the app and it can be fixed. This again takes time and ruins the fluent production.

One of the issues with the application is the same that is with most of new things. There are always workers who doubt the benefits of it and are stuck with their habits. That mostly is the problem with older workers who are not so used to with modern technology and would prefer to work still same way as they did 30 years ago, paper and pencil. Many workers feel that with this application they are too controlled and every move they make is visible and can come under debate.

Taking into consideration the feedback from the production workers it is true to say that it is worked out rather to help office workers and accounting, to get more information of the production. This helps to make better decisions and plan the production. It is vital to know the capacity of the factory and make corrections based on the information obtained.

The investment into this project was almost doubled during the development phase because of the complexity and details of the manufacturing. The project is meant to have a 5 years payback period. At this moment it has been running for almost two years. The first year was mainly deploying phase and therefore it is too soon to make thorough conclusions about the profitability but the data gained is analyzed daily by process manager.

Conclusions

As said also by Estonian ministers, the next step for manufacturers needs to be the digitalisation of production on implementing Industry 4.0. The manufacturers are expected to develop new ways to answer customer's high demands – faster delivery, personal approach, visibility of the production. For that purpose companies need to update their IT services and bring into use different software that helps to manage production and brings all different production steps to one system. Production needs to be controlled in real-time to be able to react to last minute changes.

To meet these requirements companies are bringing into use production robots that can make simple tasks, like moving products, drilling and assembling, more effectively than human workers.

Another big step for companies would be creating an automated warehouse to make the movement of raw materials from warehouse to production, from warehouse to clients and within warehouse faster. The companies need to get better overview of their inventory so the space would not be wasted for materials that are no longer priority for production and lessen the money just waiting in the warehouse. The thesis looks for solutions for making the work more fluent in Plaat Detail OÜ warehouse.

A closer look was taken on the developments already made in Plaat Detail OÜ and what steps are planned in the near future. Plaat Detail OÜ is using a mobile application that gives real-time information for process manager and project managers. This helps project managers to give updated information to customers regarding their orders and delivery times. The reason for the application came from the uncertainties in the production, there was no correct information about the work times and what were the workers doing during their 8 hours shift. Today the application gives precise time for all different projects and this has helped the company to look over the pricing of projects. This has been an investment that today cannot yet be measured in profit, but it has given a much better overview of the production and bottleneck in production.

A survey that was carried out among Estonian furniture companies about the situation with production digitalisation was not very successful taking into consideration the amount of answers. Only 20 answers were received but was expected at least 50 answers. Based on these answers a conclusion can be made that today Estonian furniture industry companies are not very enthusiastic about Industry 4.0, many have not heard about the phrase. Most of them still think that they need to develop their IT-services and connect different system with one another.

Abstract

Production digitalization in furniture industry companies is going to be an important part of manufacturing development in future years. Due to complexity and variation of orders it is difficult to implement it in furniture industry.

The aim of the thesis is to get better understanding about the situation in Estonian furniture industry and a survey was conducted among companies. Based on the answers received may conclude that Estonian companies have not yet started with Industry 4.0. This needs great investments, big changes in the production and companies must educate their workers. Many companies are at the moment not sure of the profitability.

Manufacturing companies need to find ways to connect different parts of production with one another using new MRP and ERP software. Companies need to get better overview of production and find new solutions to decrease the cost and delivery time of their products to competitive on the market.

The thesis focused on digitalisation of Plaat Detail OÜ, what has already been done and what are the next steps.

In Plaat Detail OÜ is in use a mobile application that gives real-time data about situation regarding different projects – work time, worker, estimated work time, delivery. This gives process manager chance to organize and plan the work better. It also shows the bottlenecks of the production, where is the time spent and on which aspects of the production planning needs to be more focused.

Based on that information the next step in digitalisation in Plaat Detail OÜ is digitalising the warehouse. The warehouse is one of the bottlenecks in today's process flow. Time spent for looking for materials is too high and that prevents the work of saw-centre and therefore other operations in succession. Part of the thesis is looking for ways of making the work more fluent in the warehouse, what technologies could be used and what are the benefits of the digitalisation.

Resümee

Tootmise digitaliseerimine Eesti mööblitööstusettevõtetes on kujunemas suureks väljakutseks järgnevate aastate jooksul. Mööblitööstuse keerukuse ja projektide suurte erinevuste tõttu võib digitaliseerimise arendamine osutuda raskeks ja kulukaks ettevõtmiseks.

Magistritöö eesmärk on saada parem ülevaade hetkel Eesti mööblitööstusettevõtetes valitsevast olukorrast seoses digitaliseerimisega. Selle tarbeks koostati küsimustik 11 küsimusega ning Eesti Mööblitootjate Liidu kaasabiga sai küsimustik edastatud tootmisettevõtetele. Küsimustiku vastustest võib järeldada, et Eesti mööblitööstusettevõtted ei ole suuremal hulgal veel alustanud tootmise digitaliseerimisega. Protsess vajab suuri investeeringuid, laialdasi muutusi tootmises ning töötajate koolitamist. Paljud ettevõtted ei ole hetkel kindlad, et need investeeringud end ka ära tasuvad.

Ettevõtted on otsimas võimalusi, et ühendada omavahel erinevad tootmise etapid, alustades projektijuhtimisest kuni kauba väljastamiseni. Selleks on ettevõtetes kasutusel erinevad majandustarkvarad nagu MRP ja ERP. Ettevõtted vajavad oma tootmisest paremat reaalajas ülevaadet, et seeläbi pakkuda klientidele kindlamaid tarneaegu ning leida tootmises kohad, mille arendamisel oleks võimalik toodete omahinda vähendada.

Magistritöö keskendub samuti digitaliseerimise protsessile ettevõttes Plaat Detail OÜ, millised lahendused on praeguseks juba rakendatud ning millised võiksid olla tootlikkuse tõstmiseks järgnevad arengud.

Plaat Detail OÜ-s on hetkel kasutusel majasisene mobiilirakendus, mille abil on võimalik mõõta täpselt kulunud tööaega erinevatele projektidele. See annab tootmisjuhile paremad võimalused tootmist planeerida ning projektijuhtidele ülevaate projektide tasuvusest. Samuti on rakenduse abil võimalik leida tootmise kitsakohti – mille peale tootmises lisaks tööoperatsioonidele veel aega kulub.

Toetudes rakendusest saadud informatsioonile on ettevõtte järgmiseks projektiks digitaliseerimise valdkonnas lao digitaliseerimine. Praegusel hetkel on ladu üks tootmise kitsaskohtadest - materjalide otsimisele kulutatav aeg on liiga suur ning seetõttu ootavad nii saekeskus, kliendid kui ka teised tehase töötajad. Üheks magistritöö eesmärgiks on uurida võimalusi, et muuta tootmisprotsessid lao digitaliseerimise abil sujuvamaks, milliseid uusi tehnoloogiaid oleks vaja kasutusele võtta ning millised eelised seeläbi oleksid saavutatavad.

References

1. "Digitalization is changing the future of manufacturing" https://www.fraunhofer.de/en/research/current-research/production-4-0.html (22.02.2017)
2. "4 ways digitalization is transforming manufacturing" http://www.digitalistmag.com/digital-economy/2016/04/01/4-ways-digitalization-is-transforming-manufacturing-04101356 (27.02.2017)
3. "Manufacturing's next act" http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act (18.0.2017)
4. "Tööstus 4.0 ja selle mõjud Eesti tööstusele ja haridusele" https://rito.riigikogu.ee/wordpress/wp-content/uploads/2016/02/J%C3%BCri-Riives-T%C3%B6%C3%B6stus-4-.0-ja-selle-m%C3%B5jud-Eesti-t%C3%B6%C3%B6stusele-ja-haridusele.pdf (30.03.2017)
5. "Service robotics market size, growth forecast, global industry report 2022" https://www.linkedin.com/pulse/service-robotics-market-size-growth-forecast-global-industry-billore?articleId=7194541873952047880#comments-7194541873952047880&trk=sushi_topic_posts (30.03.2017)
6. "What everyone must know about Industry 4.0" http://www.forbes.com/sites/bernardmarr/2016/06/20/what-everyone-must-know-about-industry-4-0/#64ef61a74e3b (08.04.2017)
7. "Industry 4.0 – an introduction in the phenomenon" http://www.sciencedirect.com/science/article/pii/S2405896316326386 (08.04.2017)
8. "Digitaliseerimise vajadus ja väljakutse" http://www.toostusuudised.ee/uudised/2016/11/28/digitaliseerimise-vajadus-ja-valjakutse (31.03.2017)
9. "Tööstus 3.0 oleks esialgu vajalikum" http://www.toostusuudised.ee/uudised/2017/03/15/marko-saviauk-toostus-30-oleks-esialgu-vajalikum (31.03.2017)
10. "Enterprise resource planning adoption and satisfaction determinants" http://www.sciencedirect.com/science/article/pii/S0747563216304265 (25.03.2017)
11. "Enterprise resource planning – ERP" http://www.investopedia.com/terms/e/erp.asp (25.03.2017)

12. “Enterprise resource planning – ERP” http://www.webopedia.com/TERM/E/ERP.html (25.03.2017)
13. „What is ERP?“ https://www.oracle.com/applications/erp/what-is-erp.html (25.03.2017)
14. “Material requirements planning – MRP” https://www.shopify.com/encyclopedia/material-requirements-planning-mrp (18.02.2017)
15. „Material requirements planning (MRP)“ http://www.inc.com/encyclopedia/material-requirements-planning-mrp.html (18.02.2017)
16. “Advantages and disadvantages of using MRP system” http://manufacturing-software-blog.mrpeasy.com/blog/2015/12/13/advantages-disadvantages-using-mrp-system/ (18.02.2017)
17. “The Top 5 advantages of a manufacturing execution system” http://www.planettogether.com/blog/the-top-5-advantages-of-a-manufacturing-execution-system (18.02.2017)
18. „Manufacturing excution system“ https://en.wikipedia.org/wiki/Manufacturing_execution_system (18.02.2017)
19. “Industrial process automation systems” http://www.sciencedirect.com/science/article/pii/B9780128009390000231 (04.03.2017)
20. “The Top 5 advantages of a manufacturing execution system” http://www.planettogether.com/blog/the-top-5-advantages-of-a-manufacturing-execution-system (04.03.2017)
21. “Manufacturing execution systems – the investment that keeps on giving” http://www.apriso.com/blog/2015/05/manufacturing-execution-systems-the-investment-that-keeps-on-giving/ (18.03.2017)
22. „Äripäev Tööstus 2017 veebruar, Marko Saviauk, LeanEst OÜ tegevjuht“
23. Ajakiri “Äri IT” Kevad 2017, “Digitaliseerimise ohud ja võimalused tootmises” Toomas Mõttus
24. “Warehouse management and ERP integration: Create the complete picture” http://www.panasonicforbusiness.com/2016/09/warehouse-management-and-erp-integration-create-the-complete-picture/ (02.04.2017)

25. “Building a smarter warehouse” http://www.inboundlogistics.com/cms/article/building-a-smarter-warehouse/ (08.04.2017)
26. “Smart warehouses, smarter productivity” http://www.abelwomack.com/wp-content/uploads/Smart_Warehouse_White_Paper.pdf (22.03.2017)
27. “Smart warehousing – Solutions for tomorrow” http://www.wipro.com/documents/smart-warehousing.pdf (23.03.2017)
28. “Robotics and computer-integrated manufacturing” http://www.sciencedirect.com/science/article/pii/S0736584510000177 (14.04.2017)
29. “Industrial robot” https://www.sciencedaily.com/terms/industrial_robot.htm (14.04.2017)
30. “Industrial robots – definition and classification” https://ifr.org/img/office/Industrial_Robots_2016_Chapter_1_2.pdf (14.04.2017)
31. “Industrial robots: What are the different types?” http://blog.robotiq.com/bid/63528/what-are-the-different-types-of-industrial-robots (15.04.2017)
32. “Cartesian robot” http://www.allonrobots.com/cartesian-robots.html (23.04.2017)
33. “Scara robot (4-axis robot) overview” http://www.adept.com/robots/scara-robots-4-axis (22.04.2017)
34. “Automation products” http://www.cimtecautomation.com/parts/c-658-universal-robots.aspx? (22.04.2017)
35. “Seeing, sensing, thinking, working autonomous dual-arm robots” http://global.epson.com/innovation/engineer/dualarm_robot.html (17.04.2017)
36. “Human-robot collaboration (HRC)” https://www.kuka.com/en-us/technologies/human-robot-collaboration (23.04.2017)
37. “Collaborative robots working in manufacturing” http://www.manufacturingtomorrow.com/article/2016/02/collaborative-robots-working-in-manufacturing/7672/ (18.04.2017)

Appendix 1

Projekti prognoositav eelarve

Projekti eelarve on hetkel veel esialgne ja täpsustub töö käigus

Selgitus	Maht	Summa
Litsentsid ja tugileping Laomees/Ladu20 litsentsileping (litsents+tugi) 3..6 kasutajat (hinnakiri: http://www.kma.ee/ladu20/ladu20-hinnakiri/)		224 EUR/kuu
Vajaduste kaardistus (teostatakse jooksvalt vastavalt juurutatavale lõigule)	10..20 h	750..1500
Laomees üldise süsteemi esialgne seadistamine ja ettevalmistus vastavalt Plaat Detaili vajadustele	24 h	1800
Laomees kliendispetsiifilised aerendused vastavalt Plaat Detaili vajadustele	0 h	0
Kasutajate koolitus ja esmane juhendamine	10 h	750
SAFiga andmeintegratsioonid - Klientide import - Kaubabaasi import - Sissetulekute import - Müügitellimuste import - Tootmistellimsute import - Mahakandmiste export - Väljastuste export - Laoliikumiskorralduste import - Laoliikumiskannete exprort	40...80 h	3000...6000
Projektijuhtimine (suhtlemine, juhendamine, konsultatsioonid , kooskõlastamine,...)	20 %	
KOKKU ESIALGSELT PROGNOOSITAVATE JUURUTUSTE MAHT	110...160 h	**8250... 12000 EUR**

Seadmed		
	**iData 95W** iData 95W on disaintud tööks karmis keskkonnas. **Vastupidav ja professionaalne iData 95W vastab IP65standardile** **Kannatab kukkumist kuni 1.5 m kõrguselt betoonpõrandale** **Lubatud töötemperatuur -10 ° C kuni 60 ° C** **http://www.kma.ee/product/idata-95w/**	**660 EUR**
	Koos tahvelarvutiga soovitame kasutada bluetooth laoskännerit. Koos jojo ja silikonkestaga on se väga mugav lahendus.	**220 EUR**
	Laiatarbe toodetest kõige paremini laotööks sobiv 8″ tahvelarvuti! Müügikomplekti kuulub lisaks tahvelarvutile ka tugevdatud korpus.	**400...600 EUR**

Kõigile mainitud hindadele lisandub käibemaks!

Appendix 2

StrongPoint

Männiku tee 104, 11216 Tallinn
Tel 650 4200, faks 650 4201
e-mail: info.ee@new-vision.com
http://www.strongpoint.ee

STRONGPOINT A S

KELLELE:	Plaat Detail OÜ Karmo Lomp	karmo@plaatdetail.ee	
KELLELT:	StrongPoint AS Tarvo Nõulik	KUUPÄEV:	2.3.2017

HINNAPAKKUMINE

MECTEC F-100 etiketipaigaldussüsteem

MECTEC – F100/12 – front applicator

- thermal transfer printer (300dpi)
- trükilaius 108mm
- max etiketirulli välisläbimõõt 340mm, südamik 76mm
- paigalduspadi 110mm x 110mm
- non-stick paigalduspadi
- paigaldushoob 180mm või 300mm
- start/stop fotosensor
- PCU IV (RS232, USB, Ethernet)

MECTEC – scanner

- Datalogic DS2100N-1200 std. linear laser

MECTEC – stand

- põrandakinnitus printerile ja kontrollerile

Nimetus	Hind	Kogus	Summa
MECTEC – F100/12 – front applicator	12 693,00	2	25 386,00
MECTEC - scanner	1 653,00	2	3 306,00
MECTEC - stand	1 293,00	2	2 586,00
MECWIN tarkvara	400,00	1	400,00
		Kokku	**31 678,00**

MÄRKUSED:

- Hindadele lisandub käibemaks 20%
- Maksetingimused vastavalt kokkuleppele
- Garantii 12 kuud
- Pakkumine kehtib 30 päeva
- Tarneaeg: 4-5 nädalat

Appendix 3

Survey on manufacturing digitalisation in Estonian furniture companies

1. Size of the company, number of employees (written answer)
2. Size of the company, number of employees in production (written answer)
3. Approximate market share in domestic market % (written answer)
4. Approximate market share in export % (written answer)
5. Where does the company get information about production digitalisation?
    - Buy in the consultation
    - Have our own workgroup/know-how
    - Company is not planning to digitalise their manufacturing
    - Other
6. Which IT services are in use for everyday work?
    - Material accounting
    - Warehouse systems
    - Work time accounting
    - Planning
    - Management
    - Other
7. What does the phrase Industry 4.0 say to You?
    - Have not heard
    - Know exactly
    - Have heard and led on course
    - Have heard, but know superficially
    - Have heard, but have not concentrated on it
8. Has there been implemented any Industry 4.0 projects in the production?
    - Have implemented
    - Have not implemented
    - Are planning to implement in nearest future
    - Do not see the investment benefiting
    - Are planning to implement in longer future
9. Which client oriented e-services are in use?

- Placing orders/price offerings via Internet (except e-mail)
- Ordering products from companies e-store
- Ordering via public e-store
- Not is use

10. If any, which developments are you looking for in the next 5 years time?

    Written answer

11. Company name (respond voluntary)