Kaunas University of Technology
Faculty of Mechanical Engineering and Design

Improvement of the Door Production Process and Technological Line in Furniture Manufacturing Enterprise

Master's Final Degree Project

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Supervisor

Kaunas, 2019

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Industrial Engineering and Management (6211EX018)

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Declaration of Academic Integrity

I confirm that the final project of mine, Kornelija Pikevičiūtė, on the topic „Improvement of the Door Production Process and Technological Line in Furniture Manufacturing Enterprise" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by Law) have been paid to anyone for any contribution to this project.

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Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Task of the Master's final degree project

Given to the student – Kornelija Pikevičiūtė

1. Title of the project –

Improvement of the Door Production Process and Technological Line in Furniture Manufacturing Enterprise.

(In English)

Durų gamybos proceso ir technologinės linijos modernizavimas baldų gamybos įmonėje.

(In Lithuanian)

2. Aim and tasks of the project –

The aim of this work is to improve the standard door production process and technological line by applying quality management tools.

1. To analyse current door production process and technological line; identify main problems by using different quality management tools.
2. To discuss and propose solutions for production process and technological line improvement.
3. To suggest improved door production technological line.

3. Initial data of the project –

-

4. Main requirements and conditions –

LEAN, shop-floor environment, automation possibilities

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Study field and area (study field group): Production and Manufacturing Engineering (E10), Engineering Sciences (E).

Keywords: Wooden door production, LEAN, 5S, Visual management.

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Summary

The aim of the final work was to improve the technological line of production of standard doors and production using quality tools. For this purpose, a small-medium-sized furniture manufacturing company was selected. The company's door production line has a lot of manual work, unnecessary movement of materials and workers, which causes a lot of rejects and takes a lot of time. In general, it is difficult for the wood industry to fully automate small and medium-sized enterprises as they are more engaged in individual production. After analysis of the technological line by using Pareto analysis, Ishikawa chart, Flow process chart analysis, 5WHY method, and Spaghetti chart, the main problematic production sections were identified: Painting, Smoothing and Drying. In the final work it is proposed to change the layout of the technological line, additionally purchase machines for the Painting-Drying sections. Also, Flow chart and Visual Management tools have been proposed to help manage work environment and make operations easier. These proposals would help to reduce unnecessary movement of materials, workers and would increase production efficiency.

Kornelija Pikevičiūtė. Durų gamybos proceso ir technologinės linijos modernizavimas baldų gamybos įmonėje. Magistro baigiamasis projektas, vadovė doc. dr. Rūta Rimašauskienė; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.
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Reikšminiai žodžiai: Medinių durų gamyba, LEAN, 5S, Vizualinis valdymas.

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Santrauka

Baigiamojo darbo tikslas buvo pagerinti standartinės durų gamybos technologinę liniją ir gamybą taikant kokybės įrankius. Šiam tikslui buvo pasirinkta mažoms-vidutinėms įmonėms priskiriama baldų gamybos įmonė. Įmonėje esanti durų gamybos linija turi daug rankinio darbo, bereikalingo medžiagų ir darbuotojų judėjimo, kas sukelia didelį skaičių broko ir sunaudoja daug laiko. Apskritai, medienos pramonėje sunku pilnai automatizuoti mažas-vidutines įmones, nes jos daugiau užsiima individualia gamyba. Išanalizavus liniją, taikant Pareto analizę, Ishikawa diagramą, Flow process chart analizę, 5WHY metodą ir Spageti diagramą, buvo įvardintos pagrindinės probleminės gamybos sekcijos: Dažymo, Paruošimo prieš dažymą ir Džiovinimo. Baigiamajame darbe pasiūlyta pakeisti technologinės linijos išdėstymą, papildomai įsigyti mašinų Dažymo-Džiovinimo sekcijose. Taip pat, pasiūlyta taikyti Flow chart ir Vizualinį valdymo įrankius, kurie padėtų sutvarkyti darbo aplinką ir lengviau atlikti operacijas. Šie pasiūlymai padėtų sumažinti bereikalingą medžiagų-darbuotojų judėjimą ir padidintų gamybos apimtis.

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List of abbreviations and terms

Abbreviations:

Assoc. Prof. – Associate professor;

Lect. – Lecturer;

Prof. – Professor;

SME – Small-Medium Enterprises;

QM – Quality Management;

QMP – Quality Management Principles;

TQM – Total quality management;

WWII – Second World War;

QMS – Quality management systems

ISO – International Organization for Standardization;

SPC – Statistical Process Control;

DMAIC - Define-measure-analyse-improve-control model;

TPM – Total productive maintenance;

MDF – Medium Density Fibreboard.

Introduction

The furniture industry occupies a very large part of global trade. This industry can be oriented towards the international market, can help to develop the vast majority of other related industries, which would have a significant impact on job creation, as well as would increase domestic product revenues. Therefore, the development, improvement and prosperity of this industry are very important [1].

Due to the instability of the European economy and the increasing competition in the market, the furniture industry needs to take innovative solutions to products and production processes. A lower market share is influenced by the production price. Major companies threaten smaller businesses due to increased investment in automation and computerization [2].

The aim and objectives

The aim of this work is to improve the standard door production process and technological line by applying quality management tools.

The main objectives of this work:

1. To analyse current door production process and technological line; identify main problems by using different quality management tools.
2. To discuss and propose solutions for production process and technological line improvement.
3. To suggest improved door production technological line.

1. Literature review of quality management tools, Lean and automation possibilities in Small-Medium Enterprises

QM is a system that ensures continuous improvement of the organization. There are 7 QMP that are related with customer needs and requirements, quality of process improvements and methods. Where leadership is advantage within organization and people are interested in work. Also, problem solution and relationship management can be referred as principles of quality management. ISO is based on these seven QMP`s [3]. The system of QM was created after WWII in order to improve quality in manufacturing enterprises and the extension of QM usage had grown very fast. The most popular method which connects different Company's departments and improves quality continuously in order to meet customer`s needs and requirements is TQM [4].

Lean construction – effort to use lean principals which came from Toyota production system, to improve processes of construction by using minimum cost and creating huge value for customer needs [5]. Especially, it is important for SME to adapt changes when there a vast competition with large companies.

Proven that application of Lean theory is an effective way to improve production. Lean is more as philosophy. It also includes methods and tools which help implement that philosophy. Actually, there are no formal guidelines of how to apply Lean. In fact, much of the experience with installing lean is derived from the industry [6].

1.1. Tools of quality control and its application

ISO is a network of the national standards institute that manages system of standardization. ISO 9001 standard most successful standard which provides products and service that meet requirements of customers and executive. This standard is sought after by many enterprises. The main factors that cause implementation of QMS and not maintain a certain level of quality are executive and labour understanding of having higher quality and how much it is substantial in design of organization and organizational culture [7].

Statistical process control – set of tools that is used to manage production of products and services. It identifies factors that affect process quality, monitor processes. Most of SPC tools have visual presentation for this reason it is easier to use, analyse and understand. Main tools of SPC widely used are described below [8]:

- Process flowchart is one of quality tools that define time that is spent producing, delays in different operations, distance between processes or equipment [9].
- Pareto analysis is a very easily implemented tool which shows quality problems arranged from most to less important. This analysis defines 80-20 rule which says that many occurred problems are caused by only few reasons. According to studies, 80% of defined problems have the highest impact on the process, but it does not mean that remaining 20% are not important for consideration. [4].
- Ishikawa (fishbone) diagram – graphical tool which helps to get deeper into problem by identifying causes. This tool connects different causes and shows possibilities for improvements [10] [11].

According to the case study in Sri Lanka, Pareto analysis helped to find main impact on manufacturing processes, Cause-and-effect diagram enabled to go deeper into major problems by identifying causes of the three-wheeler accessory manufacturing process [12]. As a conclusion it can be said that these tools have least cost for implementing Lean.

According to studies, SPC and DMAIC model can be used to make continuous improvement in manufacturing company. What is DMAIC model? It is a cycle of activities to improve and optimize various processes within enterprise. Define stands for problems, goals and objects identifying. Measure stands for data collection to set up baselines. Analyse stands for root cause identifying (for example using fishbone diagram). Improve stands for solution finding to the problems. Control stands for monitoring made improvements (for example by using Control chart). The conclusions were made that control charts, histograms, capability indexes can help to control process quality and achieve customer requirements. The combination of those two tools can help to achieve desired results of efficiency and quality and solve main problems which occur in processes [13].

By Sousa and others performed research, one component from automation and machine industry which had the biggest variability was chosen to investigate. Statistical process control was used to evaluate process capability. Control chart was made up, process performance indices were evaluated. It resulted that several points were outside the limits. This means that process has failed. After SPC evaluation, root cause analysis and improvement plans were made. Employees discussed in groups how to improve process capability and quality. These tools showed main causes of nonconformities. The application of Quality tools in this study helped to identify process variability which can be caused by, for example, wear of equipment [14].

Authors Gejdos and Simanova analysed the causes of abnormalities in adhesion application on furniture parts by using Ishikawa diagram. Main causes from the perspective of employees, service equipment, working conditions and input materials were identified. Identification of causes allowed to prepare a plan for moulding process of how operator should act if there would appear any abnormalities [10].

1.2. Workstation design by using 5S tool and Maslow pyramid

That production efficiency would be very high it is very important to create/ to design workstation properly like correctly arrange equipment, materials, tools that for employee would be easier to work. There is a very big differences between standard workstation and lean workstation, therefore it is substantial to maintain efficiency. In standard workstations there are no added value by worker. Lean workstation is more focused on creation and designing ergonomic environment to worker. All auxiliary and main work tools should be positioned in such a way as to enable the worker to work in a safe, comfortable and efficient manner [15].

Fig. 1 5S implementation [16]

It can be achieved by implementing 5s tool which helps to identify waste and properly prepare workspace. This tool came from Japan (see Fig. 1) and consists of five main steps. 5s is suitable for all types of organizations and industries.

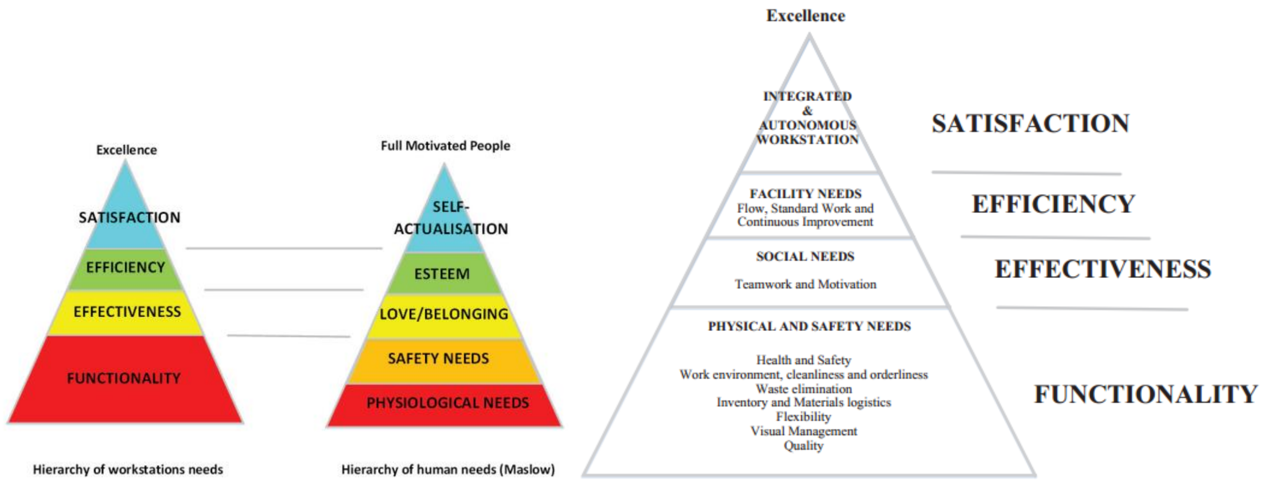


Fig. 2 Maslow and Workstation pyramids [15]

Also, there is a good practical application of Maslow pyramid to Workstation design (see Fig. 2). It shows that to reach highest levels, the lowers should be done first and how it should be developed to reach full effectiveness. To achieve excellence worker should complete functionality, effectiveness, efficiency and satisfaction which are related with safety and work environment, teamwork and motivation and continuous improvement [15].

1.3. Practical applications of Lean tools in Small-Medium Enterprises

The application of Lean not necessarily always is implemented at first time and especially in SME. Two described cases (Case A - engineering company, Case B company from construction industry) in article shows that staff domesticates Lean at a very small step because everything begins from the management and are transferred to other employees. Case A have tried to implement Lean by themselves, while Case B invited an expert. Case A had a lack of knowledge of implementing Lean and from top management this task was forwarded to the workers. Team had no clear strategy, nor inspiration in improvement and it caused team refusal. As a result, company accomplished to implement minimum of Lean tools – 5S. Different results appeared in Case B. At first, an expert got familiar the staff about Lean concept. Team was educated about different lean tools and methods, they had clarified their goals and, as result, they accomplished to implement 5S and Standard work. Not everyone can accept the changes because processes and habits going fast. As a conclusion it can be said that Manager`s aim is to be a wisdom, a leader to employees who will help accept different system and methodology of work because SME have very simple system and too much flexibility while big companies have difficult and much more systems [17].

According to [18], the implementation of Lean practices in SME located in Romania were applied. Main benefits of this tool were: minimization of inventories, reducing working time caused reduced cost, increased labour productivity – employees were motivated, fully prepared and trained.

Another research [19] was done to know how SME accomplish implementation of Lean manufacturing. Companies from metal processing, wood and paper, chemicals, food, aviation, automotive, construction industries participated in research. Those companies are very similar to Company X because all of them produce in small batch or medium batch. The main purpose of implementing lean was to reduce waste, employees, variability – they wanted to improve companies' efficiency. The main wastes were defined as unnecessary movement, rejects, machine failures, transportation. The same problems have Company X. Half of these companies implemented Lean Manufacturing systems in some areas, others did not achieve implementation or did not see any improvement. Most of the respondents implemented Lean tools individually. Main problems during implementation were huge current workload and lack of workers engagement, their refusal, lack of knowledge, motivation, top management support. The main tools of implemented lean were: 5S, SMED, Teamwork, Work standardization.

One more analysis [20] was done in mechanical equipment company and several Lean tools were proposed for improvement. During research main wastes in production were long storage of material/intermediate products, distances between different machines, absence of one-flow production, equipment stoppage. Respondents stated that manufacturing in having this kind of order, they got used to it and they have not imagined that there is another way for improvements. To have such wastes caused huge production costs. Few tools that were proposed for top management in order to eliminate non added value activities: 5S, TPM, Kanban, Line balancing, Standard work etc.

According to research in Austrian company from automotive industry, 5S implementation is inseparable from company`s culture. Every new employee is trained and educated about Lean instruments in company. Company have such practice that every worker gains monthly bonuses if they help to improve 5S in company. Implementation helped to increase productivity more than 100%. Moreover, by using 5S company has safer, cleaner environment with increased quality of products [16].

Another research from automotive industry was made. Company manufactures three-wheeler body parts and has nearly 60 employees. Most repetitive problems were identified: long lead time, products variability, low volumes. As a result, layout was changed in order to have reduced material/workers movement and 5S was installed in order to increase productivity, reduce costs and have safety environment. Implementation of 5S, Cause-effect analysis, Standardization, SPC – quality improvement tools that are financial worthwhile [12].

In summary, below are listed few Lean practices that could be adapt into Small-Medium sized companies:

Reduce setup time; Kanban; Small lot size; Supplier management; Preventive maintenance; Multifunction employees; Visual control; Quality circles (employee involvement); TQM; Training; Teamwork; Production smoothing continuous improvement; 5S and Standardization [18] [20].

1.4. Wastes of Lean and main reasons of Lean implementation failure

Lean applied tools can show improvements in cost, quality, reliability and delivery. The improvements result from better material utilization and faster work cycles. The main groups of wastes are identified: 1. Overflow when there is too much of production; 2. Frequent errors which cause rework; 3. Too much inventory which cause higher costs; 4. Not suitable manufacturing where wrong tools are used; 5. Unnecessary workers movements which lead to wasted time and higher costs;

6. Pauses when employees/materials are inactive; 7. Unused employees where abilities and knowledge are not applied properly. Those errors can be done due to poor management [21].

Often SMEs find it difficult to implement Lean, there are lot of research done when companies fail to fully implement lean, it requires a lot of commitment not only from top management but also from workers. It is said that in the range 60-90% of failures appear implementing Lean.

According to [22],[17], it is not so easy for SME to implement lean tools. It was evaluated that only 30 % of lean implementation are achieved. The key factors that showed as a challenge to implement lean were:

- Scarce resources;
- Staff declining to let in Lean;
- The lack of understanding of having lean;
- Cultural issues within company,
- The lack of knowledge,
- Lack of top management commitment etc.

1.5. Importance of knowledge creation by Lean

Knowledge creation is one of the main features to successfully implement lean construction because knowledge is vital advantage in adding value in various industries. There are two types of knowledge: Explicit – the one which can be easily shared within company (data, manuals etc.) and tacit – the one which can`t be transferred and systemized [5].

There are six steps which help to model the acquired knowledge: learning, exploring, capturing, storing, sharing and exploiting [23].

Workers are the most important assets in the company. It is important that leadership encourage, promote and truly engage in this asset in order to maximize their capabilities. Training is one of the most important activities to ensure and increase knowledge of labour, beneficial to everyone within company: to the employer and the worker. This kind of activity provides and maximize flexibility and generating ideas. The proper amount of knowledge about Lean implementation causes better results of implementation. These two factors are directly related [17]. Higher quality of products and services can be offered by workers who have such properties. Training, workshops motivates workers to seek higher goals, deepens their skills and knowledge, helps to believe in themselves. The regular workshops that are related with their jobs deeply develop workers. Also, there are plenty of other activities that helps to improve or increase knowledge like various meetings, group projects, workshops with different departments within company, exhibitions, business trips, seminars, cultural events, one day per week meetings etc [24].

According to studies, creating effective knowledge can increase the innovation in order to identify an effective way to solve problems, to dispose of waste and to maintain competitiveness. It also gives start-up knowledge to future projects, which can quickly make decisions. In addition, it also helps to reduce costs and improve quality. Executives inadvertently initiate knowledge improvement when implement Lean philosophy. But they can’t forget and should always seek to create more valuable and more potential knowledge system with regard to improve Lean efficiency [24].

1.6. Possibilities of automation in wood industry

Many industries have highly implemented and improved automation systems and robots that assist in various production processes. It is harder for those small companies to automate processes that do not have the expertise in automation or choose to automate the most complex production process that is copied from the company that is advanced in automation. Main factors that complicate application of automation system are lack of understanding how to program time and cost, how to identify key factors, additional equipment and lack of knowledge how to embody those projects. Wood industry is one of the least automated industry. Only 0.2 % of all industrial robots worldwide are installed in wood industry. Most of the processes are manual and determined as having the least improvement of production systems in the future. It is said that there is a 20- or 30-years gap between automotive and woodworking industries [25] [26].

According to the study, results are showed below in Table 1, the biggest potential for automation development has packing, painting and palletizing, machine tending processes in woodworking industry.

Table 1. Study results [25]

Driving forces	Applications	Requirements	Hinders
Improved ergonomics and competitiveness Increased capacity Quality Working environment	Packaging Palletizing Machine tending Painting	Competence of personnel Quality of raw material Redesign/adapt product system Management involvement	Fear of employees to lose their job Lack of knowledge Low production volume Problems with handling of solid wood

It is important to keep in mind that in order to have an automated system, it is necessary to adapt the product design to the abilities of the robot or think about remodelling of production system, develop new ideas of products. Usually, companies have too many requirements and take a lot of time to realize that the robots and machines have limits.

Most of small or medium sized enterprises (SME) want to be sustainable and competitive. It is important for them to have easily control interfaces, not manual monotonous working environment and high quality. Main fears are losing job because of lack of competency. However, that competency can be easily achieved.

There is very high pressure for enterprises which are located in high-cost countries to stay competitive. Companies are looking for various solutions of automation, but don’t have enough understanding of how to implement this. As guidelines, it can be presented a maturity matrix or readiness model tailor-made that would help to understand implementation of automation [25].

Another research on flexible-automated manufacturing was made [27] by interviewing 3 small-medium enterprises – two of them manufacture sheet metal and another produces wood products. All of them have under 50 employees and invested in automation possibilities or have plans for long-term automation strategies. In study case, categories of flexible automation (Collaborative robots, autonomous automation and mobile automation) were evaluated.

According to collected data, main requirements for flexible automation are:

– User friendly programming – for SME, especially which have small volumes and huge variability of products, is important to have easy operated robots where set-up operation would consume short time (it means few minutes). One of case company had to manufacture product manually because machine programming took several hours.
– Material handling – respondents require to reduce manual material feeding into/out of machines. Also, companies expect the flexible automation in manufacturing during night, therefore, without operator's support.
– Safety – companies look for possibilities to produce products in low volumes manually because it takes a lot of time to set-up machines. Also, they requested machines without safety fences because of limited space of shop-floor or required manual access to machine.
– Mobility – Companies have difficult production layout where different machines have a long distance between each other. In order to have flexible automation, they want to have moveable automated technology. Moreover, respondents highlight manually moveable technology.
– Payload – interviewers pointed the importance to have machines which could lift large and heavy materials.

After evaluation of flexible requirements, mobile automation is more suitable to fulfil those requirements because it provides handling, easy programming, mobility, safety and payload solutions.

However, in SME`s where production is mostly customized, the universal machines for manufacturing flexibility are considered as advantage.

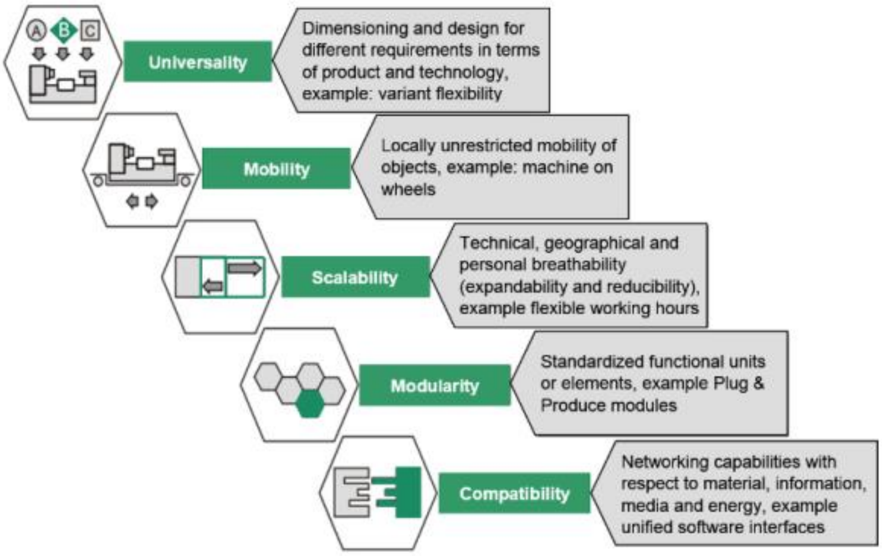


Fig. 3 Main facilitators of changeability [28]

What drive companies to automate manufacturing processes is the intention to gain bigger market share, to have sustainable technology and stable financial condition. Main five facilitators of changeability are defined above in Fig. 3 [28].

2. An overview of the manufacturing organization

The Company X was established in 1998. The company is located in northwest of Lithuania, at 7000 m2 production area. Currently, the company has 110 employees. Company produces such products as various types of doors like fire doors, acoustic doors, standard doors and production of individual design furniture (The individual production is one of manufacturing approaches when customized (make-to-order or engineer-to-order) products are made in small batches. By workshop principle, individual production is arranged where manufacturing technologies are in one area). Overall, Company X manufactures more than 1200 different parts, it means that SME should have strong skills how to manage labour and production processes to reduce production costs. For that reason, the technological line of standard door manufacturing was chosen for research to apply quality management tools in order to find which processes must be improved.

2.1. Technological line of standard door production and list of operations

Currently, standard door production has 21 operations to be completed from the semi-prepared raw material to the final product (example is depicted in Fig. 4).

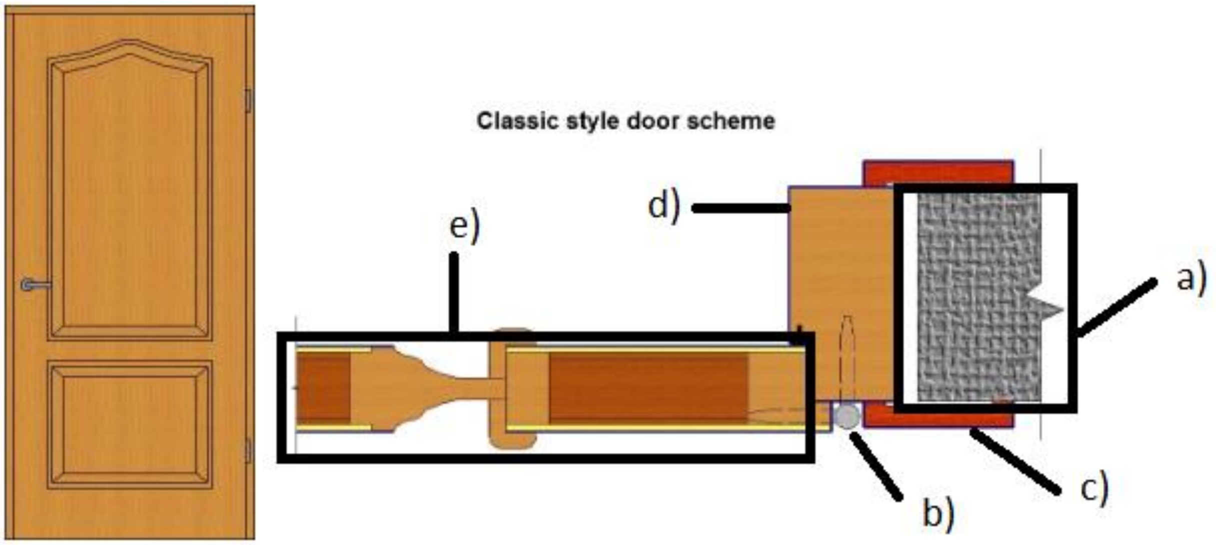


Fig. 4 On the left: Model of possible classic standard door. On the right: Classic style door scheme (a) - wall; b) – hinge; c) – collars; d) – door frame; e) – door panel)

Production operations can be divided into 6 main sections which identifies main units in production area. Accordingly, the production area could be divided into 6 different units that would remind the one-piece flow line. The units/sections are described below:

- Cutting: raw material is cut into different parts; the shape of lock is cut off according to the request of the customer;
- Smoothing: section consists of sanding, priming, varnishing processes where unnecessary particles are removed from the part surface; it helps to level the surface by powder; it prepares doors for painting process;
- Painting/Spraying: when workers manually dye parts; or special dyeing machine are programmed to dye doors with requested colour;
- Drying: doors are manually transported from dyeing machine to drying room where they are hanged;

– Bonding/Assembling: door frame and door panels are assembled;
– Packing/Shipping: assembled doors are transported to packing area where they are stacked on palettes and wrap with a special packing tape, after that they are loaded into truck by labour help.

The detailed list of operations, required labour quantity and machines are described in table below:

Table 2. Main operations of door manufacturing

No.	Operation	Machine tools	Labour force
1	Wood boards cutting to bushes (bucks, fasters)	Multi-cutting machine	2
2	Brunches cutting	Cross cutting machine	1
3	Bushes milling	Treadmill machine	1
4	Bushes planing	Four-sided planer machine	1
5	Frame of door panel assembly	Pneumatic tool and worktable	2
6	Door frame assembly	Pneumatic tool and worktable	2
7	Fibreboard (MDF) cutting for door panels and door frames	Cutting machine PAOLONI	1
8	Fibreboard (MDF) gluing on door panel and door frame	Press Gluing machine ORMA	2/1
9	Wood veneer sawing	Guillotine	1
10	Wood veneer sewing	KUPER machine	1
11	Veneer gluing on door panel and door frame	Press and Gluing machine ORMA	2/1
12	Door sawing according to exact dimensions, holes drilling for locks, handles and hinges	CNC HOMAG	2
13	Edges banding on door panel and door frame	Banding machine of edges OLIMPIC K800	1
14	Surface sanding	Grinding machine SCINDYA	2
15	Surface staining and priming	High pressure powder spray gun VAGNER	4
16	Surface peeling	Hand grinders 2 units	4
17	Product varnishing, dyeing	High pressure powder spray gun VAGNER, MAKOR dyeing machine	2
18	Product drying	Drying room	1
19	Quality control before assembly	Worktable, visual checking	1
20	Assembly of door frame and door panel	Worktable	2
21	Door packing	Worktable	2

As it was mentioned in the company`s overview, number of employees – 110; they work in 2 shifts after 8 hours. Weekends are off days. In 1st shift works approx. 80-90 people (incl. administration ~30 people), in 2nd shift works 10-20 people. To complete all operations the needed quantity of workers – 37 people. It is possible that every worker has more than one operation to complete that means that the same worker half of the day can work for example in cutting section and remaining time can work in packing section.

In Appendix 1, as can be seen, the Flow process chart of door production is described. Process has 24 operations, 21 movement operations, 1 inspection, 2 storage operations and 3 machine setup operations. There could be inserted more actions because these actions are not proceeding in turn. Operations from wood boards cutting to door frame assembly are proceeded in raw material preparation shop which is located 3 km from furniture and door production area. Some operations beginning at the same time. It is assumed that process takes 15 h 15 minutes. Data of operation length in Flow process chart was taken average. Company produces approx. 300 units per month. For comparison, Takt time is calculated below to see how much time the production should take in order to meet customers` demand.

If the average quantity of produced units per month are 300 and there is approx. 22 working days per month, then daily demand is:

Daily demand: 300 units / 22 working days = 13,63 units/day;

Hereinafter, if company works in two shifts after 8 hours, then 30 minutes takes to have lunch, also 30 minutes for additional breaks, then Total available time to work in two shifts are:

960 min – 60 min – 60 min = 840 min

Takt time: 840 min / 13,63 units = 61,63 min/unit.

The conclusion can be made that production does not proceed acc. to customer`s demand.

2.2. Factory`s layout

Company`s total area 7000 m^2. Currently, it is used more than ~3500m^2. In Appendix 2 we can find full scheme of current technological line of door production. As can be seen that there is missing the concrete flow of door manufacturing technological line. Comparing the results of flow process chart and layout of factory as can be seen there are a lot of people movement to and fro. Furthermore, some processes are used few times in the same line. To analyse deeper how the manufacturing is being done and what kind of machine tools are used below can be seen screenshots of factory layout.

In Fig. 5 the main company’s warehouse is depicted. Various plates, parts for furniture, small part of raw material etc. are stored here. The red marked area in Fig. 8 are shelfs for storage. Shelf size is 2,8 m x 2 m x 10 m. On the same shelf can be stored different materials. Approx. distance between line of shelfs is 4 m. Approximate length and width of warehouse is 48 m x 24 m. The warehouse area is quite huge because the truck can easily move inside the warehouse and is easier to load and unload materials and products. There is enough space for workers movement with loader.

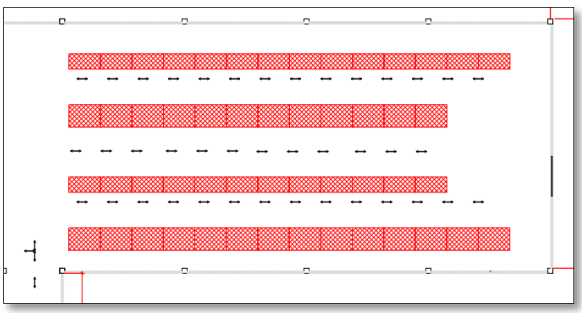


Fig. 5 Warehouse area

The cutting machine PAOLONI in Fig. 6 is automatic cutting machine where worker needs to set the cutting program and put bunch of material on special handles. Machine tool independently takes wooden plates, put automatically on cutting area and cut according to program. Also, equipment has connected dust removal which works all the time and helps to reduce dust in factory environment. Later, dust is used as biofuel in boiler house.

Fig. 6 Cutting machine PAOLONI

In Fig. 7 green marked squares devote for storing. The cut material is placed in green marked area and later are taken for another operation. Red marked are devoted for material which is used in cutting operation. The length and width of depicted area is approx. 18 m x 20 m.

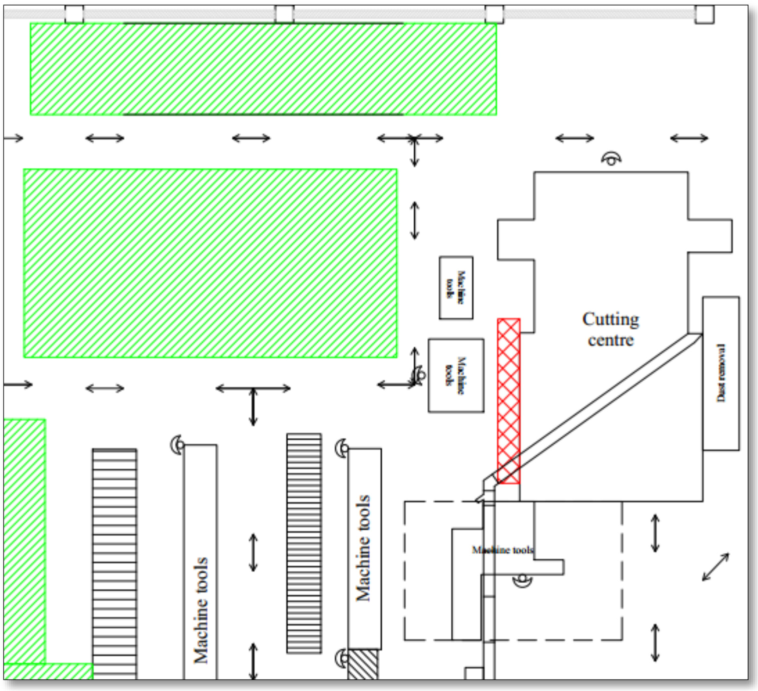


Fig. 7 Cutting centre area

CNC machining and processing centres Fig. 8 is used for woodworking. Equipment is designed for the production of furniture and components as well as the processing of solid wood and plastics with 4-axis capabilities.

HOMAG's process technologies are as diverse as the equipment features provided by CNC machining centres including sawing, routing, drilling, separating and measuring.

CNC machines are used for various material machining, cutting, drilling, milling, etc. Those CNC machines ensure large capacity increasing the capability up to 2.5 times and adaptability in manufacturing and automation systems. CNC machining processes are very important in wood industry because surface adhesion of product to other materials, waste reduction and wood appearance depends on machining quality.

Company has CNC Homag - V BMG6311/60K type 2 units. It is used for door and furniture production. In standard door production it helps to cut doors in exact dimensions, to cut off holes for hinges, place for locks, cut off the programmed pattern. Usually, it is set up repeatedly because company has a huge variety of products and customer has possibility to choose what kind of door he wants. It consumes a few minutes to set certain program for CNC. Also, like cutting centre, CNC has dust removal for dust/waste reduction in factory environment.

Fig. 8 CNC centre HOMAG (V BMG6311/60K)

Pressing and gluing centre ORMA OTTO - NPC/A/R type hot glue press with automatic glue application function and belt conveyor with rolling up system (Fig. 9 and 10). It can press up natural veneer sheets, high pressure laminate (HPL, CPL), HDF, MDF or solid wood panels with maximum size of 3000 x 1300 mm. In production line it is used for MDF plate and veneer gluing. Red marked square is as storage station where intermediate product is taken to another operation. Blue marked square is devoted as glue station. Black marked square is place for materials that are prepared for pressing operation. General length and width of depicted area in Fig. 13 is 30 m x 18 m.

Fig. 9 ORMA OTTO (NPC/A/R) press machine

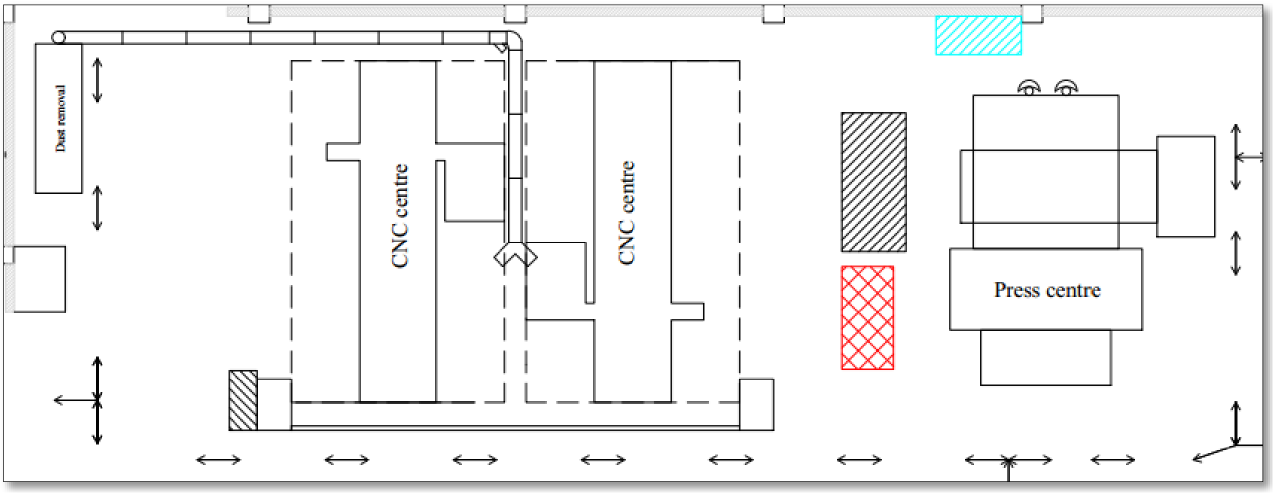


Fig. 10 CNC and Press centres area

In Fig. 11 and 12, before Press operation, veneer strips are cut off in required length by Guillotine (usually the standard length is 2,5). Width of veneer strip ranges in 8-10 cm. For the standard door it requires usually 80 cm with of sewed veneer strips. For veneer sewing Kuper machine tool is used (Fig. 11). Also, sewed veneer plates are stored near the machine tool for further press operation.

After CNC operation intermediate product is transferred to Edge Banding centre (Fig. 12) where machine brims door edges. After that, doors are placed in green marked square and waits for sanding operation. Blue marked square is devoted for edges, red marked square is devoted for cut off veneer strips and green marked area is devoted for sewed strips. Approximate length and width of depicted area is 8 m x 6 m.

Fig. 11 Veneer sewing machine KUPER

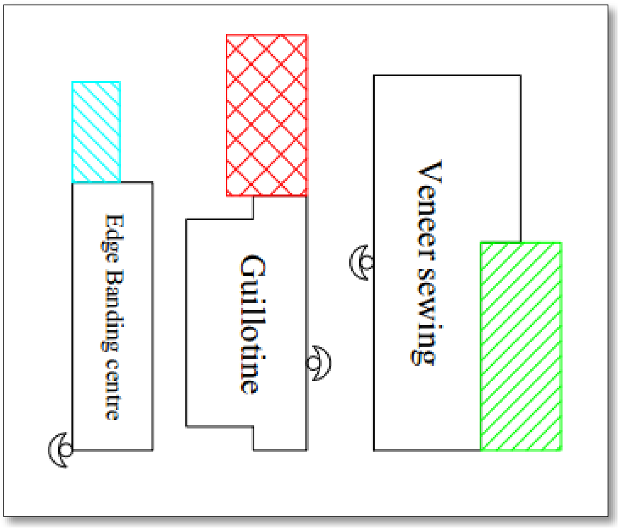


Fig. 12 Edge Banding centre and Veneer sewing machine

In Fig. 163 before spraying, doors and door panels are sanded and primed (if it is required by the created door project). Company has several machines for that operation but also, these operations are made manually by human – with hand sander or sandpaper. Machines are located separately: few of them are in main area, others are in special Preparation before painting area. Also, dust removal is installed but there is still plenty of dust.

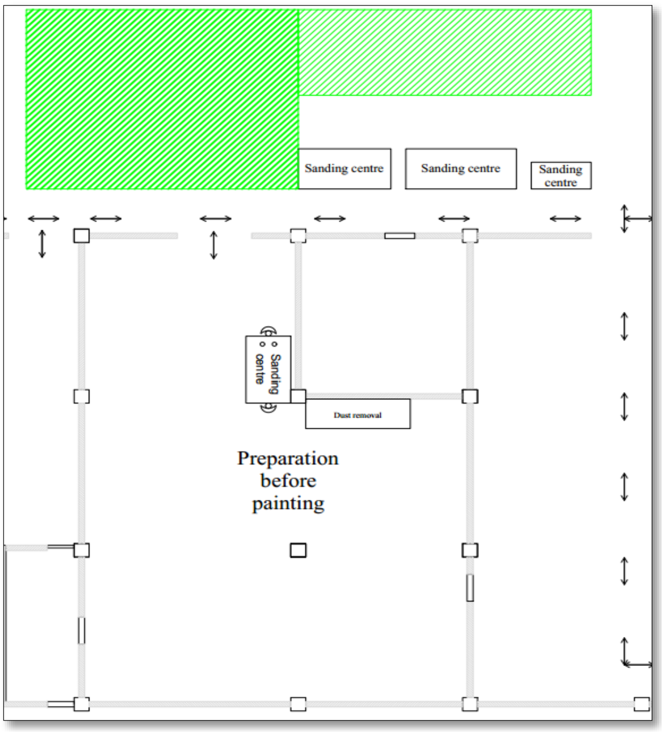


Fig. 13 Packing area and Sanding centres

Packing area is marked in bright green colour. Near to this area there are 3 sanding centres and separate room with one more sanding centre and hand tools for preparation before painting. Approximate length and width of depicted area is 18 m x 24 m.

The most complicated areas in company are spraying and drying (Fig. 14). Company has special MAKOR dyeing machine, which is used for door priming, varnishing, painting services. It is automatic spraying machine with lift and rotation mechanisms. Paints doors up to 2400 mm long and 1100 mm wide.

Also, there are built additional spray rooms for manual spraying. It is difficult and though process and worker must be well trained for this job because usually the result depends on worker`s job. Furthermore, there is a lot of dust in shop-floor environment that cause rejects. Approximate length and width of painting and drying sections is 42 m x 12 m.

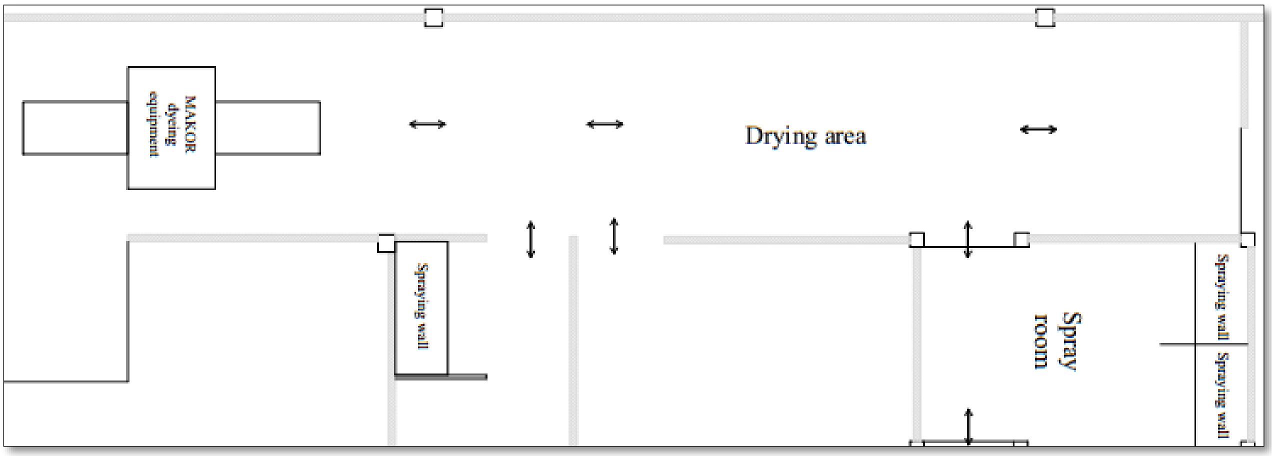


Fig. 14 Painting and Drying area

Every defined area could be and must be improved because for standard door production line has huge, inaccurate, unnecessary movement of workers and materials, a quite big part of area takes storage of intermediate products. Over too big and long storage, pallets are not marked acc. to order, so usually, workers lost the intermediate products. These factors cause rejects and due to these factors, company often fails to meet customers` demand. Accordingly, they accept fewer orders in order to meet the demand. Basically, if company would not face such problems, they could accept more and bigger orders which automatically would improve financial status.

In order to understand what the movement of materials in shop-floor environment is, Spaghetti diagram was created (Fig. 15).

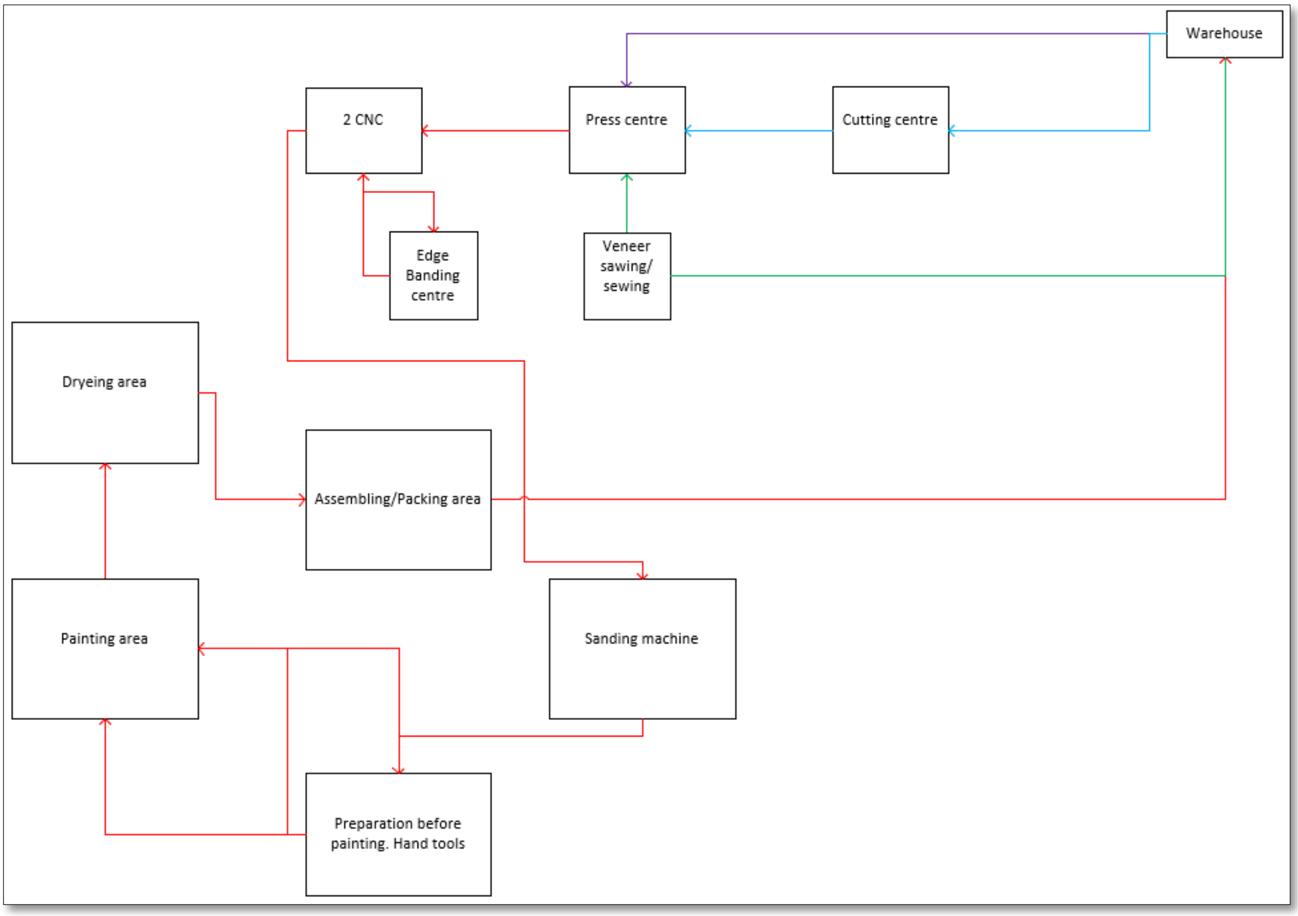


Fig. 15 Spaghetti diagram of current material flow. - Blue line marks MDF plate path; - Violet line marks door frame path; - Green line marks veneer path; - Red line marks intermediate product path to the final product.

As it can be seen in Fig. 15, there is missing concrete one-piece flow production line. Processes can be improved not only from perspective of modern machines, layout change, but also from perspective of usage of quality management tools.

2.3. Main rejects and causes in door production

It is well known that many SME confronts rejects or other non-conformities in production area. The same example is in Company X. To find out which section/unit mentioned before has most non-conformities, Pareto analysis was carried out (Fig. 16).

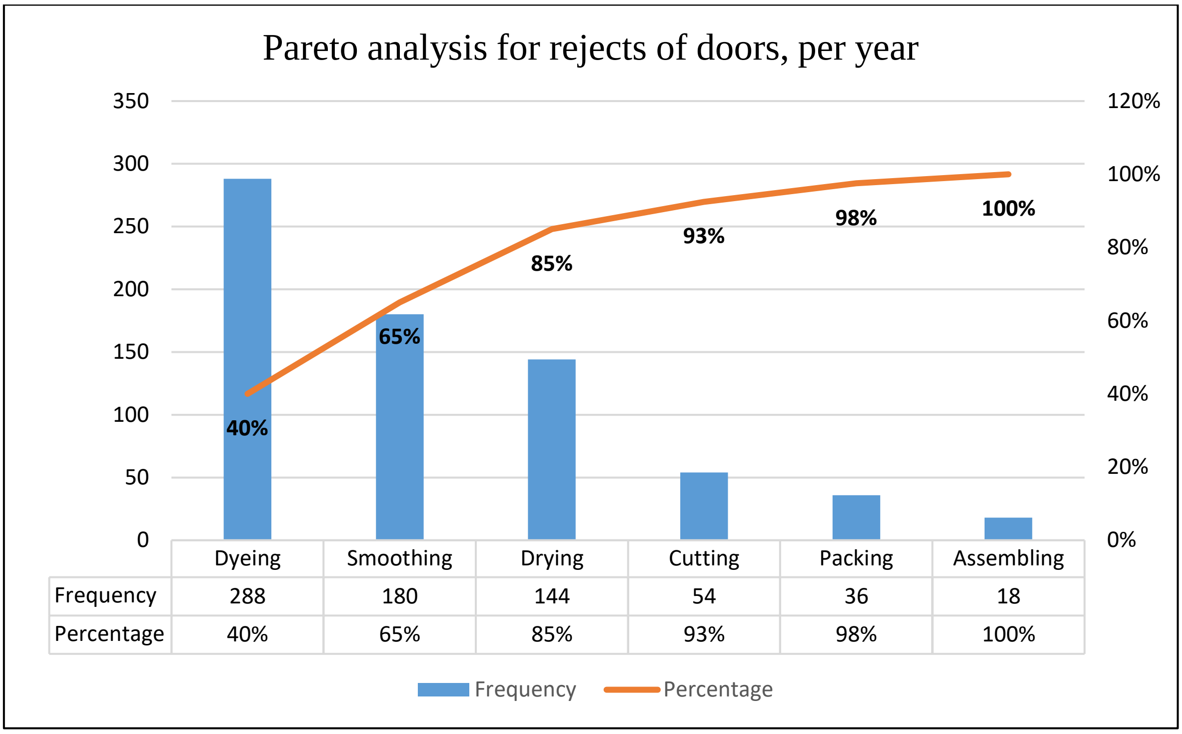


Fig. 16 Pareto analysis for rejects of doors, per year. (Data was taken from Company X)

As it can be seen, the 80-20 rule is applied, as result, more than 80% of rejects are caused by 3 sections: Dyeing, Smoothing and Drying. It shows that these sections must be improved. Company manufactures approx. 300 units per month. Accordingly, to make Pareto analysis, data of average door production per year was taken.

After observation, main problems and causes in Dyeing section were identified in Table 3:

Table 3. Main problems in Dyeing section

Problem	**Cause**	**Problem**	**Cause**
Uneven surface	Too little of dye was used	"Craters"	Contamination of painting equipment; Surface contamination
Scones on surface	Paint spamming	Poured pattern	Too much ink; the part is painted too many times, no longer notice the veneer pattern
Does not match the colour of the standard	Contamination of painting equipment; Uneven air supply; Irregular spray paint	Drip	Excessive amount of paint is sprayed at a time; Inappropriate solvent; Too much solvent; Inadequate equipment; Incorrect dye equipment settings
Rough surface	Contaminated painting environment or painting equipment	"Orange peel"	Inappropriate solvent; Inadequate painting equipment; Incorrect dyeing equipment settings; Little paint;

Since the painting section forms 40% of total rejects, it is possible to analyse causes more deeply. For root cause analysis Ishikawa diagram was applied.

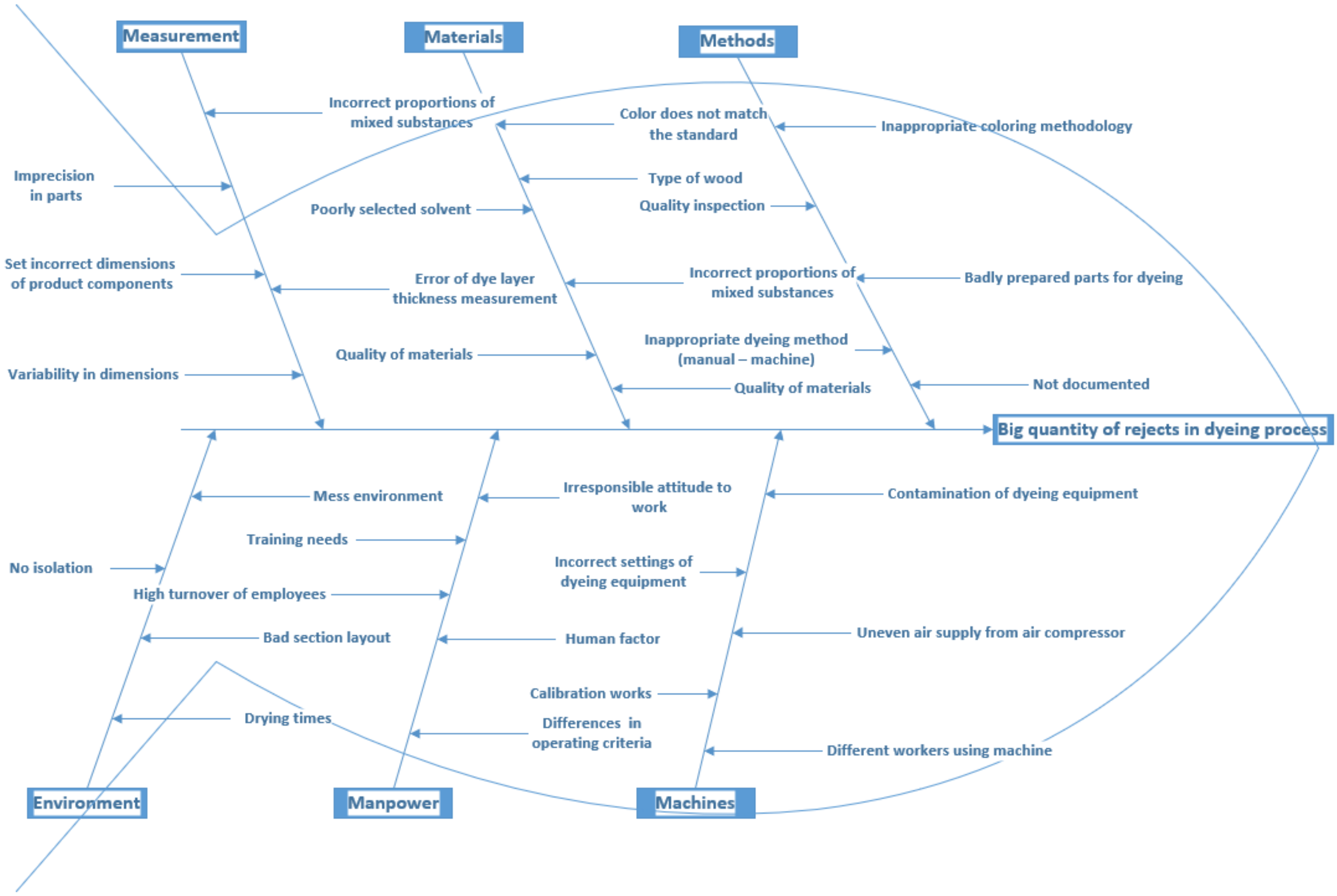


Fig. 17 Ishikawa diagram for dyeing process

As it can be seen from Fig. 17, causes were reviewed from perspective of measurement, materials, methods, environment, manpower and machines. It can be assumed that the impact for rejects have causes from all categories and effects usually observes in a process. As a conclusion, it can be said that the process needs improvements in all categories.

To deeper analyse the problem, 5-WHY method can be applied. Incorrect proportions of mixed substances from Measurement section was taken as an example which is showed below:

Problem: Incorrect proportions of mixed substances

WHY?

Worker wrongly poured dyes

WHY?

Worker didn’t look or wrongly looked at instruction of dyes mixing

WHY?

Worker`s attitude to the accuracy of the operation is irresponsible or Worker doesn’t know where to find this instruction

WHY?

There isn`t designated person who would train and supervise workers as they perform manual operations

WHY?

Company`s administration or Production manager doesn't pay enough attention to increase employee's knowledge/ qualification in how to work qualitatively in order to reduce rejects.

The conclusion can be made that Company doesn't invest enough in employee's knowledge; Company doesn't prepare workers properly for manual operations. That is why Company have so many rejects and that can be one of the reasons why Company has high turnover of employees.

After observation, main problems and causes in Smoothing section were defined in Table 4:

Table 4. Main problems in Smoothing section

Problem	**Cause**	**Problem**	**Cause**
Uneven surface	Broken veneer, primer	Orange peel	The badly strangled surface
Irregular edges	Frayed edges; poorly prepared	Grinding marks	Too rough sanding paper; Unsaturated primer
Scrub paint	Too rough grinding paper	Dust	Badly blown dust from the details

After observation, main causes and problems in drying section were identified in Table 5:

Table 5. Main problems in Drying section

Problem	**Cause**	**Problem**	**Cause**
Scones on surface	Drying spamming	Drip	Incorrect handling in drying area
Dust	Contaminant drying area, bad insolation, mess in production area	Spots	Fingerprints; dyed parts handling on dirty, uneven surfaces

As it can be seen from tables given above, most rejects are made manually, by humans. Company do not have automatic flow, and every movement, transportation of parts should be made with human help. Human factor has a huge impact on rejects. Another huge problem in all 3 sections is dust. Since all production are made from timber, and different processes are proceeded in the same area, the rejects occur very usually. Company has equipment for dust reduction, but it is not effective enough because the area is big and there is no isolation or "tunnel" for dyeing and drying processes, door production line does not have one-piece flow line. Although workers clean area periodically and spend a lot of time for it, the dust builds up on the surface of the parts because the air flow is not regulated.

3. Improvement proposals

Main possibilities to reduce waste as unnecessary material transportation and worker`s movement, possible rejects, production time are to restructure door production technological line, buy new equipment for finishing line, to install transportation lines, change hand tools to machines, to take more attention to dust prevention. These proposals are based on Lean Manufacturing, 5S tool application and Visual management.

3.1. Restructure of door technological line

As it was mentioned before Company X activity is related with individual production. Proposed restructure of door technological line is depicted in Appendix 3. It begins from Warehouse, continuous through Cutting centre, Gluing centre, Veneer sawing/sewing, CNC centre, Edge Banding centre, Sanding centre, Painting centre, UV dryer centre, Assembly and packaging centre and ends on Finished product warehouse. The purpose of this restructure is to have one-piece flow, that would remind push-pull system. Since restructuration could not be made live, it will be proposed in the AutoCad drawing. Description and screen of every section is depicted below.

3.1.1. Suggestions for Warehouse area. Unloading-loading principle

Since there is enough free space, almost half of the factory, the factory could be expanded. Other storage materials from the production department could be moved to the New warehouse. Such warehouse could have unloading-loading system. It means that Cargo would enter the warehouse through 1st gates, unload raw material or semi-prepared raw material. Then the truck would drive through the warehouse area to the finished product storage, there products would be loaded to the Cargo and would leave Factory through 2nd gates (Fig. 18). It would help to reduce logistics costs.

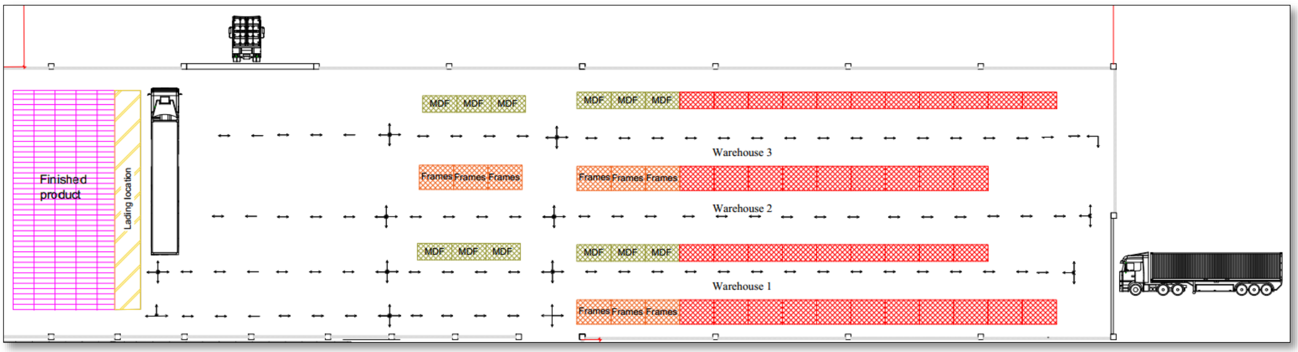


Fig. 18 Warehouse area. On the left: Area for materials unloading; On the right: Area for products loading

Red marked squares are devoted for other materials and intermediate products, orange squares are devoted for door frames, yellowish squares are devoted for MDF plates, pink marked area is for finished products and yellow area is marked as lading location. Suggested warehouse would be a little bit expanded and approximate length and width would be 102 m x 24 m.

3.1.2. Suggestions for Cutting centre area

Cutting centre is the start point where MDF is cut in request dimension for the door panel and door frame. In Appendix 3 it can be noticed that centre is placed in line with Gluing and CNC machines. In Fig. 19 it is proposed to have prepared place for MDF (marked in yellowish).

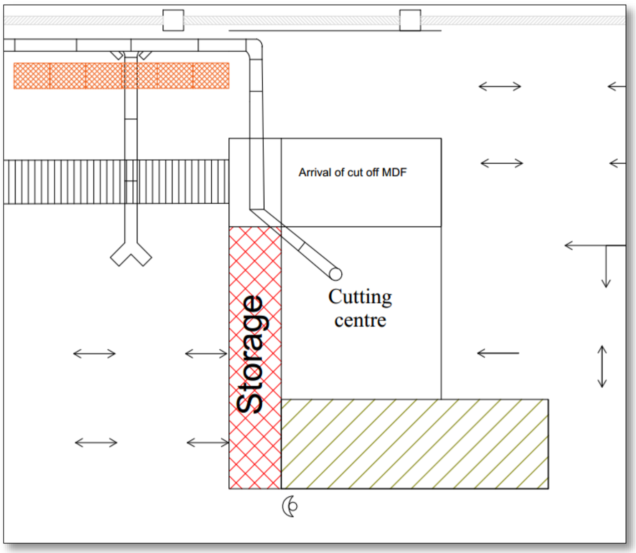


Fig. 19 Cutting centre area

Red marked area is depicted as storage place for cut materials, door frames are prepared and stored in orange marked area to be put on the transporter. After cutting operation MDF plate is put on the door frame and then it is transferred to the press centre. Approximate length and width of depicted area is 10 m x 12 m.

3.1.3. Suggestions for Press centre area and Veneer sawing/sewing centre area

Cut off MDF by the help of transporter line arrives in 1st Press centre where MDF (Fibreboard) are glued on frame. Frames are prepared for press operation, when MDF arrives, frame is put between 2 MDF plates (Fig. 20). After operation it goes to the 2nd Press centre where before 2nd operation, between press centres, veneer is put on the both sides of frame. There is special place for sewed veneer which should be prepared before gluing operation and arranged by the type of veneer. Veneer is glued on both sides; accordingly, it is proposed to have two Presses in line in order to reduce material, workers movement and unexpected machine shutdown. It is proposed to move 2nd Press from previous location in main production area.

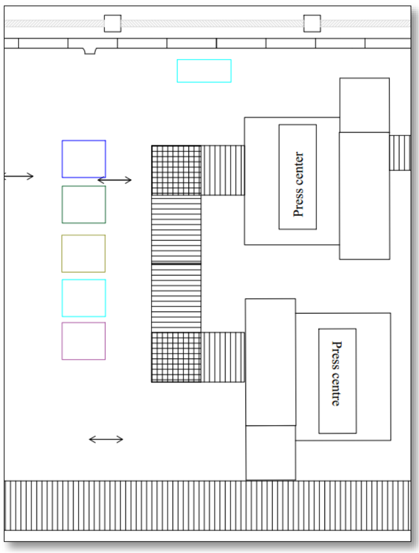


Fig. 20 Press centre and Veneer storing area.

As it was mentioned before, prepared veneer is arranged acc. to colours: each colour for each type of wood. The bright blue marked square is devoted as glue station. Approximate length and width of depicted area is 10 m x 12 m.

3.1.4. Suggestions for CNC and Edge Banding centre area

The location of CNC machines remains the same (Fig. 21), except it is proposed to rotate it 90° degrees in order to have easier product transportation from press to CNC centre. Edge Banding centre is moved closer CNC machines, near the Sanding centre in order to avoid unnecessary movement and rejects. Transportation line between CNC centre is not required because distance is too short and manual transportation by worker would be more comfortable than it was previous.

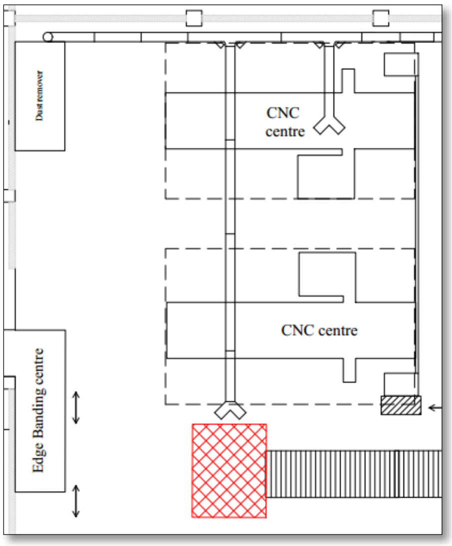


Fig. 21 CNC and Edge Banding centre area

Red marked area is designated as storage for glued intermediate product. Approximate length and width of depicted area is 13 m x 12 m.

3.1.5. Preparation for dyeing operation. Suggestions for Smoothing area

From the CNC centre, intermediate products are transported to sanding centre/smoothing room (Fig. 22).

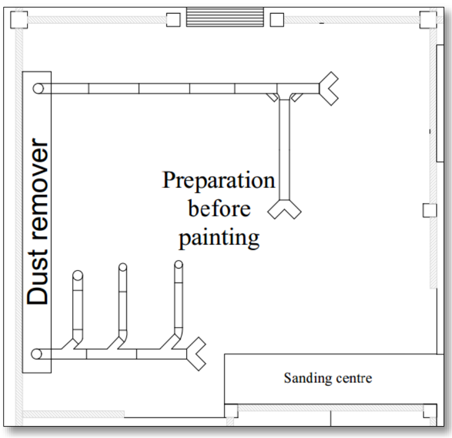


Fig. 22 Smoothing area

Hand tools for smoothing and grinders are moved near to the CNC centres in order to have production flow and avoid additional movement which can cause rejects. Smoothing area have 3 gates: 1st gates connects with Old Drying area (it could only be used for emergency cases in order to avoid uneven air supply which causes dust in the Painting and Drying room), 2nd with main production department and 3rd connects with Painting area. Also, smoothing room would have dust removal machine.

3.1.6. Suggestions for Painting and Drying area

In Fig. 23 possible layout for finishing line is depicted below.

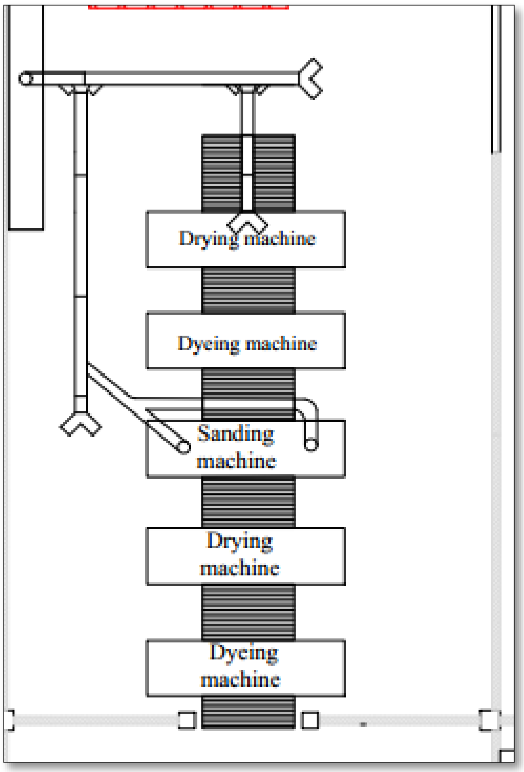


Fig. 23 Painting and Drying area

Considering that Painting and Drying areas cause 40% and 20% of rejects respectively, there is a possibility to install 2 painting machines 2 drying machines and one sanding machine between 1st Painting and Drying machine because after 1st coating it is required to brush the surface in order to have good quality product and avoid unnecessary particles on surface (machines will be described in next chapter), they would be connected by transportation line. In order to avoid dust, additional dust removal would be installed on the brushing machine.

3.1.7. Suggestions for Assembly and Packing area

In Fig. 24, Assembly/Packing/Quality check location is moved from the middle of production department near to the Drying machine in order to reduce movement, also, it would be more comfortable for workers to assemble and pack in the same place. Near the packing area, place for packed doors would be prepared, then with help of forklift it would be transported to the finished product storage.

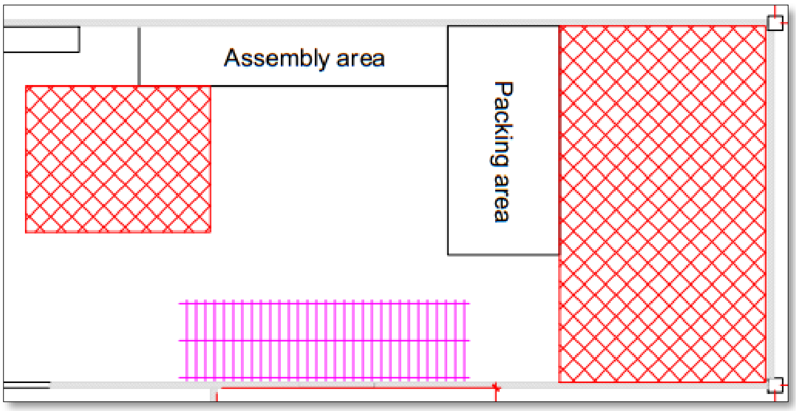


Fig. 24 Assembly and Packing area

In order to see how the material flow would look after layout restructure, Spaghetti diagram was created (Fig. 25).

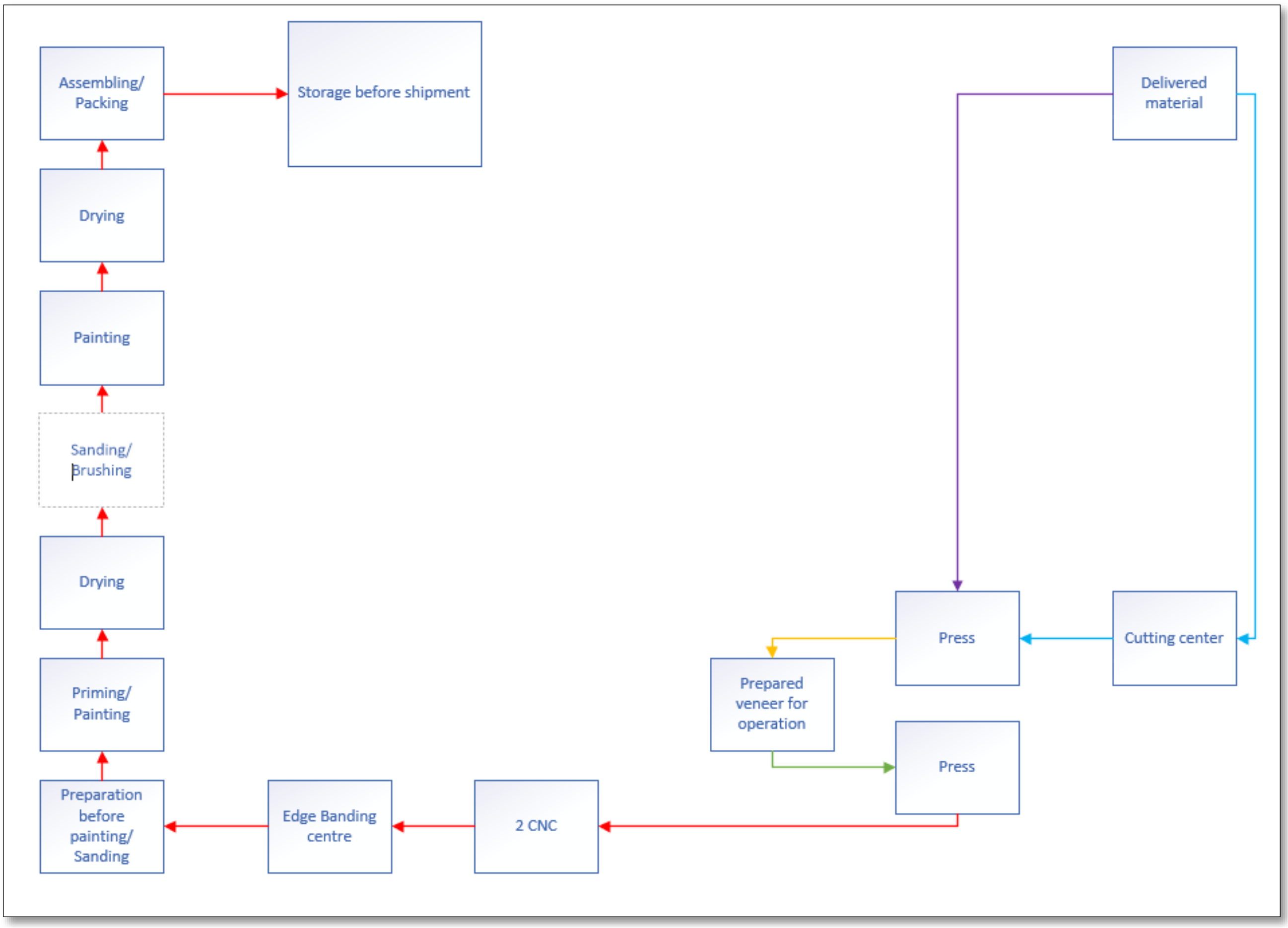


Fig. 25 Spaghetti diagram of material flow after proposed shop-floor layout. - Blue line: Fibreboard (MDF) plates; - Violet line: frames for door panels and door frames; -Yellow line: pressed frame and MDF (intermediate product); - Green line: veneer gluing process; - Red line: further operations from intermediate product to final product.

It can be seen, that there is an even flow of materials for standard door production. Also, line balancing should be done to reduce unnecessary material storage as more as possible. Company, also, should reconsider to eliminate some products which do not add any value from their production and focus more on standard door production. It is very difficult for company to have fully automated door production line because the orders are very individual, and it consumes a lot of time. In Appendix 4 Flow Process chart was used for determination approx. distance between equipment. Actions of transportation decreased from 21 (defined in Appendix 2) to 18.

Evaluation of percentage of distance between equipment:
Decrease = 3551 m – 3283 m
% decrease = 268 m / 3551 m x 100 %
Distance reduction would increase by 7,5 %.

3.2. Equipment selection

It is proposed to leave the same machines for Cutting, Pressing, Sewing, Edge Banding and CNC centres because it is suitable for operations and are not amortized enough in order to be changed. Also, fixed amount of rejects is related when hand tools were used for example to cut raw material into bushes etc.

3.2.1. Suggestions for Finishing line

The most problematic section which contain 85% of all rejects is Finishing line (from Sanding to Drying operations). In order to reduce reject number from the perspective of human factor it is proposed to install semi-automated finishing line which consists of 2 connected machines: 2 sanding machine, 2 coating/painting machines, 2 drying machines. Recommended properties are described below in Table 6 [29] [30] [31] [32].

Table 6. Properties of machines

Machine purpose	Brand name	Properties	Price range acc. to manufacturer, Eur
Sanding	HiCas	Cast iron elevator guide, Electric lifting system, Independent dust removal, shock structure, feed speed 2,5-12,5 m/min	20.000,00-100.000,00
Painting	Pilot	Rotary double-position feeding, and automatic turnover mechanism are provided. Reduce the time of working procedure and increase efficiency. Only two operators are enough to complete the whole procedure, with output per shift up to 160-240 wood doors. Spray gun movement route is under computer precise control. It ensures precise spray and dyes saving. Simplified clamps are provided and there is no need to change the current working procedure. Spray guns are isolated and its effectively guarantee operators' health. Example is depicted in Fig. 26.	22.000,00-230.000,00
Drying	LJMachine	Transportation line is with door brackets for 2-sided drying. It dries immediately, reduces time of waiting for drying and coating. It dries six sides for one time. The height and angle of the lamp in both sides can be adjusted for many sizes of products. The whole machine is adopted by electrostatic coating which is anti-corrosion and easy to clean. The part of electrical control has high sensitivity and prolonged durability. The conveyor with stainless steel net-style. The machine is designed with non-dust filtrate. Wind cycle cooling system is more useful for lowering the temperature for UV area, reduces dust at the same time.	25.000,00- 250.000,00

Fig. 26 Example of painting machine

There is a lot of different versions and brands of these machines. Asian market is cheaper than European. Decision of investment in machines depends on company`s managers. According to analysed data of few manufacturers like Burkle, Homag, Doscornio, Aagaard-Finnrose, they can adjust machines acc. to client`s requirements. Average time to paint, dry, sand and again to paint and dry door would take approx. 15-17 minutes when comparing to current time it takes 630 minutes (current times of Sanding – 5 min., Priming – 5 min., Drying – 120 min., Sanding – 15 min., Painting – 5 min. and Drying – 480 min. operations are defined in Appendix 1).

Evaluation of percentage of time decrease in finishing line operations:
Decrease = 630 min. – 17 min.
% decrease = 613 min. / 630 min. x 100 %
Time reduction of finishing line would increase by 97%.

Considering only operations of finishing line, the total door production time could be decreased from 15 h 15 min to 5 h 02 min. (915 min – 630 min + 17 min). The time reduction could be bigger if the assessment of transportation time would be done. Time reduction of total door production line would increase by 67%.

Decrease = 915 min. – 302 min. (15 h 15 min – 5 h 02 min)
% decrease = 613 min. / 915 min. x 100 %
Time reduction of finishing line would increase by 67%.

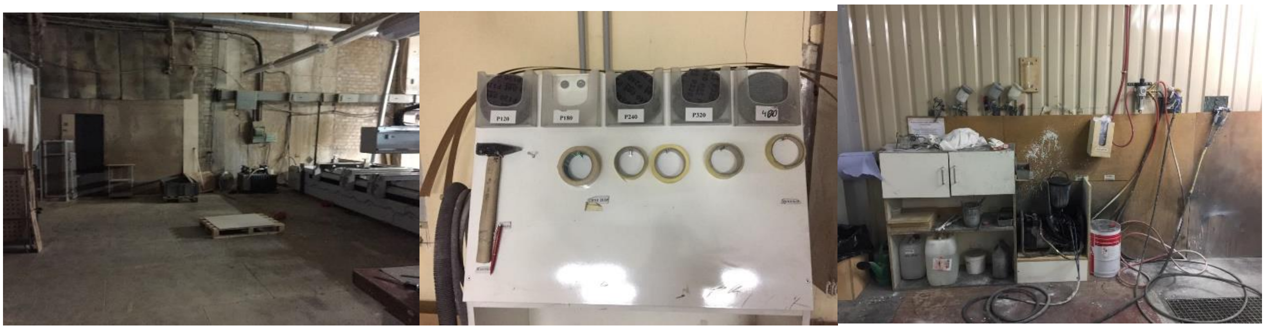
Real time reduction could be evaluated if the line balancing would be done for door production line.

3.3. 5S application, Visual management, Flow chart and dust prevention

As it was mentioned before, Company X has a big dust problem not only in the main production area but also in painting, drying sections, on the constructions of building, on the floor and machines. It creates bad quality and poor first impression when company tries to find new clients. Company have installed special dust removal machines which are the part of Cutting centre, CNC, sanding machines (Fig. 27) but it seems that it is not enough for cleaner environment. Wooden wastes after hand tools operations, especially for sanding and cutting operations, are cleaned by simple broom. Sweeping dust rises into the air and settles on the products, machines, construction elements or enters drying and painting area. For that reason, it is recommended to acquire industrial vacuum, example is depicted in Fig. 27. The price range 1.200,00 – 2.600,00 Eur [33]. To prevent dust, wooden wastes should be cleaned several times a day.

Fig. 27 On the left: Dust removal machine; On the right: Special wood dust vacuum [33]

Company X tried to implement one of Lean tools – 5S that would help labour to have better conditions and would increase productivity but somehow implementation and efforts to continue this have stopped. As it can be seen from below Fig. 28, company tries to work clean, some tools have their own place, anyway there are points and places that can be improved and it could be recommended to continue implement 5S tool by the initiative of employees, to have 5S evolution like continuously improvement of work environment and after achieved good results workers could get bonuses. It would increase employee's motivation to work qualitatively and safer.



a) b) c)

d) e) f)

Fig. 28 Shop floor environment. a) – CNC area, b) – hand tools for sanding, c) – hand spraying workstation, d) – storage-press machine-various tool area, e) – cleaning tools in painting/drying areas, f) – drying area.

During the Company`s observation it was noticed that intermediate products, raw materials were stored on pallets without any card which should indicate for which order it belongs, for which operation it is prepared. Visual management can be applied not only for standard door production but for all products in order to avoid product losses in production area and reduce manufacturing time. It is recommended to apply Visual management tool for veneer gluing by arranging it on different colour of pallets, where different types of veneer are used. Especially it would be useful for new employees, that they would easier recognize what type of veneer should be used for operation. The same could be used in Cutting centre where frames and MDF would be stored for operation.

Fig. 29 Veneer identification through Visual management.

In Fig. 29 example of Veneer identification is depicted. Currently, Walnut, Oak, Ash, Birch and Maple materials are used for door production.

Another tool which would improve production quality is Flow chart method. It could be used as help for employees to prepare materials, machines for operations. This kind of tool could be used as step by step guide. It is fully understandable that employees should have enough knowledge for processes, they should process a lot of information and for that reason, this tool could be appropriate. For example, Veneer gluing process in Appendix 5, Flow chart is made as process guide to complete the operation. It guides step by step to have necessary amount of veneer, to assure what type of veneer will be glued, it is also guiding to choose proper glue or even describe steps how to prepare glue. Especially, this kind of tool could be used in sanding operations, spraying operations etc. where hand tools are used. That would help to reduce number of rejects.

4. Economical evaluation

According to given balance sheet in Table 7, company`s values of cost of revenue are huge. It means that company spends a lot to manufacture a product. These expanses consist of made rejects, material is used irresponsibly, cost of material etc. It is proposed to invest into door production line. Currently, operations of door finishing in factory take a lot of time to prepare final product. In new line it is proposed to buy a new equipment and machines, like new 2-side sanding machines, 2 painting machines and 2 UV drying machines which will be used for door finishing line. According to currently production line, finishing operations are most unprofitable. Acc. to discovered data from manufacturers regarding price of equipment, it is roughly assumed that total project price (taken average equipment cost) with new equipment installation would be 647.000,00 Eur. Renewed production line in company could enlarge quantity of orders.

The project ratios are based on all production volume (incl. all types of doors and furniture).

Table 7. Company`s Income data of 2016, 2017 and 2018 years

	2016	2017	2018
Revenue	**2,811,619.00**	**3,240,566.00**	**3,955,177.00**
Cost of revenue	*-2,067,949.00*	*-2,303,608.00*	*-2,670,295.00*
Gross profit	**743,670.00**	**936,958.00**	**1,284,882.00**
Operating expenses	*-40,851.00*	*-51,469.00*	*-1,194,536.00*
General and administration costs	*-604,495.00*	*-811,682.00*	
Other operating income		*660.00*	
Operating Income or Losses	**98,324.00**	**74,467.00**	**90,346.00**
Interest expenses	*-66,847.00*	*-5,071.00*	*953.00*
Pre-tax Income	**31,477.00**	**69,396.00**	**91,299.00**
Income Tax Expense	*-4,322.00*	*-14,067.00*	
Net Income/Net Profit	**27,155.00**	**55,329.00**	**91,299.00**

Table 8. Company`s Balance sheet of 2016, 2017 and 2018 years.

	2016	2017	2018
Assets			
+ Cash & Near Cash Items	112,148.00	192,537.00	99,114.00
+ Accounts & Notes Receivable	579,958.00	525,703.00	518,427.00
+ Inventories	149,008.00	227,116.00	261,754.00
+ Other Current Assets	4,000.00	8,044.00	6,087.00
Total Current Assets	841,114.00	945,356.00	885,202.00
Tangible assets	258,128.00	234,970.00	252,326.00
Intangible Assets	232.00	1.00	8,587.00
Total Long-Term Assets	258,360.00	234,971.00	260,912.00
Total Assets	1,103,474.00	1,188,371.00	1,146,114.00
Liabilities & Shareholders' Equity			

Total Current Liabilities	497,337.00	562,874.00	499,014.00
Total Long-Term Liabilities	70,000.00	47,353.00	
Total Liabilities	567,337.00	610,227.00	499,014.00
+ Subsidies	39,968.00	26,646.00	4,305.00
+ Share Capital & APIC	26,341.00	26,341.00	26,341.00
+ Reserves	436,232.00	436,232.00	436,232.00
+ Retained Earnings & Other Equity	88,925.00	33,596.00	180,223.00
Total Equity	496,169.00	551,498.00	642,796.00
Total Liabilities & Equity	1,103,474.00	1,188,371.00	1,146,114.00

In order to evaluate investment payback period, ROA must be calculated. This ratio shows how Company X profitable is comperative to its assets.

Return on assets (ROA) formula:

$$ROA = \frac{Net\ income}{Total\ assets}$$

$$ROA_{2016} = \frac{27115{,}00\ Eur}{1103474{,}00\ Eur} = 2{,}45\%$$

Table 9. Profitability ratio evaluation of 2016, 2017 and 2018 years.

Profitability ratio			
	2016	2017	2018
Return on assets	2,45%	4,65%	7,96%

Return on assets was lowest in 2016 and increased every year by approx. 3%. ROA means that from 1 euro invested in assets it gave only 2,45 cents. The biggest ratio was in 2018, it was 4 times higher, from 1 euro it gave 7,96 cents.

In order to calculate what would be payback period for Company, it is needed to calculate Cash Flow and Depreciation ratios.

Table 10. Project Cash Flow forecasting

YEAR	**CF**	**∑CF**
0	-647.000,00	-
1	180.901,20	180.901,20
2	180.901,20	361.802,40
3	180.901,20	542.703,60
4	180.901,20	723.604,80
5	180.901,20	904.506,00

Table 11. Extra information for Cash Flow forecasting

Investment	647.000,00 euro
Depreciation	129.400,00 euro
CF	180.901,20 euro

$$Depriciation = Investment/5$$
$$Depriciation = \frac{647.000,00}{5} = 129.400,00\ euro$$

$$CF = Depriciation + Investment \times ROA_{2018}$$
$$CF = 129.400,00 + 647.000,00 \times 7,96\% = 180.901,20\ euro$$

It is assumed that cash flow will be the same through the 5 years period.

Table 12. Investment payback period

Investment payback period	3.57 years

$$PB = 3 + \frac{647.000,00 - 542.703,60}{180.901,20}$$

As a conclusion it can be said that if the company would have the same Cash Flow through 5 years period, the investment would pay back in 3,57 years.

Conclusions

1. Technological line of standard door production was analysed by applying Quality Control Tools (Pareto analysis, Flow Process chart, Ishikawa diagram, 5 Why method, Spaghetti diagram). After analysis it can be seen that equipment are set out without order in different locations of production area, there is no one-flow technological line. Average monthly demand of door production is 300 units. To produce 1 unit takes 15 h 55 minutes. Main and most problematic sections are Dyeing (40 % of all rejects), Smoothing (25 % of all rejects) and Drying (20 % of all rejects). Mostly rejects appear due to manual work, excessive material-workers movement, unregulated air flow and dust.
2. It was proposed to change the layout of the technology line, i.e. create a door production bar. Restructure would help to reduce storage in the production area, reduce total distance of material flow (by 7,5%), reduce total door production time (by 67%). Secondly, it was proposed to apply the Flow Chart tool to workstations in order to simplify performance of manual operations. Moreover, it was proposed to apply the Visual Management tool to sort the required materials for operations or intermediate products according to orders. For dust prevention, it was suggested not to collect dust with the broom but to purchase special vacuums designed for the wood industry. Dust collection with the broom carries dust throughout the production area and enters the painting or drying sections.
3. Based on the new technology line layout, 6 machines were offered to be purchased: 2 dyeing, 2 drying and 2 sanding in order to reduce manual work and possible rejects. Average time to do finishing operations would take approx. 15–17 minutes when comparing to current time it takes 630 minutes. Time reduction of finishing line operations would increase by 97%. The investment would cost approximately 647 thousand Eur that could be paid back by the company in 3.57 years (evaluation was made based on financial indicators of company`s total production).

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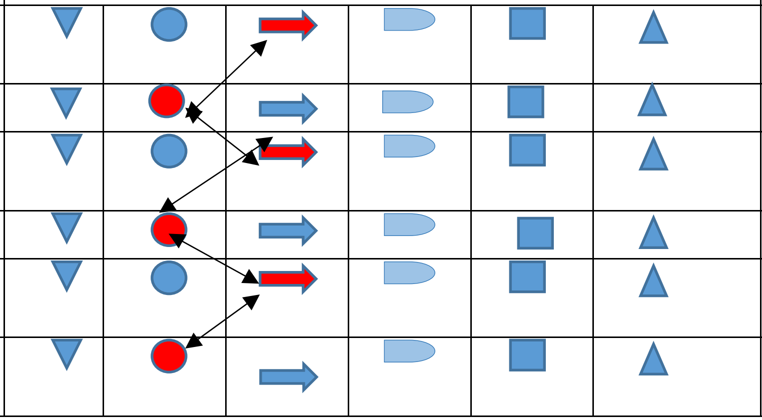
Appendices

Appendix 1. Flow process chart for current door production technological line

Location: Company X	Summary	
Activity: Door production	Event	Present
	Preparation	3
Date: -	Operation	24
	Transportation	21
Remarks: For flow process chart average time of each action was taken	Delay	0
	Inspection	1
	Storage	2
	Time (min) approx. 15 h 15 min	
	Distance (m) approx. 3551	
	Cost	

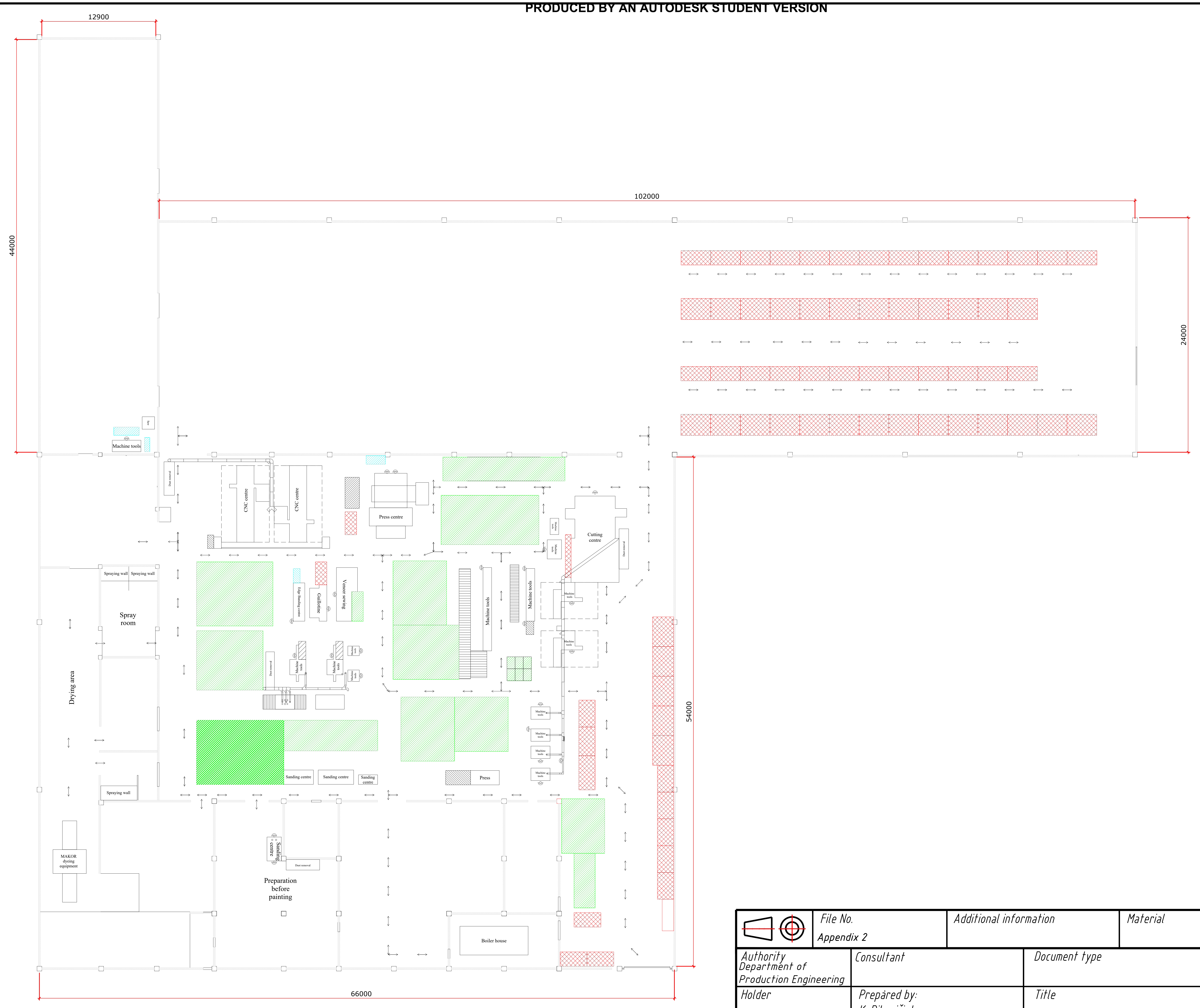
Event Description	Symbol	Time (min)	Distance (m)	Method Recommendation
Transport raw material to the saw machine tool		-	0	
Cutting wood boards to sticks		15	-	
Move sticks to the transverse cutting machine tool		2	20	
Branch cutting		10	-	
Move sticks to the tile and planing machine tools		2	10	
Tile and planing of door panel and door frame		35	-	

Carry parts to the worktable							2	10	
Frame assembling of door panel and door frame							8	-	
Load frames of door panels and door frames to the truck							15	-	
Transport frames to warehouse at main factory							15	3000	
Unload frames in warehouse							15	-	
Storage							unknown	-	
Move frames from warehouse to the press centre							5	40	
Take MDF plate from warehouse and move to Cutting centre							5	25	
Setup Cutting centre							2	-	
MDF plate cutting							3	-	
Move cut plate to press centre							2	20	
Setup Press centre							5		
MDF plate gluing on frame							8		
Move veneer from warehouse to guillotine							5	50	
Veneer sawing							5	-	
Move sawed veneer to sewing machine							2	2	
Veneer sewing							15	-	
Move sewed veneer to the press centre							2	8	
Veneer gluing on frame with MDF							15	-	

Move intermediate product to CNC centre							3	8	
CNC preparation, setup, program							5	-	
Door sawing according to exact dimensions, cutting locks, holes							5	-	
Carry door to the Edge Banding centre							2	6	
Gluing edges							9	-	
Transport door to the sanding machine tool							5	70	
Surface sanding							5	-	
Move intermediate product to the spraying area							4	45	
Staining, priming with hand tools							4	-	
Drying							120	-	
Move intermediate products to preparation before spraying area							5	45	
Brushing with hand tools							15	-	
Transport door to the spraying room							5	40	
Spraying							5	-	
Move door to the drying area							2	10	
Drying process							480	-	
Move door to the assembling area							2	30	
Put door on worktable							1	-	
Quality inspection							5	-	

Assembling	▽	○	⇒	D	□	△	20	-	
Move door in packing area	▽	○	⇒	D	□	△	1	2	
Storing assembled door	▽	○	⇒	D	□	△	unknown	-	
Packing	▽	○	⇒	D	□	△	10		
Transport door to warehouse	▽	○	⇒	D	□	△	4	110	
Load the cargo	▽	○	⇒	D	□	△	-	-	
Shipment	▽	○	⇒	D	□	△	-	-	

Appendix 2



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Appendix 2			1:250

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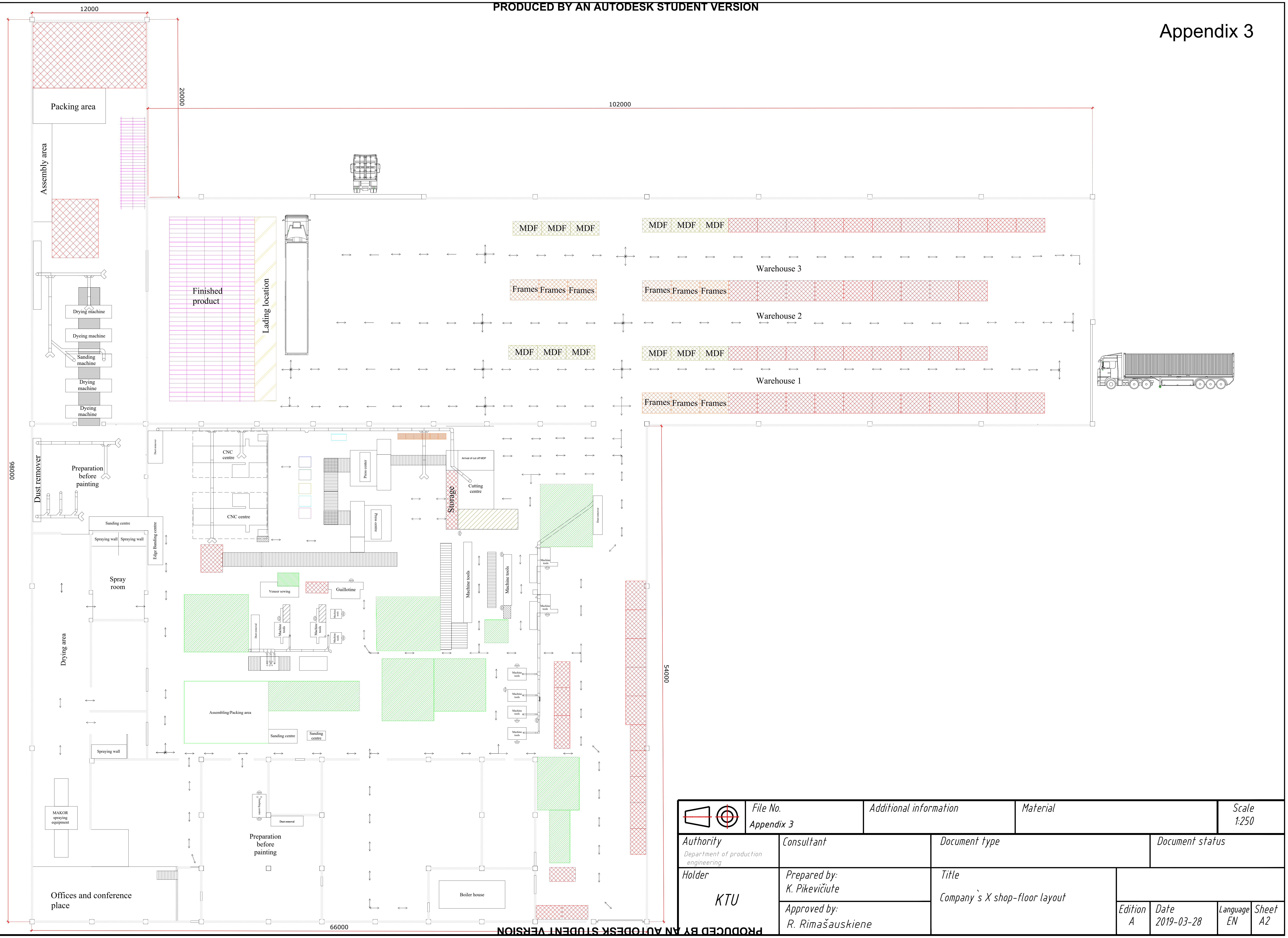
Appendix 3



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Appendix 4. Flow Process Chart for distance evaluation of proposed door production technological line between equipment

Location: Company X	Summary	
Activity: Door production	Event	Proposed
	Preparation ▽	3
Date: -	Operation ○	24
	Transportation ⇨	18
Remarks: approx. distance between equipment was taken	Delay D	0
	Inspection □	1
	Storage △	1
	Distance (m) approx. 3283 m	
	Cost	

Event Description	Symbol							Distance (m)	Method Recommendation
Transport raw material to the saw machine tool	▽	○	**⇨**	D	□	△		0	
Cutting wood boards to sticks	▽	**●**	⇨	D	□	△		-	
Move sticks to the transverse cutting machine tool	▽	○	**⇨**	D	□	△		20	
Branch cutting	▽	**●**	⇨	D	□	△		-	
Move sticks to the tile and planing machine tools	▽	○	**⇨**	D	□	△		10	
Tile and planing of door panel and door frame	▽	**●**	⇨	D	□	△		-	
Carry parts to the worktable	▽	○	**⇨**	D	□	△		10	

Frame assembling of door panel and door frame								-	
Load frames of door panels and door frames to the truck								-	
Transport frames to warehouse at main factory								3000	
Unload frames in warehouse								-	
Storage								-	
Move frames from warehouse to the press centre								46	
Take MDF plate from warehouse and move to Cutting centre								45	
Setup Cutting centre								-	
MDF plate cutting								-	
Transfer cut plate to press centre								12	
Setup Press centre									
MDF plate gluing on frame									
Transport veneer from warehouse to guillotine								62	
Veneer sawing								-	
Move sawed veneer to sewing machine								2	
Veneer sewing								-	
Move sewed veneer to the press centre								6	
Veneer gluing on frame with MDF								-	
Move intermediate product to CNC centre								10	

CNC preparation, setup, program								-	
Door sawing according to exact dimensions, cutting locks, holes								-	
Carry door to the Edge Banding centre								6	
Gluing edges								-	
Transport door to the sanding machine tool								2	
Surface sanding								-	
Move intermediate product to the finishing line								14	
Priming								-	
Drying								-	
Sanding								-	
Painting								-	
Drying								-	
Move door to the assembling area								8	
Put door on worktable								-	
Quality inspection								-	
Assembling								-	
Move door in packing area								8	
Packing									
Transport door to finished product storage								22	

Load the cargo								-	
Shipment								-	

Appendix 5. Designed Flow chart for Veneer gluing at Press workstation