TALLINNA TEHNIKAÜLIKOOL
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PRODUCT DEVELOPMENT PROCESS OF BAR STOOL AND DINING TABLE

Master`s Thesis

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Technology of Wood and plastic - KVEM12/13

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TALLINN UNIVERSITY OF TECHNOLOGY

POLÜMEERMATERJALIDE INSTITUUT

PUIDUTÖÖTLEMISE ÕPPETOOL

BAARIPUKI JA SÖÖGILAUA TOOTEARENDUSPROTSESS

Magistritöö

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Declaration

Hereby I declare that this master`s thesis, my original investigation and achievement, submitted for the master degree at Tallinn University of Technology has not been previously submitted for any degree or examination.

All the work of other authors, important aspects from literature and data from elsewhere use in this thesis are cited or (in case of unpublished works) authorship is shown in the text.

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MASTER’S THESIS ASSIGNMENT

Student data:

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Master´s thesis topic:

“Product development process of bar stool and dining table.”

“Baaripuki ja söögilaua tootearendusprotsess.”

Supervisor:

Jaan Kers, Chair of Woodworking, Professor

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Aim and tasks of the master´s thesis:

The main objective of this thesis is to work out product development process of bar stool and dining table that meets the furniture quality standards and is sustainable in the business field.

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LIST OF TERMS

Added value - something which makes a product more appealing to customers [1].

Brand - a distinctive product offering created by the use of a name, symbol, design, packaging, or some combination of these intended to differentiate it from its competitors [2].

Competitor analysis - an examination of the nature of actual and potential competitors, and their objectives and strategies [2].

Customer analysis - a survey of who the customers are, what choice criteria they use, how they rate competitive offerings and on what variables they can be segmented [2].

Dexterity - skill of using your hands, or sometimes your mind [1].

Hot-bed - a lot of activity is going on there or being started there [1].

Industry - a group of companies that market products that are close substitutes for each other [2].

Innovation - the commercialization of an invention by bringing it to market [2].

Landmark - feature which is easily noticed and can be used to judge other features [1].

Low-cost competition - a pricing strategy in which a company offers a relatively low price to stimulate demand and gain market share [3].

Niche objective - the strategy of targeting a small market segment [2].

Price - the agreed value placed on the exchange by a buyer and seller [2].

Product - a good or service offered or performed by an organization or individual, which is capable of satisfying customer needs [2].

Product line - a group of brands that are closely related in terms of the functions and benefits they provide [2].

RTA furniture – ready-to-assemble furniture supplied in pieces packed into a flat box for assembly by the buyer [4].

Sandwich panel - a panel of sandwich construction; made by bonding facing sheets, of high strength and density, to a relatively light core [4].

Smugness - being satisfied about something you have achieved or something you know [4].

Sustainable design - the philosophy of designing physical objects to comply with the principles of social, economic, and ecological sustainability [4].

Target market - a market segment that has been selected as a focus for the company`s offering or communications [2].

Workshop - training class in which the participants work individually to solve actual work related tasks to gain hands-on experience [3].

ABSTRACT

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Certificated furniture is important for end consumer in order to implicate its durability. Hence furniture design companies are testing the furniture according to relevant furniture testing standards. Small market like Estonia does not demand certificated furniture but when starting export it is vital. During this thesis two products were designed and tested according to European furniture standards against deformations. The tests implicated no major deformations but gave data about weak points in the design. After completing case studies it came clear that testing the products was vital for both the designer as well as product.

Keywords: target market, product design, wood, metal, sandwich panel, laboratory tests, simulation.

INTRODUCTION

Estonian design furniture is currently at a stage whereas majority of the products are produced to home market, which is very small and cannot offer desired profit. For that reason several companies have stopped their business over time due to loss in profit, although their products could have had big success. It is vital to show Estonian furniture designers, who do not have enough courage for export, that by testing the furniture according to European standards and by forming a strong platform for product design, it is possible to overcome Nordic countries market demands.

This leads to the strategic question:

- What are the demands for designer furniture in Nordic market?
- Could design furniture outlast the international conditions under which furniture will be tested?

It is important to investigate what international furniture market demands from design and how to add value to a small sized furniture exporter.

The main objective of this thesis is to work out product development process of bar stool and dining table that meets the furniture quality standards and is sustainable in the business field.

Product development is a long-lasting process that could take more time than was predicted. Because of that it may not be possible to present a product line but only a fraction of it. Despite that, priority is to develop at least one product that has been tested according to international standards and taking into consideration the results future decisions regarding design shall be stated.

For performing the project fully and reaching the objectives several resources are to be used, considering the limitations and the focus point previously defined.

The project is delimited in a space of time defined from September 2014 until May 2015, covering 30 weeks of work approximately.

In Chair of Woodworking it is possible to use Laboratory for Furniture and Wood Materials Testing. Small scale prototypes will be made. For 1:1 prototyping further negotiations with

TTDisain OÜ (metal construction) and Sarkop Ltd (sandwich panels) will be held for collaboration. As for product development partnership with Finnish designer Simo Heikilä will be made.

Four programs are to be used for completing final thesis:

1. AutoCAD

   All 2D detailed drawings and primitive 3D drawings shall be made using this software.

2. Google Sketchup

   For making 3D drawings and renderings.

3. SolidWorks and ANSYS Workbench

   Simulation programs for determining product deformations.

1. CHARACTERISATION OF DESIGN FURNITURE AND TARGET MARKET

All the Northern countries and the Netherlands have different historical backgrounds (Appendix 1), but when it comes to consumer behaviour and taste of design, many similarities can be found. Therefore when planning on entering Nordic market several countries should be considered.

For the following a short overview of target market demand factors (Table 1) are stated out:

Majority of the products are produced as fully-assembled form and are therefore somewhat more expensive than ready-to-assemble (RTA) furniture. RTA means that furniture comes in components and the buyer will build the furniture according to instructions. For example Swedish company IKEA produces large amounts of RTA furniture [5] but design furniture companies unanimously produce fully-assembled items.

There is a higher tendency for value-adding process in order to move towards higher price point. Manufacturers move from standardized products towards original design and ultimately to branded products. This process could be defined as never ending business philosophy that provides real value of the product [6].

Majority of the furniture companies have realized the key elements which would keep them away from low-cost competition. The characteristics of success are following: flexible but efficient production, hi-tech equipment, timeless design, innovative marketing and minimal stock-keeping.

Northern countries and The Netherlands have tendency to value more designer furniture and find it normal to buy big designer names. It has led to an obsession whereas it is not just a plaid or a carpet in their living room but brand names and designers [7]. It has even given an impact to housebreaking in Denmark where thieves are no longer searching for electronic devices but designer furniture.

Quality standards are optional in most of the Northern countries. Though it is not an obligation, variety of design furniture companies test the products to improve them.

Certification as well as country of origin, type of product, materials used, and type of finishing is required on the packaging.

Nordic people value natural materials like wood and metal which is regularly painted, overlaid or laminated. Simple visual effects and quality are valued when detailing the materials.

Based on target market segmentation table there is no unified trend tendency to thrive for. It has become so individual that there is something for every taste. All styles and design approaches are developing on a global scale thanks to media awareness [5].

Table 1. Target market segmentation.

Target market	Denmark	Finland	Norway	Sweden	The Netherlands
Furniture industry	country`s thriving exports; advanced technology and technical competence [6]	furniture design has central role in everyday life and society [8]	small player in the furniture sector; firms tend to cluster together in larger urban areas rather young companies [13]	country`s thriving exports [17]	small player in EU; higher than average share of imports in furniture consumption [6]
Structure of the industry	small and medium-sized furniture makers, which collaborate through a manufacturers association, a local business council and a technical school [6]	dominated by small enterprises [9]; furniture prices above EU average [10]	small and medium sized companies; few larger firms; highly automated and produces mainly high quality products; leading segment upholstered furniture [13]	industry is gathered in Tibro where furniture distributor LBC is located [6]	average firm size very small; office and upholstered furniture are country`s main output [6]
Quality standards	obligatory to mark country of origin, type of product, materials used, type of finishing and in some cases EN standard [6]	general safety requirements laid down in consumer safety legislation; EU standards [11]	Möbelfakta; furniture is tested for strenght and durability, stability and security, surface, textiles and fire by EU and Norwegian quality standards [14]	Möbelfacta, the voluntary reference and quality system that uses stringent testing and documentation to approve manufactured products [6] EU Standards also in use.	EU standards volunteerly used if not obligatory by laws
Design trends	sheet board with painted, veneer and laminated surfaces; simplicity in design; focal point on details and proportions; value practical shapes [6]	focusing on end-user needs; sustainable; creative ideas in new contexts [12]	combines stylishness from Danes with the functionality of Sweden and the dexterity of Finland; including smugness of everything Icelandic [15]	modern and compact; firm functional detailing and clear lines; simple visual effects; quality; design and innovation; preferred are single colours; metal is more popular than wood [6]	hot-bed of innovation, creativity and design due to strong product design education; high quality design services like BNO [18]
Advertising	TV, radio, newspapers, retailers	magazines, TV, radio, e-environment	TV, radio; English is the international language of business [16]	consumer magazines, TV, newspapers, direct mail [6]	general restrictions on when, where and how goods may be sold; requirements for location and professional expertise for sale [19]

1.1 Competitor analysis

Knowing the competitors thoroughly gives the advantage to locate their vulnerability and therefore come out with business strategy that eliminates previously made weaknesses [2].

Competitors for Table 2 were chosen from each of the five countries listed in target market. The companies were selected based on outstanding results in export, which has given their home countries a strong landmark.

As can be seen from the contents of competitor analysis table, there are some fundamental key factors that one company must have. It is essential that every business has its own website but besides that a showroom where people can actually experience the product and see the quality and proportions with their own eye.

Based on Table 2 it can be concluded that positive references gathered from competitor analysis are:

- standardised products;
- sustainable and simple design;
- witty detailing;
- durable materials.

Next competitors' flaws are stated that have been changed into pros:

- conceptual similarities between different product lines;
- exploring new options in product development phase by stepping out of comfort zone;
- various amount of product development lines.

1.2 Identity

Design can enhance the value and usefulness of products not only to end consumers, but very much in the business to business field as well. There are different aspects that design impacts upon a product that often are much more important economically.

Product fundamentals rely on concept and function but what the customer cannot see is the machinery it will require, how difficult the assembly is and how much effort is put into material optimisation. In short design will influence aesthetics, properties, production process and development of a product [15].

Table 2.Competitor analysis.

Major players	Artek [20]	Swedese [21]	Fjordfiesta [22]	HAY [23]	Mooi [24]
Country	Finland	Sweden	Norway	Denmark	The Netherlands
Website	http://www.artek.fi/	http://www.swedese.se/	http://fjordfiesta.com/	http://hay.dk/	http://www.moooi.com/
Founding	1935	1945	2001	2002	2001
Distribution channels	dealers all over the world	dealers all over the world	dealers all over EU	dealers all over the world	dealers all over the world
Showrooms	four stores in Finland	one in Sweden	one in Norway	Denmark, Norway, Germany,Belgium, The Netherlands	England, The Netherlands
Products	furniture and lighting	wooden and upholstery furniture	chairs, accessories	furniture and accessories	furniture, accessories and lighting
Material	laminated wood, metal, fabrics	laminated wood, metal, fabrics	laminated wood, matte chrome	metal, wood, marbel, paper	wood, metal, glass, plastic, textile
Quality	high quality, based on standards and systems	high quality, has approved according to ISO 9001 quality standards	high quality	high quality	high quality
Guarantee	not mentioned	not mentioned	not mentioned	not mentioned	12 months
Price	high, starting from 250€ (stool)	high, starting from 600€	high, starting from 600€	reasonable, starting from 200€	very high prices, starting from 600€
Delivery time	varies	varies	6-8 weeks	varies	varies
Target audience	design aware people who value timeless design and good quality	people who value beautiful furniture for the future, which is built on the foundations of modern Scandinavian traditions	people who value timeless design that originates from the 50`s	people who value simple and useful products that fit into a modern context	people who appreciate innovative design with unprecedented value
Niche	to sell furniture and to promote a modern culture of habitation by exhibitions and other educational means	the furniture shall be functional, of a high material quality and standard of manufacturing	to reintroduce the timeless «Scandia» range of chairs, designed by Hans Brattrud in the 1950's	return to the innovative greatness of the 1950's and 1960's in a contemporary context	exclusive, daring, playful, exquisite and based on the belief that design is a question of love
Reputation	functionality and timeless aesthetics are the essential elements in the creation of every product that bears the Artek name	Swedese is a classic Swedish furniture producer with a strong anchor in both the public and domestic domain	Fjordfiesta wishes to combine continental elegance with Scandinavian simplicity	HAY is committed to nurturing and promoting the originality of young talents as well as exploring the twisted minds of established designers. HAY always circles around architecture, sustainable design and high quality at affordable prices	one of those companies that simply refuse to play by the rule book, throwing out challenging – yet potentially iconic – pieces like they're going out of fashion
Pros	product development strategy are ethics, aesthetics and ecology wich translates into a combination of high quality, timeless classics and strong ideology in design thinking	a Swedese product of the correct quality is one, which, after delivery to the customer, meets their needs and expectations	to create furniture that will last for generations to come regarding ethic and environmental issues	creates meaningful and sincere design, uses new materials and modern technologies	designer pieces with high quality
Cons	-	-	they are only producing Hans Brattrud designer chairs	-	eclectic style, high prices
Similarities ...	constant search for new materials and added value	has a strickt understanding of how valuable product has to be	they have proven theirselves to the target market by producing design that has high quality and have sticked to that niche	celebrates the uncomplicated design and strives to stay solid, straight-forward, joyful and functional	innovative solutions to make one`s landmark, daring design
... and differences with on going project	no differences	could be more innovative when thinking about the era we are currently living in	they only produce one furniture family and don`t take into concideration to develop new products based on the same values	could be more daring in the product development phase	doesn`t have a distinctive design pattern to be recognizable by singel unit

Aesthetics of a product is the most vital phase for a successful business and need therefore thorough consumer analysis (Table 4). This method was applied because people in market seek different benefits from a product, e.g. designer furniture as opposed to Ikea`s RTA furniture. Providing customers with benefits they value by giving the products sustainable design, high quality standards and small but exceptional details that make the customer feel special indirectly [2].

After examining consumer preferences it all came down to well-prepared marketing and customer relationship. When that was achieved people were willing to pay more for added value. Aside from just marketing the average customer wanted to experience pleasure (physical as well as mental). Frequently the customer bought the aesthetics of a product, not just a function, although the latter was important as well. With that being said a platform for product identity was defined in Table 3 showing that products need to have high quality and certification. This table simplified the methods used in next chapters and helped to keep the same path during design process.

Table 3. Starting point of product development.

Industry size	Relatively small. All production brought in from Estonian furniture companies. Producers vary based on speciality.
Distribution channels	Dealers all over the world (online shop, local design shops).
Showrooms	One in every target market capital, including Estonia.
Target audience	People who value products that simplify their lives by having timeless design with high criteria for quality.
Quality standards	High quality. All products are tested according to European quality standards.
Products	Furniture and accessories.
Materials	Wood, metal, composites.
Design trends	Sustainable design; clear lines; innovative; focus on details. Single colors and durable materials are preferred.
Niche	Quality products that brighten everyday life.
Price	High, starting from 220€.
Advertising	Social media, design magazines, distribution channels, furniture fairs, showroom events.

Table 4. Consumer segmentation.

CONSUMER SEGMENTATION	BEHAVIOURAL	**Benefits sought**	*Pleasure seekers:*	Using products is all about pleasure (comfort, enjoyment and well-being).
			Image seekers:	Having a good looking interior is all about self-image. The furniture provides feelings of power, prestige, status and good taste. The usage of products is important too, but secondary.
			Functionality seekers:	Furniture is only a way of helping people to carry out activities that require staying on put for a longer period of time. They enjoy the convenience of afforded by the product rather than the act of using it.
		Purchase occasion	*Self-buy:*	Furnishing homes. Bigger demand near Christmas and Midsummer Day but still bought all year round.
			Construction project:	Final period of furnishing facilities (homes, offices, bars, hotels, restaurants). Bigger demand near Christmas and Midsummer Day but still bought all year round. The bigger the quantities, the smaller sales price.
		Purchase behaviour	*Innovators:*	People are more willing to buy these products after intense marketing period (magazines, social media, exhibitions).
			Brand loyalty:	Success is depending upon good service, delivering on time, durability and sustainable design. This segment will buy again if satisfied with formerly purchased products.
		Usage	*Heavy:*	Where about 80 per cent of a product`s sales come from 20 per cent of its customers. Meaning that there are many loyal customers e.g. interior architects that use these products in their projects.
		Perceptions and beliefs	*Value based segmentation:*	People who believe that quality and sustainability are important in everyday life. They believe their choice of a furniture provides evidence of their understanding of life quality.
	PSYCHOGRAPHIC	**Lifestyle**	*Aspirational:*	Added value by using products with sustainable design and therefor creating better living environment with functional products.
		Personality	*Extraverts:*	They are proud about the purchased products and seek attention in it every possible way. At the same time feel satisfaction from the means of looks and usage.
	PROFILE	**Age**	*23-55*	Target audience are people who are becoming independent or already are and value innovative design approach.
		Gender	*Female:*	Most products are made for both genders but some designed especially for women.
			Male:	Most products are made for both genders but some designed especially for men.
		Life cycle	*Starting out, singles/couples, older couples, project managers*	Home furnishers and project managers are being a prime target market.
		Social class	*Upper and middle class:*	People who are willing to pay more for added value and investment for the future.
		Terminal education age	*17 years:*	Nominal high school + bachelor`s degree + master`s course
		Income	*Above average level:*	Income level starting from 1500€ neto.
		Geographic	*Finland, Sweden, Norway, Denmark, The Netherlands:*	As stated in the market research all five countries have segments that are interested in niche products but when it comes to marketing different approaches must be carried out.
		Geodemographic	Upwardly people setting up their own homes; Interior architects decorating public buildings e.g. restaurants, shops, hotels.	

In order to have bigger market share than just domestic usage, all products were tested according to standards in the category of general use (see Table 5) which involve facilities like cafés, restaurants, canteens and bars. It was essential to widen the target market to meet the requirements both for private and public buildings. This approach was taken into consideration in product development phase, where all items were designed accordingly.

Table 5. Furniture levels and application [25].

Level	Type of use	Range of application
L1	general use	Areas in which seating is usually intended for mixed use (short-time and for a period of several hours, light to heavy load). Examples of end-use: all kind of applications in office buildings, showrooms, public halls, function rooms, cafés, restaurants, canteens, banks, bars.
L2	extreme use	Areas in which seating is occasionally or repeatedly subject to extremely high loads due to their specific types of use or due to improper use. Examples of end-use: night-clubs, police stations, transport terminals, sport changing rooms, prisons, barracks (non-controlled areas).

1.3 Terms of reference for the design

The design approach was defined by Nothern countries that find intimidating to buy design furniture. The basis was to design products with the same aesthetics to give marketing advantage. Creatig a product line was important characteristic because avarage cutomers will be interior architects and design aware people whom decision making will be therefore encouraged.

Although products will be suitable both for residetal and commercial space, the application level was chosen to be general, inorder to withstand public use regulations for furniture. Based on competitor analysis all products will be tested and certificated. This means creating products with high quality.

The target audience was defined to be upper middle class. This gives the oppurtunity to use expensive materials that meet the quality standards. The design will be built on the foundation of geometry and lightness with witty detailing. Materials selected were wood and metal that were defined using target market analysis.

2. PRODUCT DEVELOPMENT PROCESS

Based on previous research results and Tables 4-5 contents the process of product development was started. The scheme from idea to final product consists roughly about twenty phases. All phases are shown in Figure 1 which is followed by a detailed description below.

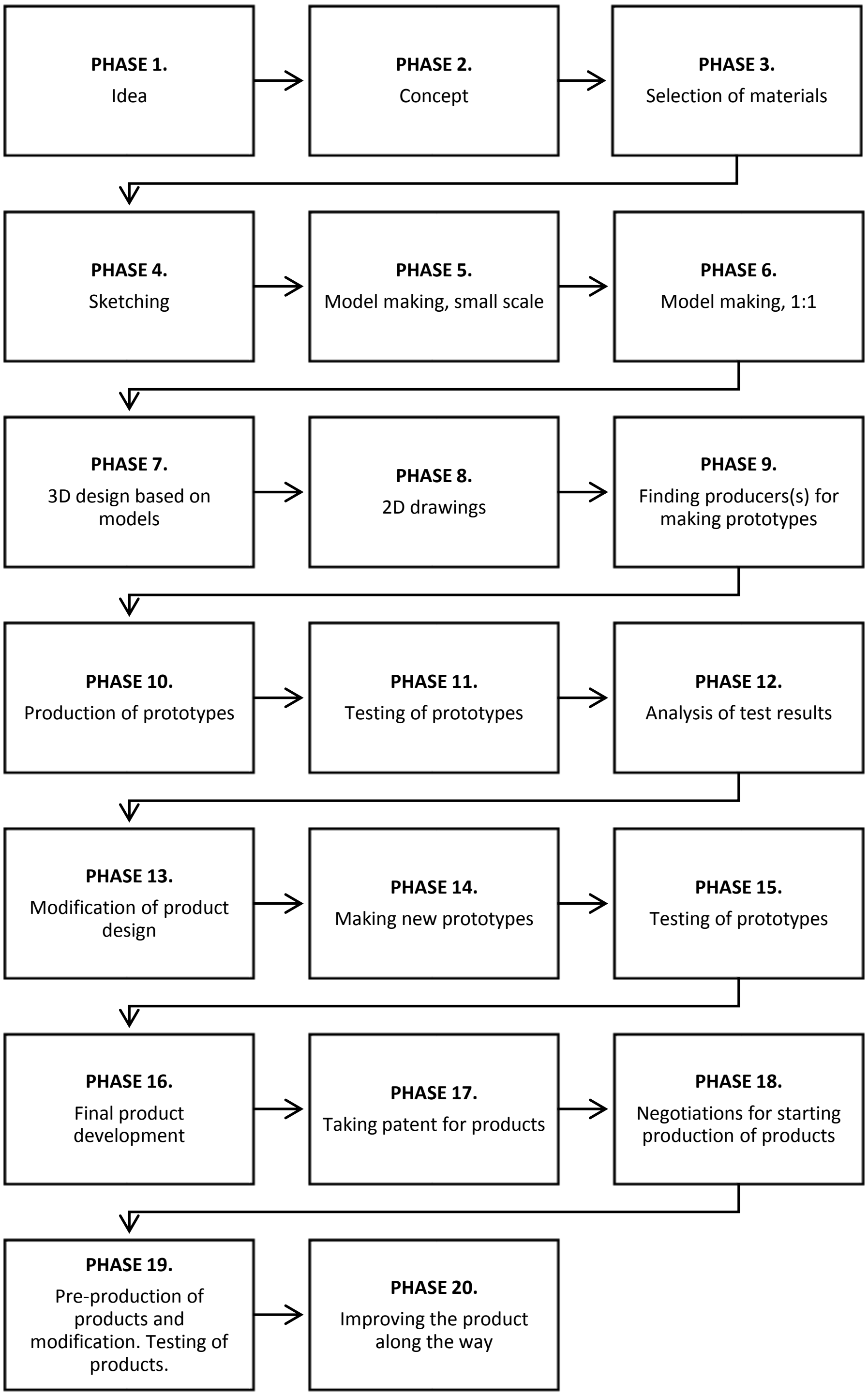


Figure 1. Product development scheme.

Phase 1. Idea

Definition: A concept developed by the mind.

The initial idea for creating a product line came from a metal workshop held in Estonian Academy of Arts in winter 2014. By completing the subject it came clear that having several furniture items that form a unity and have a strong concept, will simplify marketing strategies.

Phase 2. Concept

Definition: An invention of something to help develop a unified solution for the idea.

The concept was based on an idea that the most vital elements for decorating an interior should be purchased from one supplier by offering a product line. It simplifies customers' needs by offering them items that have the same values in terms of aesthetics and quality.

Phase 3. Selection of materials

Definition: Selection of materials is the essence of product design.

Materials used in metal workshop were rod and glued laminated timber, therefore it was easy to select materials for all product line items. Although some additional materials were added, e.g. metal tube and sandwich panel.

Phase 4. Sketching

Definition: Hastily executed drawing of a final product.

With the help of Simo Heikkilä came the development of furniture items that had the same aesthetics as the initial bar stool. The process provided a lot of opportunities of how to interpret the original design into a product line. As an opposite to predictions it came out to be the most difficult part of the final thesis and forced to give up the idea of making the product line ready during final thesis.

Sketching started with drawing the schematic functions of a product (Figure 2). By determining the basic needs of a furniture item it was possible to start developing the overall looks.

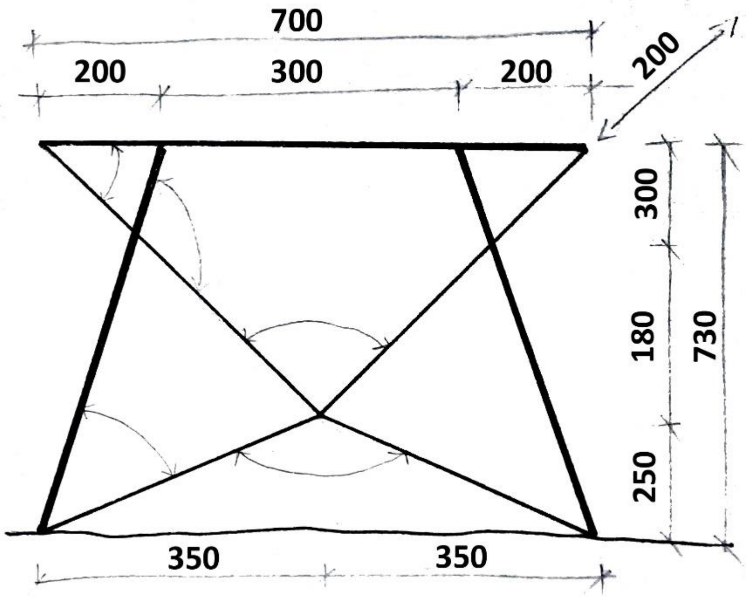


Figure 2. Sketch. First stages of table development.

By examining several design options a decision had to be made regarding product line aesthetics. Meaning all furniture items had to have distinctive appearance that combined them into one product line. After a long creative period a selection of designs where combined into a unified design (Figure 3). X-shaped geometry became the distinctive look of all products.

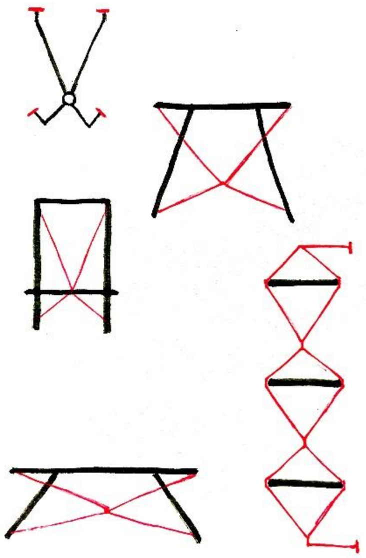


Figure 3. Sketch. Final sketches of product line.

Phase 5. Model making, small scale

Definition: Making of miniature models to determine the potential of a sketch.

Based on selected sketches small scale models were made. This phase was vital for the whole process by providing information that was needed in order to select the designs that went into further development.

Sketches that had the potential of becoming a real life furniture were made into small scale models (Figure 4). Bamboo sticks and hot glue was used as a construction material and amongst them were chosen one design for each purpose (Figures 5-7).

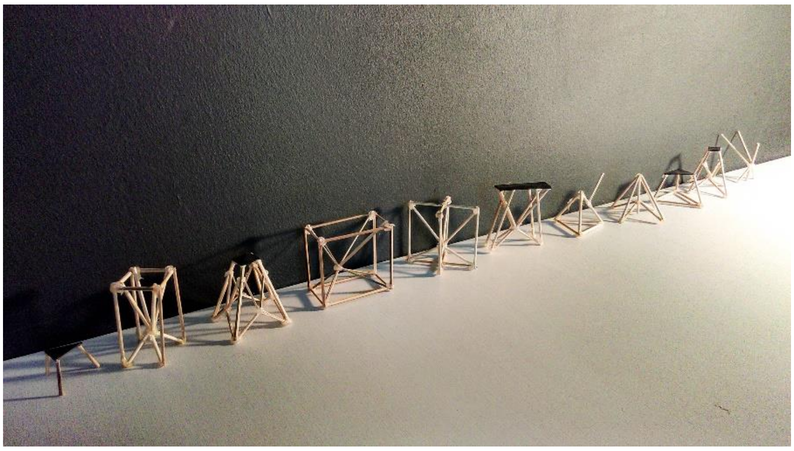


Figure 4. Miniature models. Selection of sketches made into small scale models.

Figure 5. Miniature model. Bar stool.

Bar stool design was picked out in the workshop and thereby all following designs had to ensure the same aesthetics. Creating a product line by using the same geometrics as in bar stool, came out to be harder than could have been imagined. Primarily due to the fact that there were several ways for interpretations. Thereby in the case of dining table leg there were two options amongst whom the decision had to be made (Figures 5-6). In the final decision Figure 7 was favoured based on aesthetics.

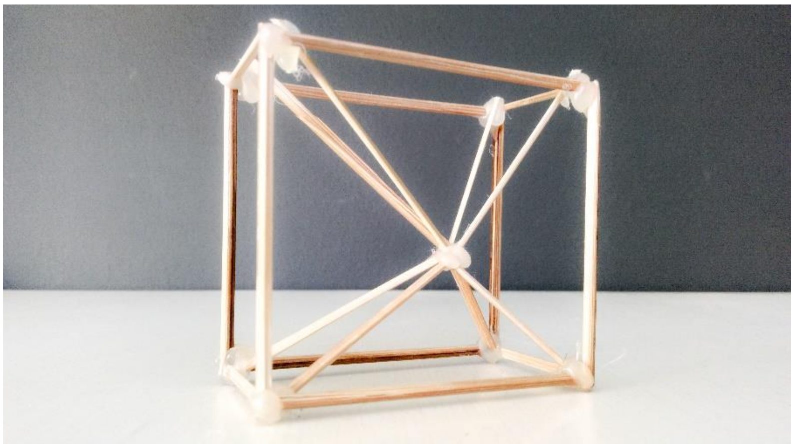


Figure 6. Miniature model. Dining table leg. Version 1.

Figure 7. Miniature model. Dining table leg. Version 2.

Phase 6. Model making, 1:1

Definition: Making of true scale models, from alternative materials, for proportioning the final design.

Sketches were given dimensions and proportioned in 1:1 drawing, before making true scale models (See Figure 8). It pointed out all weak points in the design and helped to improve it before prototyping. Round timber sticks, rope and hot glue was used as a construction material. All materials were chosen with the same dimensions as real products would have.

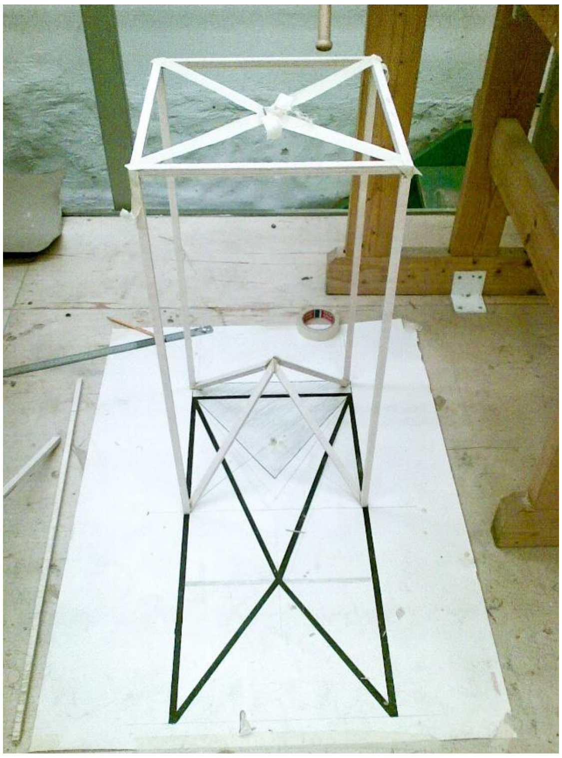


Figure 8. True scale drawing and model. Bar stool.

Phase 7. 3D design based on models

Definition: Making of 3D design and applying final corrections, including selection of surface finishes.

After finishing improvements with the models all designs were made into 3D. It was essential to start the technical phase with 3D, due to difficult shape and the alternative use of materials in model making. By the help of 3D it was possible to see proportional errors and give the designs unified dimensions. During this phase surface finish was also selected.

Phase 8. 2D drawings

Definition: Detail drawings of final product.

3D models gave a platform for developing detailed drawings. All dimensions for making 2D drawings were based on standards. In general the products were suitable for people between 1510mm and 1920mm in body height. People with body height outside this range may need furniture of different dimensions or a footrest [26].

Phase 9. Finding producer(s) for making prototypes

Definition: Searching local companies with the right equipment in order to produce furniture components for making prototypes.

Before final manufacturing process it was necessary to find furniture companies that were willing to make prototypes for testing. Though AS Jalax was selected based on productivity ratio to be the producer of metal components the process for making prototypes was not labour-intensive enough and the offer was declined. By taking price offerings from different firms the bar stool frame was made in TTDesign, who is the co-partner of Kalla Mööbel. Due to complex design of the dining table, all components regarding the sandwich panel construction were consulted with Sarkop AS, but they were unable to make the necessary prototype.

Phase 10. Production of prototypes

Definition: The production process from crude material into furniture item.

Based on detailed drawings made during Phase 8 the manufacturer produced bar stool prototype that went in Phase 11 for further testing, in order to determine constructional flaws that may occur during the product lifetime.

From Figure 9 the difference between 1:1 model and prototype can be seen. This picture proved the necessity of model making, because in general it gave relatively realistic understanding of final product, thereby eliminating flaws in early stages of development.

Figure 9. Bar stool. Prototype and 1:1 scale model.

All prototypes produced during this thesis were self-financed. Both, the bar stool and dining table, had rather complex structure, making the production costs relatively high. This fact concerned only the prototyping phase because single items were made, not mass production. For example the end cost of bar stool wooden seat cost six time more, because glued laminated timber comes only in big dimensions (See table 6).

Table 6. Prototyping costs for making one bar stool.

BAR STOOL	Variable raw material cost	Measuring unit	Quantity	Unit cost
Glued laminated timber	57,00 €	piece	1	57,00 €
Wood finishing	9,70 €	piece	1	9,70 €
Metal frame	65,00 €	piece	1	65,00 €
Felt pads	0,05 €	piece	4	0,20 €
Wood screws	0,04 €	piece	4	0,16 €
Labour costs	0,00 €	piece	1	0,00 €
			TOTAL :	**132,06 €**

Compared to bar stool, dining table had more complex structure. Though the basic idea remained the same, by having metal legs and wooden top layer, the constructional details had to be built very accurately. Due to the fact that wood and metal components strongly influenced each other's properties, it had to be produced by one manufacturer. Although it would have been cheaper to produce components based on company's specialty (See table

7). Unfortunately the actual dining table prototype could not be made, but the production costs can be examined below.

Table 7. Prototyping costs for making one dining table.

DINING TABLE	Variable raw material cost	Measuring unit	Quantity	Unit cost
MDF plate	24,30 €	piece	2	48,60 €
Oak veneer	44,62 €	1/m2	2,6	116,01 €
Making of shuttering	29,75 €	piece	2	59,50 €
Gluing	9,60 €	piece	1	9,60 €
Suporting frame	24,30 €	piece	1	24,30 €
Oak boarder	0,12 €	1/jm	6,2	0,74 €
Metal legs	83,00 €	piece	2	166,00 €
Felt pads	0,05 €	piece	8	0,40 €
Screws	0,04 €	piece	8	0,32 €
Company profit	200,00 €	piece	1	200,00 €
Labour costs	7,00 €	€/1h	10	70,00 €
			TOTAL :	**695,48 €**

Phase 11. Testing of prototypes

Definition: Testing of prototypes according to EU standards in TUT furniture testing laboratory.

For testing the prototypes Tallinn University of Technology furniture testing laboratory was used, which is currently the only facility in Estonia that provides this kind of service. Furniture was tested according to European standards, which are pointed out in Chapter 5. Tests included visual inspection. Descriptive pictures are given in next chapter.

Phase 12. Analysis of test results

Definition: Taking into consideration product development decisions based on test results.

Analysis of test results was vital in product development. It pointed out the majority of mistakes that might occur during heavy usage. In this phase everything concerning constructional strength and durability was stated out and modified in Phase 13. Detail analysis can be investigated in Chapter 5.

Phase 13. Modification of product design

Definition: Eliminating flaws occurred in furniture testing process and improving the design.

During the first stages of product development, e.g. model making, the majority of flaws that might affect the product durability, were eliminated. Despite that, there were still some aspects that needed modifying. These include changing material properties and few dimensions. For additional information see Chapter 5.

Phase 14. Making new prototypes

Definition: Making of new prototypes according to improved drawings.

All previously tested and then re-designed furniture items were sent to manufacturers for making new and improved prototypes that should meet the expectations that were lacking before.

Phase 15. Testing of prototypes

Definition: Testing prototypes for the second time according to EU standards in furniture testing laboratory.

New and improved bar stool was tested second time according to EU standards and additional improvements were made in the following phase. By this phase majority of mistakes were eliminated.

Regarding this thesis not all phases of product development can be covered. Most of the design process ended with Phase 15. This project gave an idea of how much time product development takes and what stages have to be covered in order to enter the market. The following phases will describe processes that must be done in order to finish the development of product line.

Phase 16. Final product development

Definition: Making improvements in product design based on previous test results.

Based on previous test results all minor mistakes shall be corrected. No additional prototypes will be made that concern small changes that do not affect overall construction.

Phase 17. Taking patent for products

Definition: Patenting the product line.

Before manufacturing authenticity of the products will be examined by using e-environment and patent office documentations. If defined as one of a kind all products will be given international patent. This will come in handy in terms of brand marketing and gaining trust as a newly established furniture company.

Phase 18. Negotiations for starting production of products

Definition: Searching local companies for producing furniture components, based on their speciality.

In order to be successful in international market a partnership with companies that have good productivity will be needed. This is one of the reasons Jalax AS was picked, because they have big production line and experience in export. Jalax speciality will be to make all metal components and all furniture parts concerning wood are brought in from Sarkop AS. Metal and wooden components shall be joined and sent abroad.

Phase 19. Pre-production of products and modification. Testing of products.

Definition: Making the products production ready and testing for certification.

The production process is optimized for highest quality and minimum time for manufacturing operations. Testing is done for the last time for giving the product a certification.

Phase 20. Improving the product along the way

Definition: Improving the products along the way, e.g. based on customer needs additional finishing options shall are added.

During the years several flaws may occur that cannot be avoided during product design phase. Usually it is something that does not influence the construction but the aesthetics. For example the felt furniture glide may not be the perfect material for that purpose or powder coated paint is for some reason peeling off. All these minor mistakes will be improved along the way.

2.1 Bar stool design

The initial idea for a bar stool construction came from seat, shaped like pyramid (see Figure 10), but by the end of product development, the form was translated into supportive frame. Using the Ø6mm rods as a frame support, gave lightness to the design with minimum amount of material used.

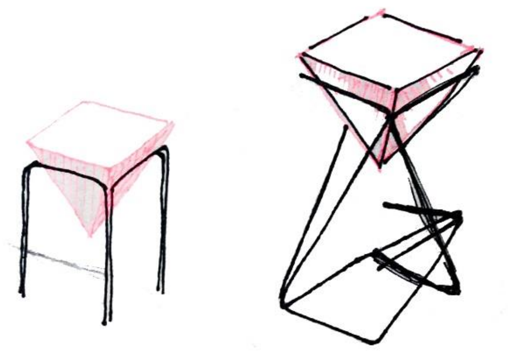


Figure 10. Bar stool. Pyramid seat.

Aside from just designing a stool, it needed to be with a twist. For that purpose the seat plate was made 30mm shorter from back, leaving the metal frame naked (Figure 11). This simple move gave a railing that could be used for manoeuvring the stool or as an umbrella stand.

The design process of a bar stool was very fast. By the end of third day the sketches turned into 1:1 models, that were made out of wooden sticks, styrofoam and hot glue. Within five days the product was ready. The help of Finnish designer Simo Heikkilä gave the bar stool a well through proportions and technical details.

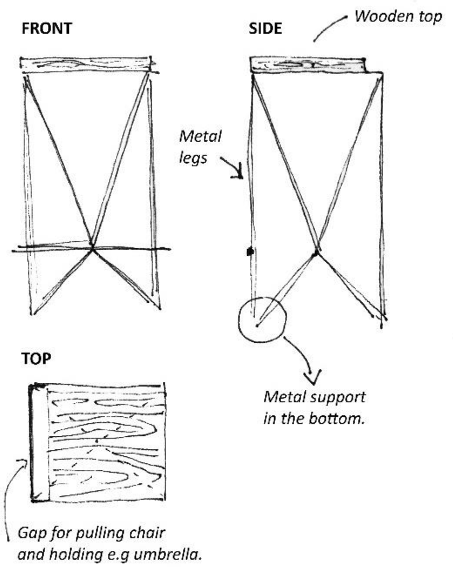


Figure 11. Bar stool. Detailed sketch.

First prototype of bar stool had zero budget. All materials were given from the school and formed by oneself. Only welding was done by an expert. The first prototype fulfilled its function but had some off-balance complications and needed to be lighter. All flaws stated above were corrected during this thesis and new drawings made for producing second prototype.

Common knowledge is that chair weighing under five kilos is easy to use. This means that regular user can move and lift the chair without any effort. By relying on that statement the first bar stool came too heavy for the end user and needed to be re-proportioned. This lead changing Ø10mm rods into Ø12mm tubes and making wooden seat thinner, by giving bar stool lightness (Table 8). Changing the materials helped to avoid permanent deformations, because metal rod cannot recover its shape afterwards. Whereas metal tube is self-regulative meaning in case of deflection half of the material works on pressure and the other on thrust.

Table 8. Bar stool weight.

BAR STOOL WEIGHT			
	Wooden seat weight	**Metal frame**	**Total weight**
Bar stool_1	2,6 kg	4 kg	**6,6 kg**
Bar stool_2	1,6 kg	3,2 kg	**4,8 kg**

The dimensional requirements for bar stool were not defined in European Standards. Although there were few ISO standards regarding bar stool design (see Chapter 5). Therefore for correct dimensions information was gathered from different sources. Seat height for visitor chair was stated to be between 400mm and 500mm [27]. Taking that into consideration a footrest was added in 250mm, making the seat height from that point onwards 500mm.

After finishing the first design, came the idea of creating a product line. This meant improving bar stool and making a new prototype. In order to start manufacturing new drawings were made, including 3D design (Appendix 2). For precise material and price calculation parts list (Appendix 3), detailed drawings of metal leg and wooden seat (Appendix 4) were given. To simplify workers job assembly drawing was made that showed all parts that were included in bar stool construction (Appendix 5) and in what order the details will be assembled.

2.2 Dining table design

The design process started from absorbing bar stool geometrics and dimensions. Developing dining table had remarkable influence upon all future products that will be designed for creating this specific product line. Making it the most intense phases of product development, because the logic of coping bar stool details, to all items, had to be defined.

X-shape in the middle, came out to be the thriving detail for all products. At the end there were three options of how to create legs for dining table:

1. stretching the bar stool construction longer, for creating a rectangle (Figure 12);

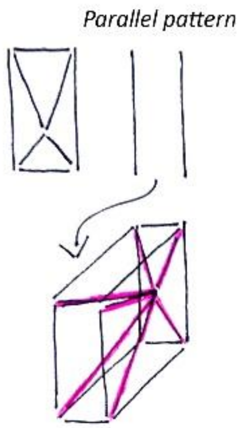


Figure 12. Table leg. Parallel pattern.

2. placing x-shape as a cross pattern (Figure 13);

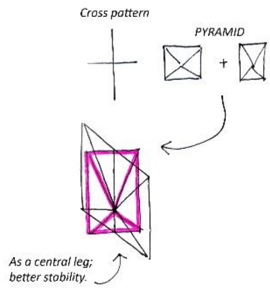


Figure 13. Table leg. Cross pattern.

3. stretching bar stool legs to form diagonals that have better stability (Figure 14);

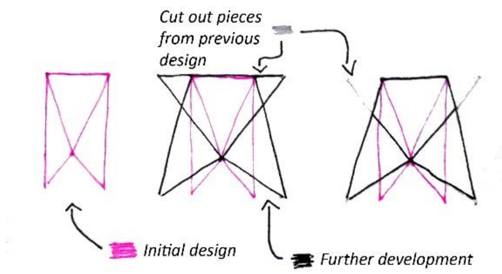


Figure 14. Table leg. Stretched pattern.

Based on initial concept whereas the product line had to be strong jet innovative, option number three was chosen. Prior to model making dimensions were gathered from furniture standards and proportioned 1:1 scale on blackboard (Figure 15).

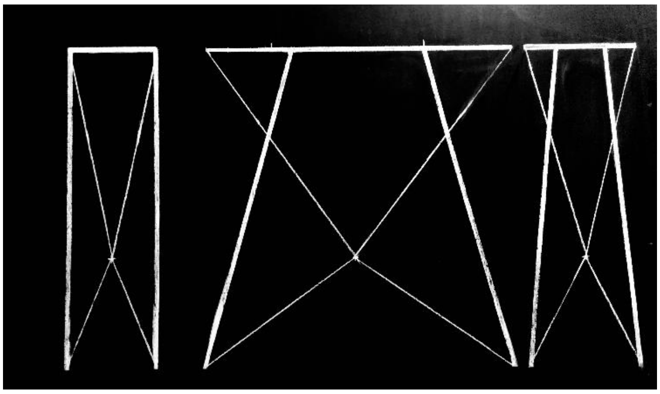


Figure 15. Table leg. Proportioning on blackboard.

It allowed to see the very basic dimensional errors and correct them before modelling. All table outside dimensions were calculated by the means that one person needs space for eating 600x350mm and for moving legs 250mm in depth.

By using Ø12mm wooden sticks, Ø6mm rope and hot glue 1:1prototype was created. Although materials used could not be compared with metal construction the dimensions and engineering weak points were easily examinable. In this phase a major flaw was eliminated which concerned the diagonals created with Ø12mm sticks (Figure 16). While on paper the construction seemed stabile, on model it was obvious that the angle of the structure was too big and would break immediately after applying pressure.

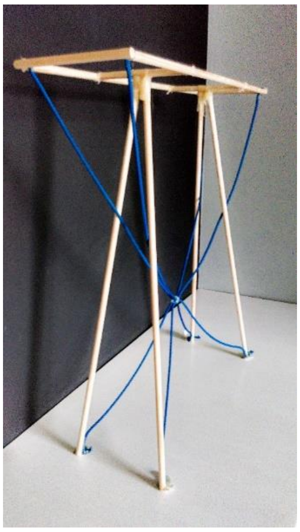


Figure 16. Table leg. Model from sticks.

After finishing 3D, it was time to define the product more accurately by making detailed drawings. By taking into consideration the fact that bar stool was created from gluelam, the initial idea was to use same material for dining table. After coming up with the solution for table top, it came clear that solid wood cannot be used. The main problem was weight, which could have made the table top heavy and could cause deformations to metal legs (Table 9). Sandwich panel was an alternative in order not to change the design and avoid horizontal fluctuation.

Table 9. Dining table weight.

DINING TABLE WEIGHT		
	Solid wood	**Sandwich panel**
Table top	~140 kg	74 kg
Metal frame	7,4 kg	7,4 kg
Total weight	**~147,4 kg**	**81,4 kg**

To give the manufacturer an understanding of dining table looks 3D models were created (Appendix 6) that visualised materials and gave overall scope of project. For calculating the end price, parts list was given with quantities (Appendix 7). Technical drawings, including constructional details were given for table top (Appendix 8) and metal leg (Appendix 9). To simplify workers job assembly drawing was made that showed all parts that were included in dining table construction (Appendix 10) and the order of assembly.

Although all dimensions and material properties were strictly shown on drawings, manufacturer still changed details in the production phase. This was inevitable in product development phase. That can be seen when comparing actual prototype to 2D drawings.

3. SELECTION OF MATERIALS AND TECHNOLOGIES

Based on information gathered from Chapter 1 and 2, the materials used for creating product line are metal and wood. Metal is easily formable and strong material that gives the ability to create unique structures with a variety of finishes. Wood on the other hand is warm and has good strength.

3.1 Metal frame manufacturing technologies

The basis of furniture construction is made from commonly used carbon steel AISI 1020 (Table 10), which responds well to cold work and heat treating.

Table 10. Properties of AISI 1020.

PROPERTIES	METRIC
Tensile strength	420 MPa
Yield strength	350 MPa
Modulus of elasticity	205 GPa
Machinability	65 out of 100

Pipes and rods with variety of diameters are used based on formability and strength. It gives the products quality together with great control over properties [28]. Steels are easily formable, strong and come with good price, making it ideal material for complicated construction. They are also recyclable with minimum amount of energy [29].

Bar stool

Bar stool vertical legs and upper frame is made out of Ø12mm tube, which will give the product its lightness. Stability is given with central diagonals, made from Ø6mm rod.

Dining table

Dining table legs are made entirely out of rod material. Ø12mm rod is used for the construction, only central support is made from Ø6mm rod.

3.1.1 Forming technology

Angle grinder

For cutting metal rods and tubes hand held power tool is used (Figure 17). Productivity rate is highest by using angle grinder and multiple disks for forming can be used.

Figure 17. Makita 9005B angle grinder [30].

Bending

Almost all pieces used in the metal construction need bending (Figure 18). Therefore roller bending has been chosen whereas the section of the pieces to be bent does not undergo any deformation. Rollers spread the mechanical effort over a greater portion of the matter [29]. The size of the rotating die determines the radius of the bend. The distance travelled determines the angle of bend.

Quality: Applying a bend to a constructional element increases its strength.

Environmental impacts: Efficient use of energy with no scrap produced [31].

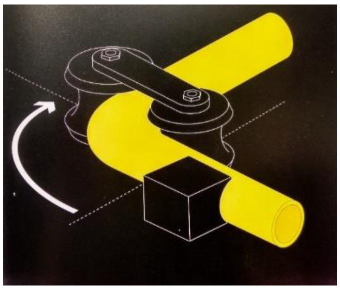


Figure 18. Roller bending [29].

Spinning

Spinning is used to form curved thin-walled shapes of metal sheet (Figure 19). The sheet is formed over a rotating mandrel or forming block, against which it is pressed by a rigid tool or roller as it spins. This process is not hazardous for the environment [28].

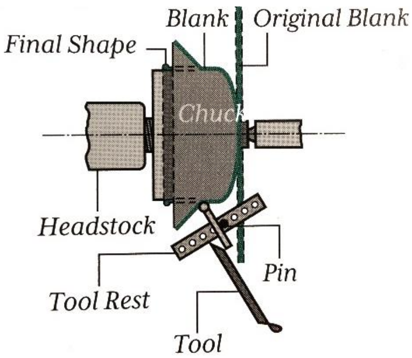


Figure 19. Spinning [28].

3.1.2 Joining technology

Tungsten Inert Gas (TIG) Welding

TIG welding (Figure 20) is a precise and high-quality welding process [32]. It is chosen due to joints that need accuracy. Although it makes very clean and precise weld, it is also expensive. TIG welding can be used manually, but is easily automated [28].

Quality: Dependent on operator skill. It is possible to form precise and clean weld beads with all manual techniques.

Environmental impacts: Inefficient use of energy with limited scrap [32].

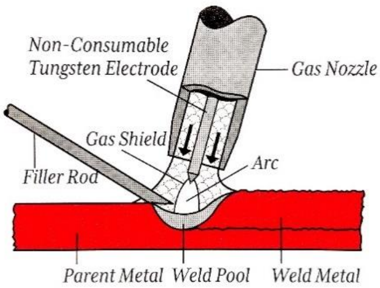


Figure 20. TIG welding [28].

Gas metal arc (MIG) Welding

MIG welding (Figure 21) has stream of inert gas, which surrounds the arc formed between the consumable wire electrode and the component; the wire is advanced from a coil as the electrode is consumed.

Quality: High quality. It is best for fillet welds through an adaptation – MIG spot welding – and lends itself well to lap joints. It is indispensable for welding difficult, non-ferrous metals such as aluminium, magnesium and titanium.

Environmental impacts: Radiation from the weld can be harmful to the eye, requiring that a welding helmet and tinted safety goggles must be worn [28].

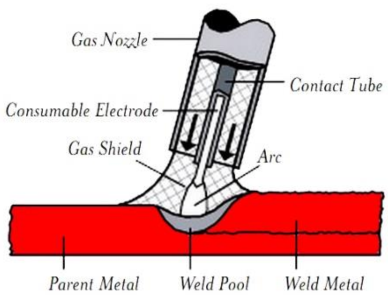


Figure 21. MIG welding [28].

3.1.3 Finishing technology

Powder Coating

Powder coating (Figure 22) is the easiest way for protecting metal parts against corrosion and wear. The products are stacked into a rotating jig and coated by computer-guided spray guns.

Spray guns use a jet of compressed air and coating is applied onto the surface in an overlapping pattern. This procedure comes at a low price and has high quality. Finished products have uniform, durable coating and attractive finish [28].

Quality: Comes in thin layers with different finish options.

Environmental impacts: Spraying is usually carried out in a booth or cabinet to allow the paints to be recycled and disposed of safety [32].

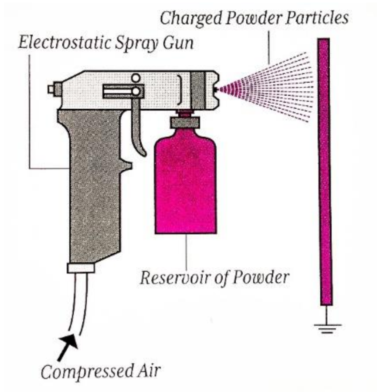


Figure 22. Powder Coating [28].

3.2 Wooden table top and seat plate manufacturing technologies

Wooden top is used for making solid surface on top of metal frame. It has strong durability and will age decorously. Only in case of dining table the solid wood surface is substituted with sandwich panel.

Glued-laminated timber

Glulam (Figure 23) is defined as a material that is made from suitably selected and prepared pieces of wood, that are glued together with the grain of all layers, parallel to the length. The effects of checking and other drying defects are minimized, because gluelam lumber is seasoned or dried prior to use [33].

Figure 23. Glued-laminated timber, oak [34].

3.2.1 Sandwich panel manufacturing

For the construction of dining table top, sandwich panel is used, due to complex shape and inappropriate weight of solid wood. Using composite panel decreases the total weight compared with gluelam more than fifty percent. Sandwich panel consists of veneered MDF and kertopuu constructional ribs.

Oak veneer overlay

Veneer overlay, a thin layer or sheet of wood (Figure 24) is bonded on MDF panel to provide decorative face in order to look like gluelam [34].

Figure 24. Veneer [34].

Medium - Density Fibreboard (MDF)

MDF is a dry-process fibreboard (Figure 25) manufactured from lignocellulose fibres combined with a synthetic resin. Its stability, good machinability and high strength make it a suitable alternative to solid wood [35].

Figure 25. MDF panel [35].

Constructional ribs from kertopuu

For giving the table increased strength and durability, constructional ribs (Figure 26) are added inside the panels. They are made out of kertopuu that follow the angles defined by the design.

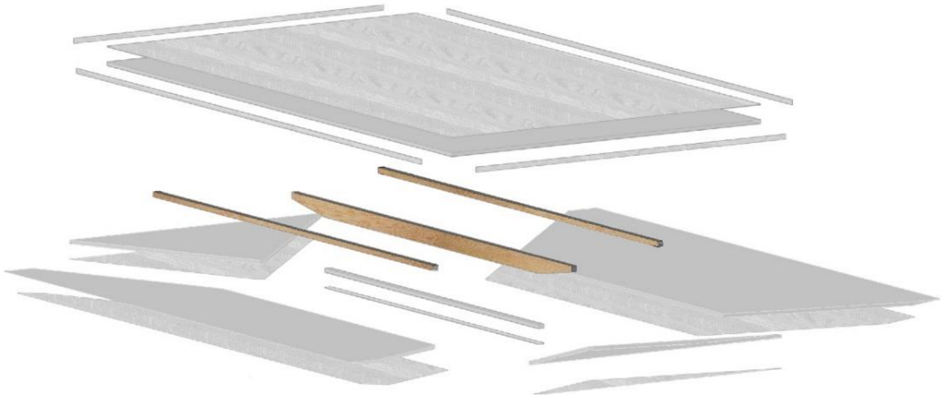


Figure 26. Constructional ribs.

Edge band

Finishing of the sandwich panel edge is done using edge band (Figure 27).

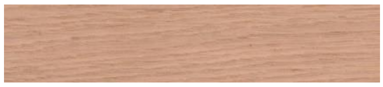


Figure 27. Edge band, oak [34].

3.2.2 Forming technology

Spray adhesion

Glue is applied for veneer overlay and joint fixing by using spray gun (Figure 28) that is under compression. This method gives evenly coated surfaces and minimum amount of waste. It is essential to seal the plates temporarily with clamps during curing time.

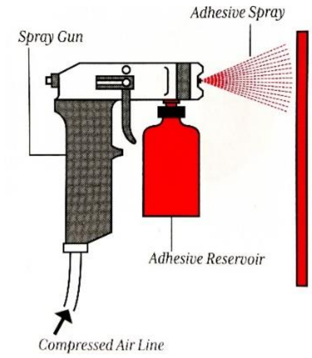


Figure 28. Spray adhesion [28].

Hydraulic veneer press

Surface gluing of veneer on MDF panels is carried out with white dispersion glue (PVAc glue) using hydraulic press (Figure 29). Edge finishing of profiled MDF panels coated with veneer, is carried out after the spray application of a two-component, water base polyurethane glue [35].

Figure 29. Hydraulic veneer press [36].

Sawing

For cutting both gluelam and sandwich panels pieces into shape, workbench is used (Figure 30). It has toothed disc that cuts very precisely under different angles and therefore needs only few amendments.

Figure 30. Felder KF 700 S Professional format saw [37].

Milling cutter

For clean look all panels are connected with dowels and milling cutter is used for carving the pocket for the dowel (Figure 31).

Figure 31. Makita milling cutter [38].

Driver drill

Making holes into metal frame and fastening wood components together is done by using driver drill (Figure 32).

Figure 32. Makita driver drill [38].

Shuttering

The form of table top is created by using shutter made out of plywood. The plates are cut into defined shape with format saw and fixed tightly, to outlast the whole weight of sandwich panel.

Banding machine

The final phase of making sandwich panel is edge banding by using proper equipment. Edge banding can be done manually when prototyping, but in mass production banding machine is used (Figure 33).

Figure 33. Banding machine [39].

3.2.3 Finishing technology

Varnishing

All wooden panels (both glulam and sandwich) are covered with matte transparent lacquer to protect against defects and colour changes. Tikkurila Unica Super lacquer is used that is suitable both for interior and exterior use (Figure 34).

Figure 34. Tikkurila Unica Super lacquer [40].

3.3 Furniture fittings

Bolts

For securing metal and wooden parts tightly together M6 bolts are used (Figure 35). Their tolerance is DIN7991, lengths and quantities are defined in detailed drawings that can be found from the appendixes chapter.

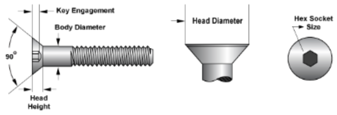


Figure 35. DIN79991 bolt [41].

Domino Tenon

Connecting wooden panels is done with PVA glue and domino Tenons (Figure 36). It allows to secure pieces without visible joints. The dowels will be assembled after every 200mm, by using adhesive.

Figure 36. Domino Tenon, Festool [42]

3.4 Production process of bar stool

The production process for making bar stool started from welding the metal frame. Along came the cutting of wooden plate and finishing. Metal and wooden parts were then assembled together and felt pads added under furniture glides. All processes and machines used are described below in Figure 37.

For making one bar stool approximately 5m of metal tube and 3.5m of rod was used. Two workers were needed for completing the task within the timeframe of one hour. Additional information about process sequences and material quantities see Appendix 5.

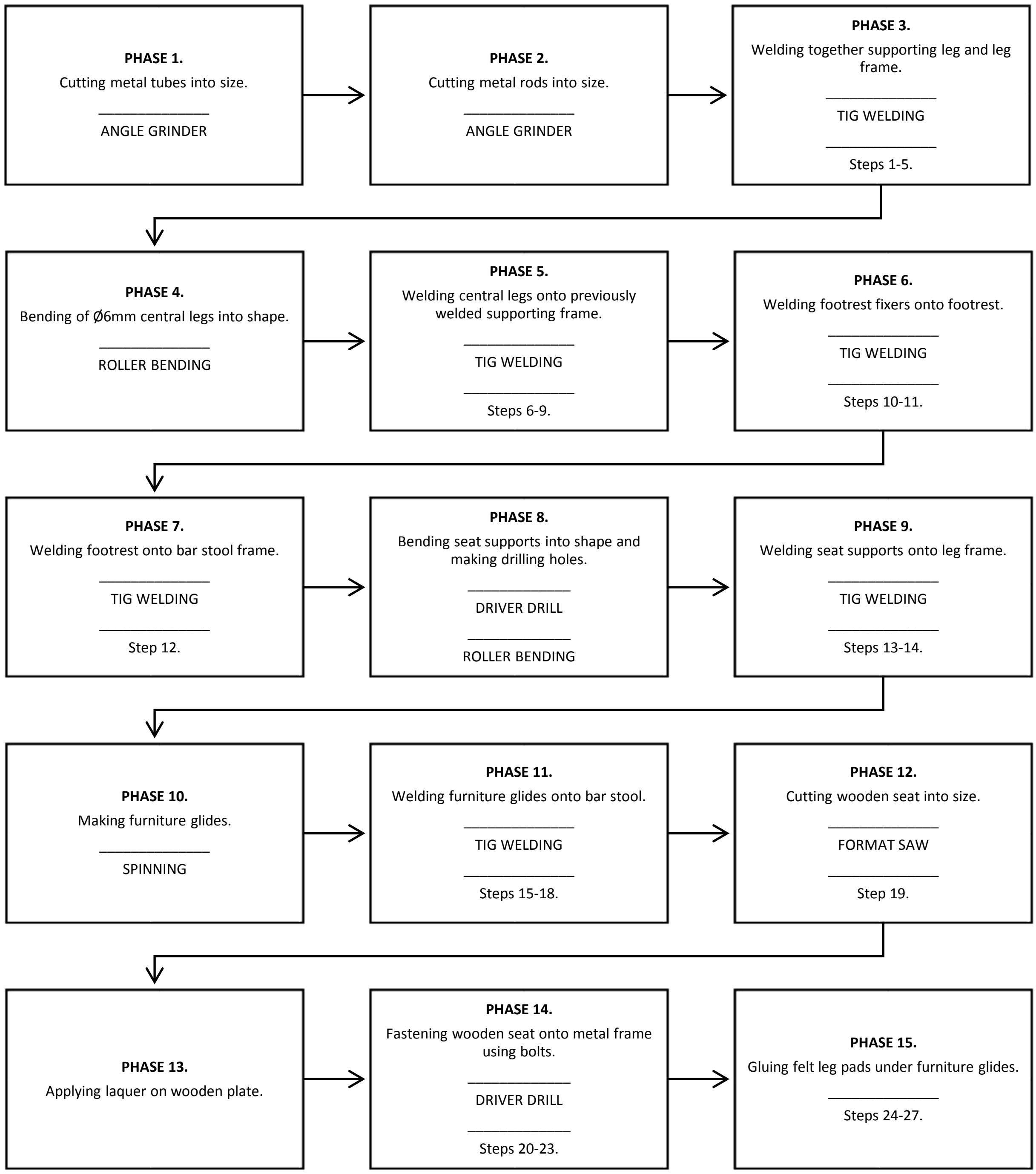


Figure 37. Bar stool production process scheme.

3.5 Production process of dining table

Constructing dining table legs was relatively same as within bar stool. The first phase was to weld both metal legs together and add felt pads under furniture glides. Table top had different construction than gluelam and was replaced with sandwich panel. Shuttering needed to be made in order to start the manufacturing of table top. All materials were temporarily fixed onto shuttering to give sandwich panel its shape.

Making of composite panel took longer production time, approximately 4.5 hours, but redeemed it with weight and constructional stability. Sandwich panel had inside constructional ribs that gave it technical durability and support for leg. Altogether 7m of Ø12mm and 8m of Ø6mm rod was used. Additional information about material quantities can be seen in Appendix 10. Methods and machine usability are defined in Figure 38.

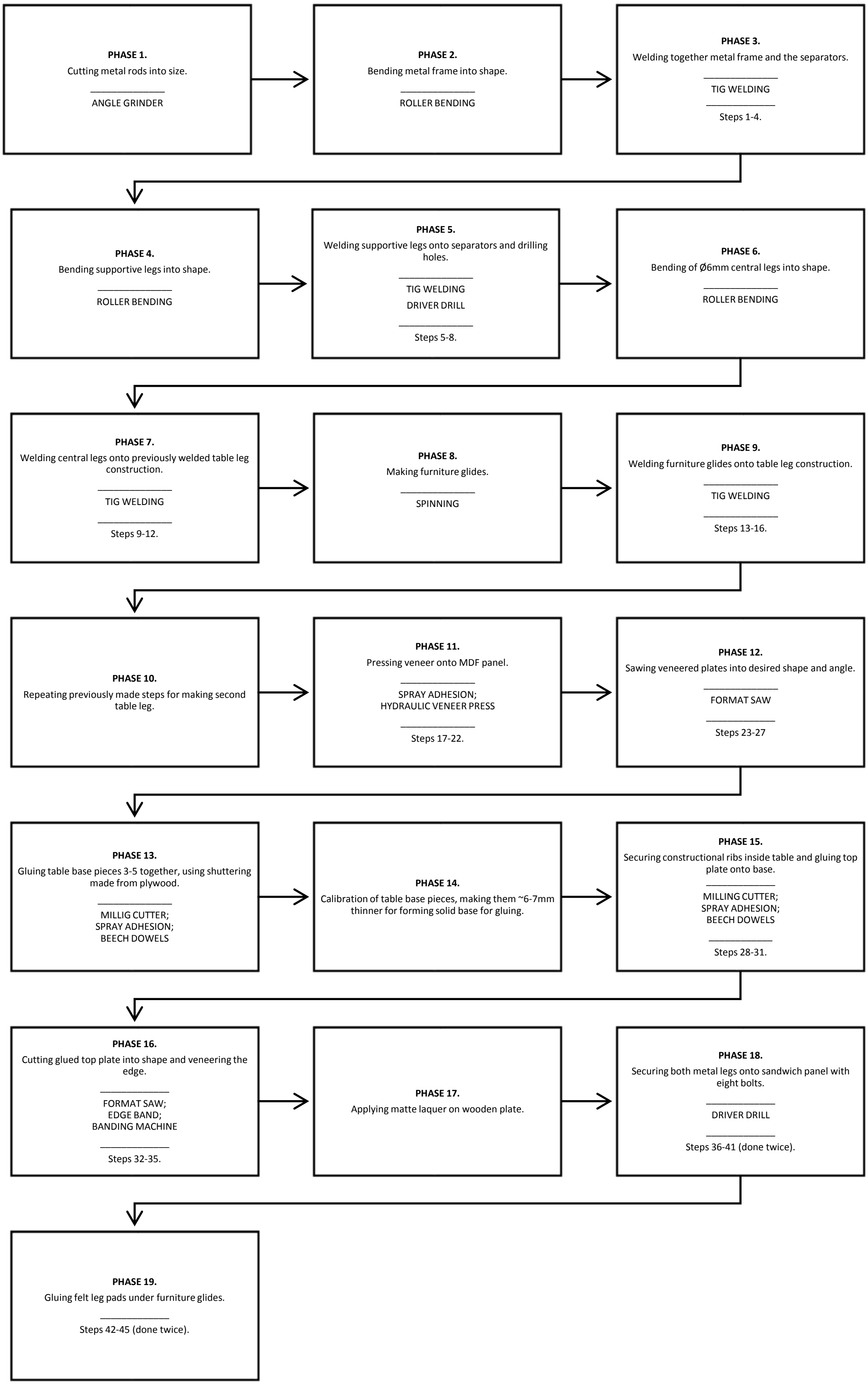


Figure 38. Dining table production process scheme.

4. TESTING OF PRODUCT PROTOTYPES

Stool prototypes were tested for strength and durability according to furniture testing standards (see Table 11; 12). It ensures both for client and business associates that the furniture is safe to use and durable. Aside from good looks durability was a key factor and in order to assure it, applying standard in the product development phase, gave the opportunity to be ahead of time and make a good first impression.

The following standards were used for testing bar stool and dining table prototypes:

Table 11. European furniture testing standards.

Standard name	Definition
EVS-EN 15372:2008	Furniture - Strength, durability and safety - Requirements for non-domestic tables
EVS-EN 1730:2012	Furniture - Tables - Test methods for the determination of stability, strength and durability
EVS-EN 16139:2013	Furniture - Strength, durability and safety - Requirements for non-domestic seating
EVS-EN 1728:2012	Furniture - Seating - Test methods for the determination of strength and durability

Some additional standards needed to be examined, e.g. the requirements regarding bar stool and table testing:

Table 12. ISO standards.

Standard name	Definition
ISO 7172:1988	Furniture - Tables - Determination of stability
ISO 7173:1989	Furniture - Chairs and stools - Determination of strength and durability
ISO 7174-1:1988	Furniture - Chairs - Determination of stability - Part 1: Upright chairs and stool

Aside from processes carried out in Laboratory for Furniture and Wood Materials Testing certification will be carried out to assure that a product meets the requirements of the standard or standards concerned. Buyers in France, Germany and Sweden, for example, may require product certification for imported furniture. Many manufacturers are reluctant to apply for the certification of their products because it is expensive [5].

When the products are in accordance with the standards, manufacturers and importers will avoid errors in product related to any complaints and claims for reimbursement. Also export of the products is easier [43].

4.1 Equipment

Two testing machines were used in TUT furniture testing laboratory. Several tests were made using universal test rig (Figure 39). For determining seat durability drop test rig was used (Figure 40).

Figure 39. Universal test rig for alternating bending tests on furniture [44].

Figure 40. Drop test rig for impact loading of seating furniture [44].

Aside from Hegewald Peschke testing equipment additional accessories were used for completing the tests. For determining seat loading point metal template was used (Appendix 11) that was placed on the stool (Appendix 12) and necessary point marked. This laid an important role on the whole testing procedure because seat loading pads (Appendixes 13; 14) and impactor (Appendix 15) were installed according to template.

4.2 Bar stool

Both bar stool prototypes were tested in Laboratory for Furniture and Wood Materials Testing for deformations. Examining the test results gave comparison weather changing the proportions and materials (Table 13) was reasonable decision and what were the weak points of design.

Table 13. Barstools 1 and 2 material comparison.

	Bar Stool_1	Bar Stool_2
Metal frame	Ø10mm rod	Ø12mm tube
Metal support frame	Ø6mm rod	Ø6mm rod
Wooden seat	30mm gluelam, ash	19mm gluelam, oak

4.2.1 Testing of prototypes

All laboratory tests were made for both of the bar stools. Detailed table of forces and cycles applied during testing can be seen in Appendix 16. For the following a short description of technical requirements for testing is given.

Seat static load test

Using the seat loading pad 1600N force was applied at the seat loading position (Appendix 17). The chair was prevented from moving onwards by using fixtures (Figure 41). Static load was maintained for 10 seconds. Loading was repeated 10 cycles [45].

Figure 41. Seat static load test.

Seat front edge static load test

The seat static load procedure was done on a point, 100mm back from the front edge of the structure and repeated 10 times, using seat load 1300N only (Figure 42) [45].

Figure 42. Seat front edge static load test.

Foot rest static load test

The specified force of 1300N was applied from periphery on the centre line of a foot rest and applied 10 times. If the article overturned additional load was applied on the seat (Figure 43) [45].

Figure 43. Foot rest static load test.

Seat front edge durability test

The vertical seat load for fatigue test loading 800N was applied alternately on two points, each 100mm from the edge (Appendix 18). Altogether 50 000 cycles were performed (Figure 44) [45].

Figure 44. Seat front edge durability test.

Leg forward static load test

In the seat loading position the load 1000N was applied (Appendix 19). The stool was prevented from movement by fastenings against front legs (Figure 45). Horizontal force of 500N was applied centrally to the rear edge of the seat 10 times [45].

Figure 45. Leg forward static load test.

Leg sideways static load test

A pair of front and rearleg was affixed to the testing floor see Figure 46). The seat was loaded with 1000N (Appendix 20). The horizontal force 400N was applied centrally to the side at seat level towards the floor affixed stool legs 10 times [45].

Figure 46. Leg sideways static load test.

Seat impact test

One layer of foam was placed on the seat. The falling height was determined when the impactor (mass 25kg) laid on the foam. The determined drop height had to be 240mm. The second layer of foam was placed before starting the drop test (Figure 47). The impactor fell freely 10 times (Appendix 21) [45].

Figure 47. Seat impact test.

4.2.2 Test results

Both bar stools were tested in the timeframe of two weeks. During that time seven tests were carried out, one of them cycled test. The following will give an overview of test results and a conclusive table with all deformations occurred during laboratory testing (Table 14).

Table 14. Deformations occurred during laboratory testing.

	Seat static load test	Seat front edge static load test	Foot rest static load test	Seat front edge durability test	Leg forward static load test	Leg sideways static load test	Seat impact test
Bar stool_1	0.2mm	-	1mm	-	2mm	-	-
Bar stool_2	0.6mm	-	2mm	-	-	2mm	broke* during first attempt

*Wooden seat was broken during first attempt due to wrong placement of wood grain. Seat did not breake during second test after changing wood grain direction.

Tests that might have biggest deformations were compared with ANSYS WorkBench program simulation. It was used to see how much the real deformations compared to program simulation match and can it be used in product development phase in the future to improve products.

The simulation was made based on first prototype dimensions. Whereas Ø6mm and Ø10mm metal rod was used, combined with 30mm glulam seat. All situations were tested with the force of 100kg=1000N.

Seat static load test

For precise measuring an indicator was placed 50mm back from seat front edge during testing. Both bar stools had almost non-existent deformations. Although the wood grain was in the same direction, thickness and density of the material differed and influenced test results. This caused bigger deformation with Bar stool_2 and could have been prevented if wood grain would have been placed sideways.

Compared to simulation the laboratory tests had smaller deformation. Total deformation of bar stool simulation was 0.36mm (Figure 48), which in case of Bar stool_1 was 0.2mm. Due to misplacement of Bar stool_2 wood grain, the comparison was not made.

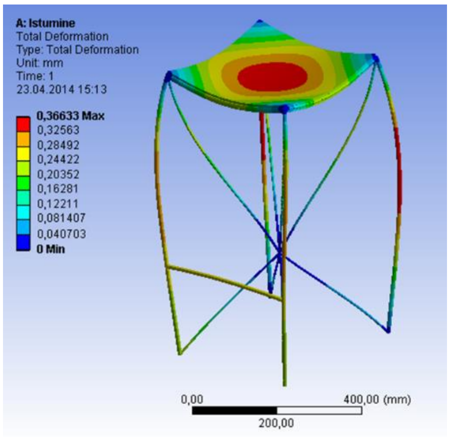


Figure 48. Seat static load test simulation.

Seat front edge static load test

This specific test did not have any influence on either bar stool constructions. Though direct stress on seat front edge was set using simulation 0.7mm (Figure 49).

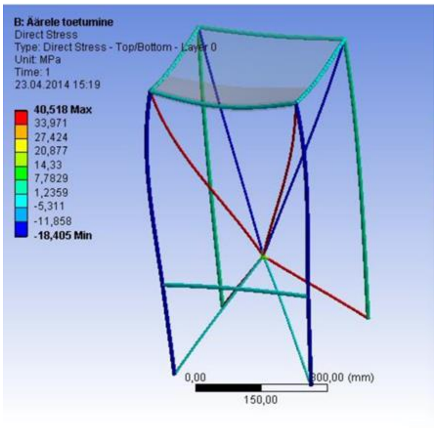


Figure 49. Seat front edge static load test simulation.

Foot rest static load test

Additional weight bags of 30kg were used during this test, in order to prevent the stools from falling. The deformations occurred were relatively small but as can be seen from Figure 50 Bar stool_2 foot rest is not esthetical anymore. Although the deformation was only 2mm (Figure 51) it can be noted in visual inspection. Simulation defined that the biggest deformation was 1.47mm (Figure 52). Which gives relatively accurate result to real situation.

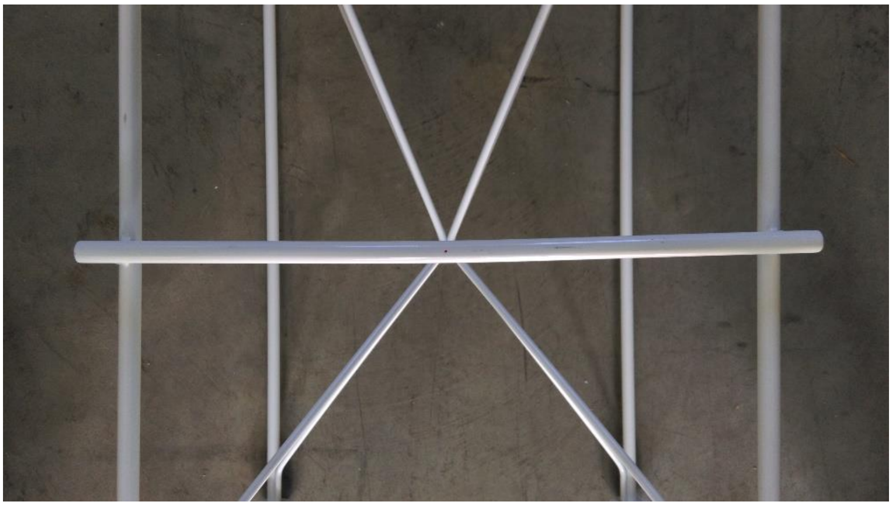


Figure 50. Bar Stool_2. Foot rest visual inspection.

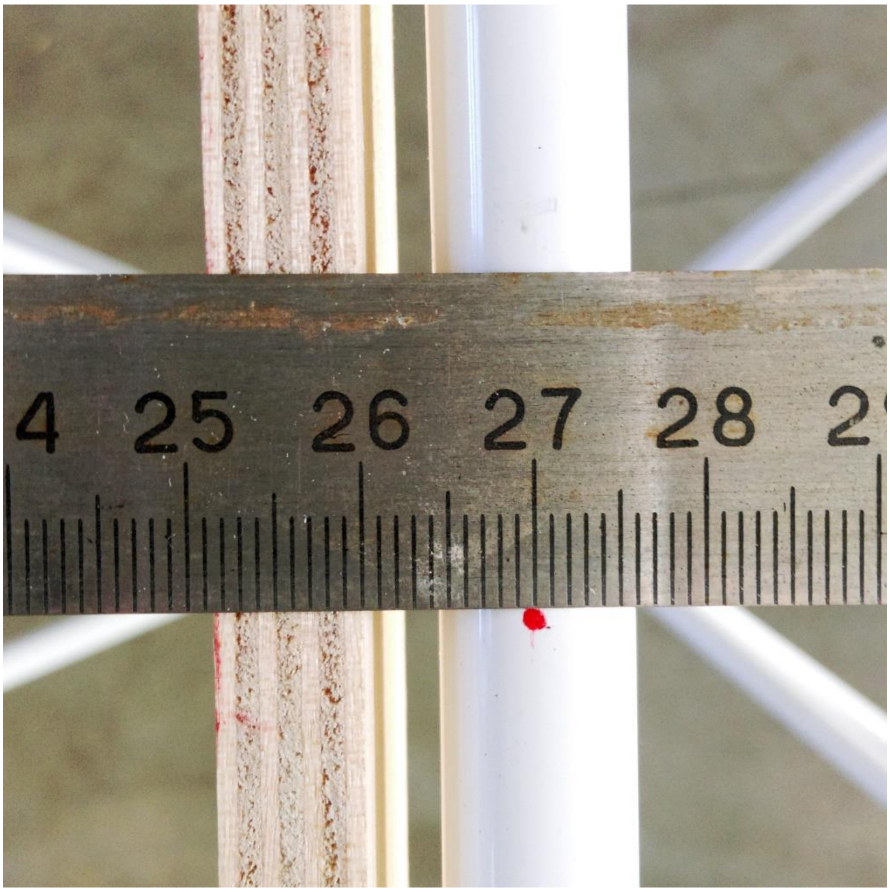


Figure 51. Bar stool_2. Foot rest deformation.

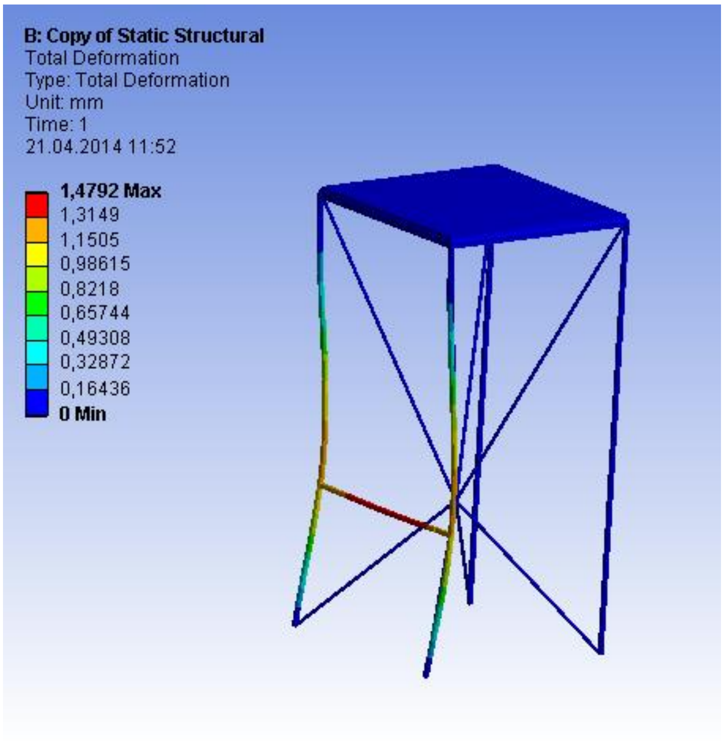


Figure 52. Foot rest static load test simulation.

Seat front edge durability test

Completing 50 000 cycles took 2.5 days for each bar stool but no deformations were registered. For accurately measurable test results high-technology equipment has to be used. This way the deformations can be compared using digital image correlation.

Leg forward static load test

Because of the height of the stools, official horizontal testing force of 500N was changed into 300N to prevent them from falling. Therefore forces applied were not very big and only Bar Stool_1 had 2mm deformation. The data gathered from this test could not be trusted due to measuring the distances by using templates and measuring tape.

Leg sideways static load test

The vertical load was applied 100mm back from the front edge and 200N horizontal force was set. That meant replacing standard 400N test load smaller in order to prevent the stools from falling. Tests did not have remarkable results, although Bar Stool_2 deformed 2mm. Yet again the data gathered from this test could not be trusted due to measuring the distances with measuring tape.

Seat impact test

The seat impact test had no influence on Bar Stool_1. The biggest deformation happened with Bar Stool_2 by braking the gluelam plate during first impact from glued joint (Figures 53-54). This result strongly implicated that wood grain direction influences the seat durability.

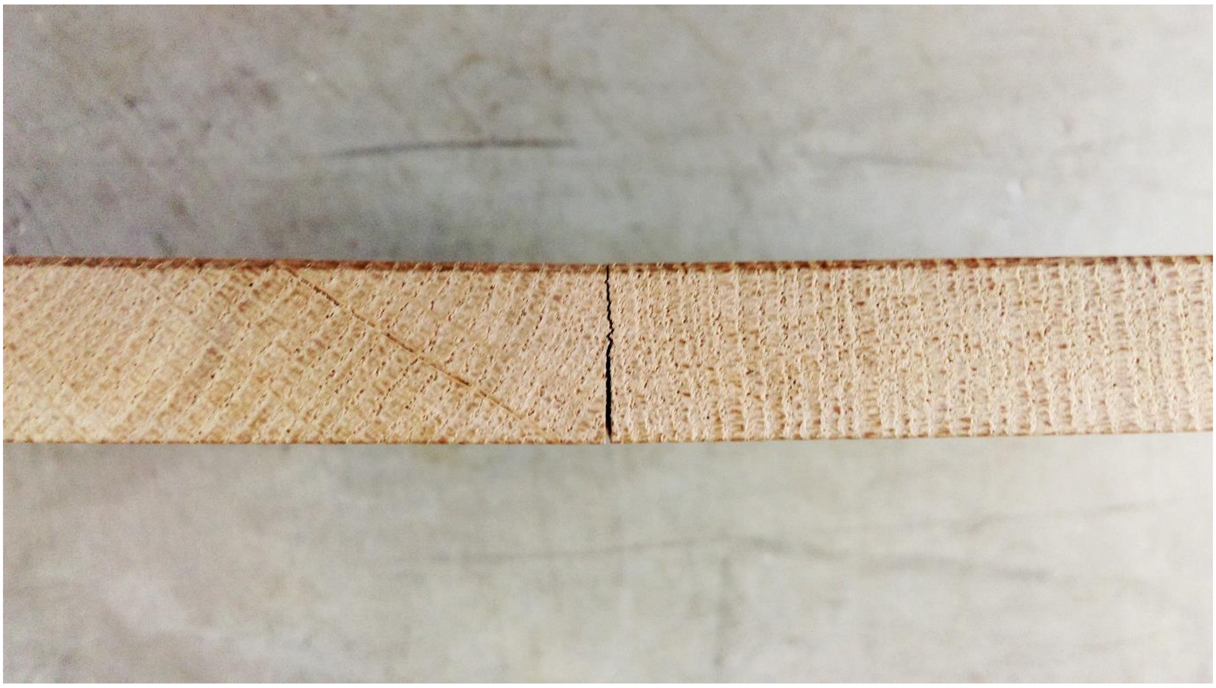


Figure 53. Crack in Bar stool_2 seat plate.

Figure 54. Crack along glue connection of boards.

4.2.3 Further decisions regarding bar stool product design

Laboratory tests were carried out to check overall design of the bar stool, to see if it is durable enough to withstand commercial use. Minor mistakes were discovered and corrections should be made regarding technical drawings. Involving changing the direction of seat plate wood grain and possibly replacing the foot rest material back to steel rod.

4.3 Dining table

Although dining table prototype did not get ready in the timeframe of this thesis program based simulation about deformations was created. SolidWorks software was used to determine critical points in the design and weather additional changes have to be carried out. Program simulations are relatively accurate to real life situation and can be therefore trusted.

All tests carried out were based on European furniture standards EVS-EN 15372:2008 and EVS-EN 1730:2012. Testing conditions and forces applied were set accordingly, but minor adaptations had to be made for SolidWorks program.

4.3.1 Testing of prototypes

Based on feedback that was given during product development phase, horizontal durability seemed to be the biggest weak point in dining table design. In order to determine if this statement was true, simulations were made regarding horizontal fatigue.

By knowing the test severity level (Appendix 22) it was possible to examine stability, strength and durability test conditions (Appendix 23) and choose the necessary methods. For testing the dining table durability against horizontal forces two tests were simulated in computer (see Appendixes 24; 25).

Simulation program was easy to use for determining solid material deformations, but when it comes to wood, setting the right material conditions is nearly impossible. For that reason table top material was defined by weight to match 74kg, which is the actual weight of sandwich panel (See Table 8). AISI 1020 was defined as metal material for table legs, due to relatively average properties that create realistic situation (Figure 62).

For simulating the tests accurately table legs were fixed onto ground according to standard conditions. Legs that would have stayed unattached in lab condition were applied with rollers, to avoid going into ground surface and allowing the leg to move.

Big red arrow in the simulation pictures indicated the direction of gravitational force. Green arrows showed fixed surfaces and places were rollers were applied. Purple arrows pointed the direction and area of force applied.

Horizontal static load test

For making the test one pair of table legs were fixed on the ground and force was applied on each side parallel to the fixed legs (Figure 55). This procedure was repeated by changing the fixings (Figure 56). 400N was applied in the centre of table and pushed from the side with 400N (Appendix 24). During this test forces were applied from each of the four sides. Following describes the two principal directions and the deformations. Additional pictures regarding the deformations can be seen from Appendixes 26-31.

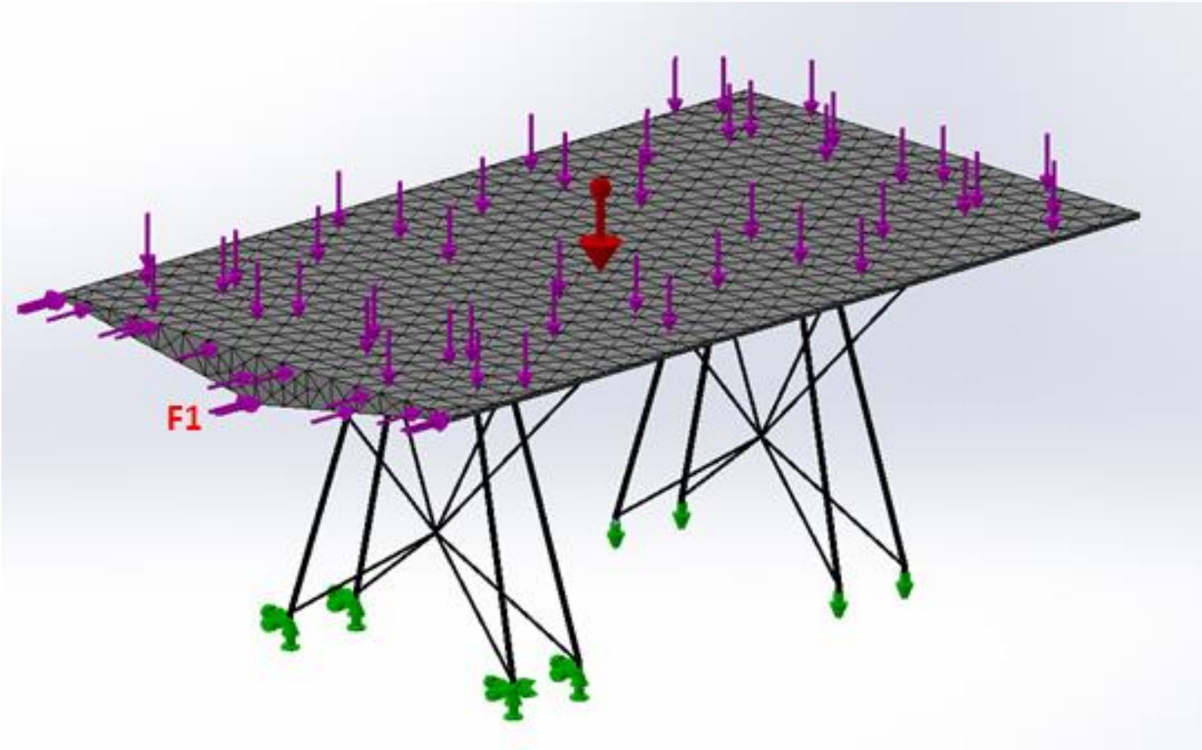


Figure 55. Horizontal static load. Force 1.

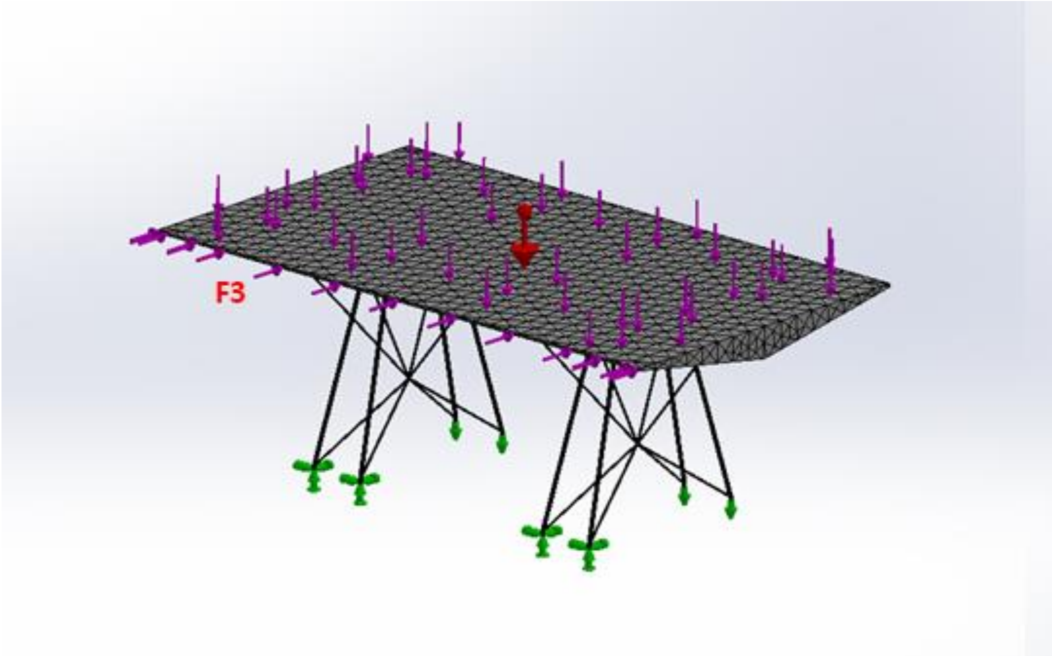


Figure 56. Horizontal static load. Force 3.

In principle only metal legs deformed during this simulation. Therefore table top had rather sparse structure and became unessential. Whereas metal mesh size was several times bigger (Figure 57).

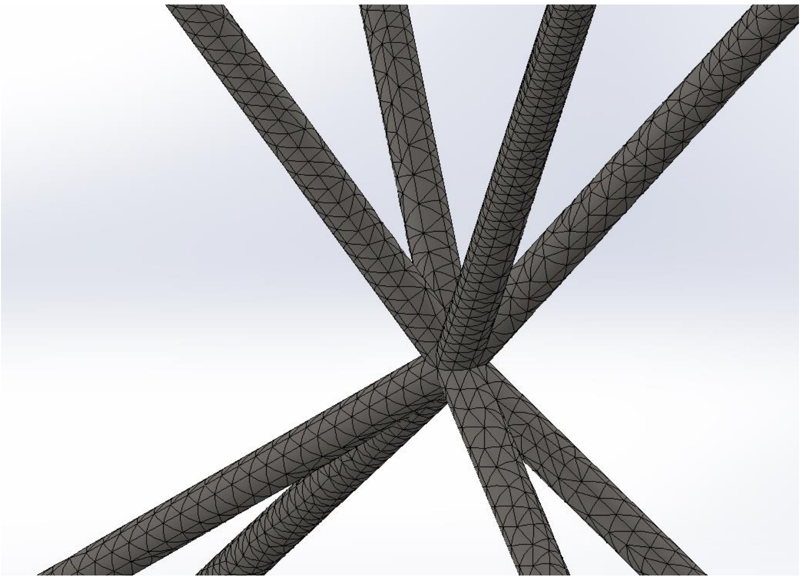


Figure 57. Horizontal static load. Mesh size.

Horizontal durability test

For performing test all four table legs were fixed and 300N applied onto the table (Appendix 25). Durability was set into test by applying force from all sides, 50mm from the corner (Figure 58). All material properties were stated the same as with previous test.

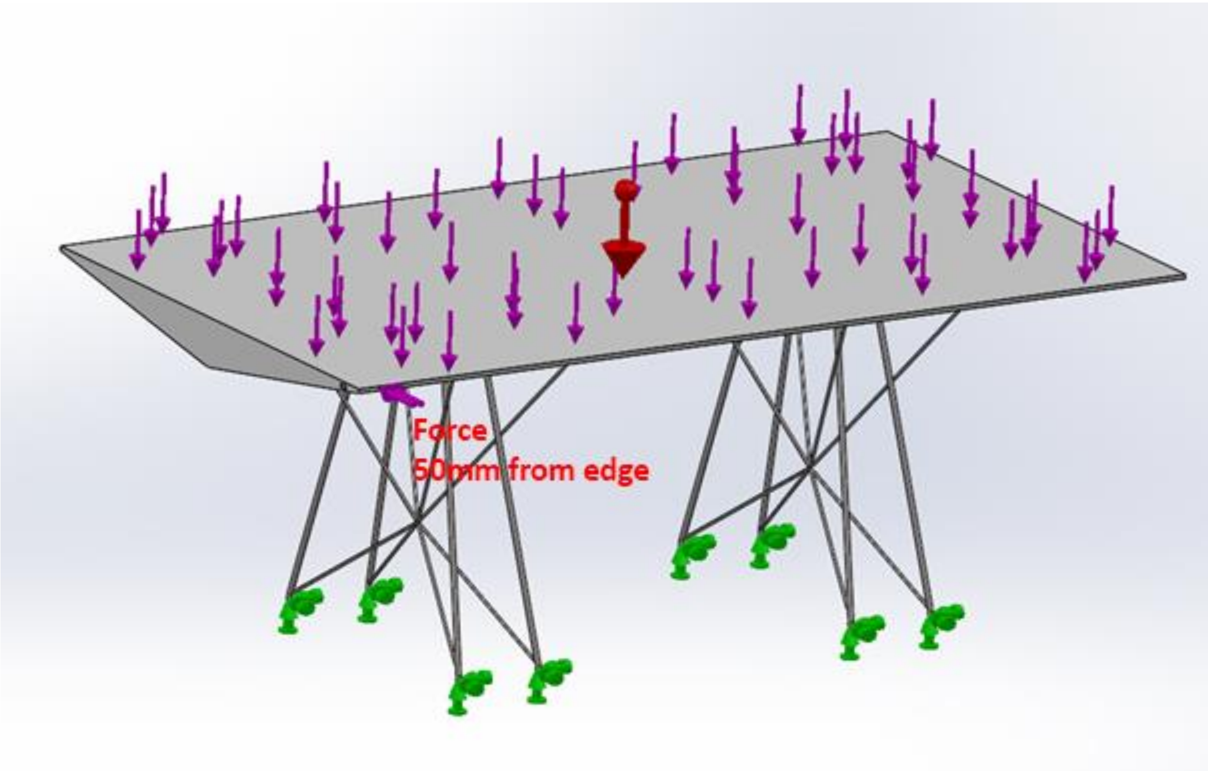


Figure 58. Horizontal durability test. Testing conditions.

4.3.2 Test results

Making the appropriate model for simulating deformations took approximately 10h. Due to complex structure majority of time went into making the metal leg model. Whereas getting the results took only couple of minutes.

Note! All simulation pictures are figurative and deformations shown oversized 10x to give better visual image.

Horizontal static load test

Figures 59 and 60 clearly stated that the biggest stresses occurred in the tip of metal leg, where it was connected to sandwich panel. As a result of this simulation the maximum stress of metal leg was 17,95MPa (Figure 60; 61). Additional testing conditions for Forces 2 and 4 see Appendixes 31-36.

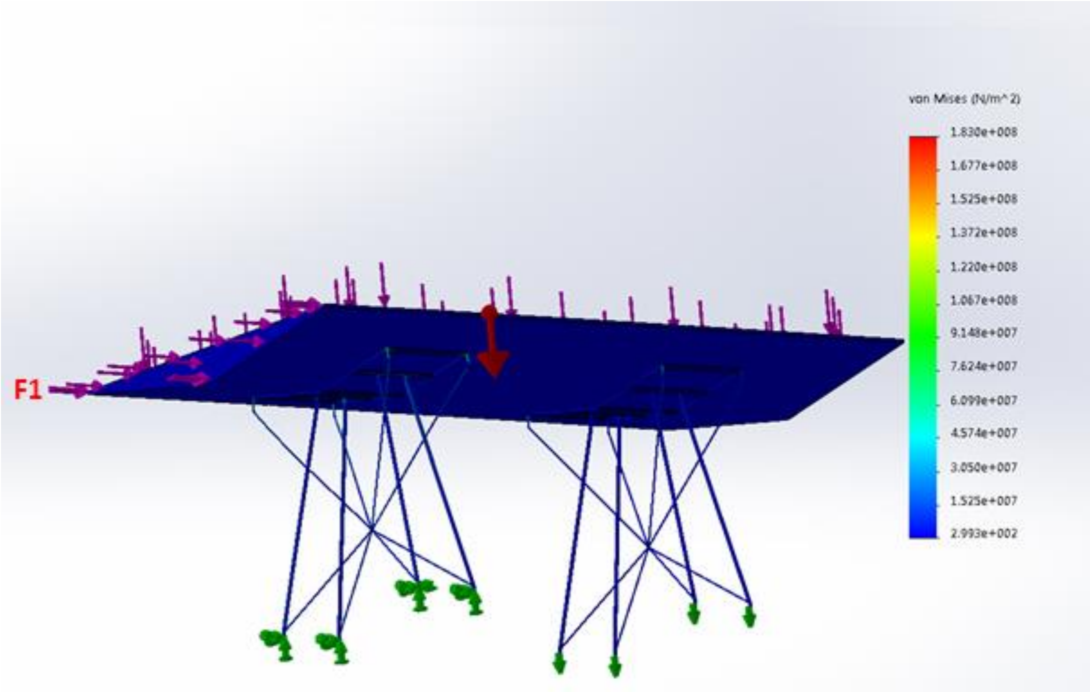


Figure 59. Horizontal static load. Force 1. Direct stress.

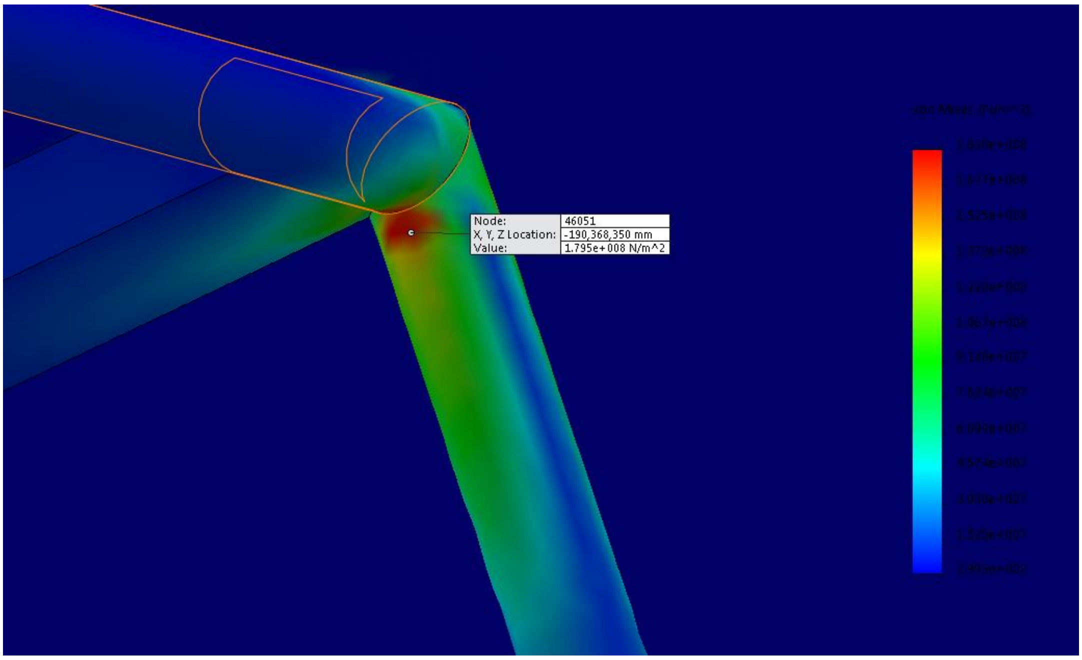


Figure 60. Horizontal static load. Force 1. Direct stress in weakest joint.

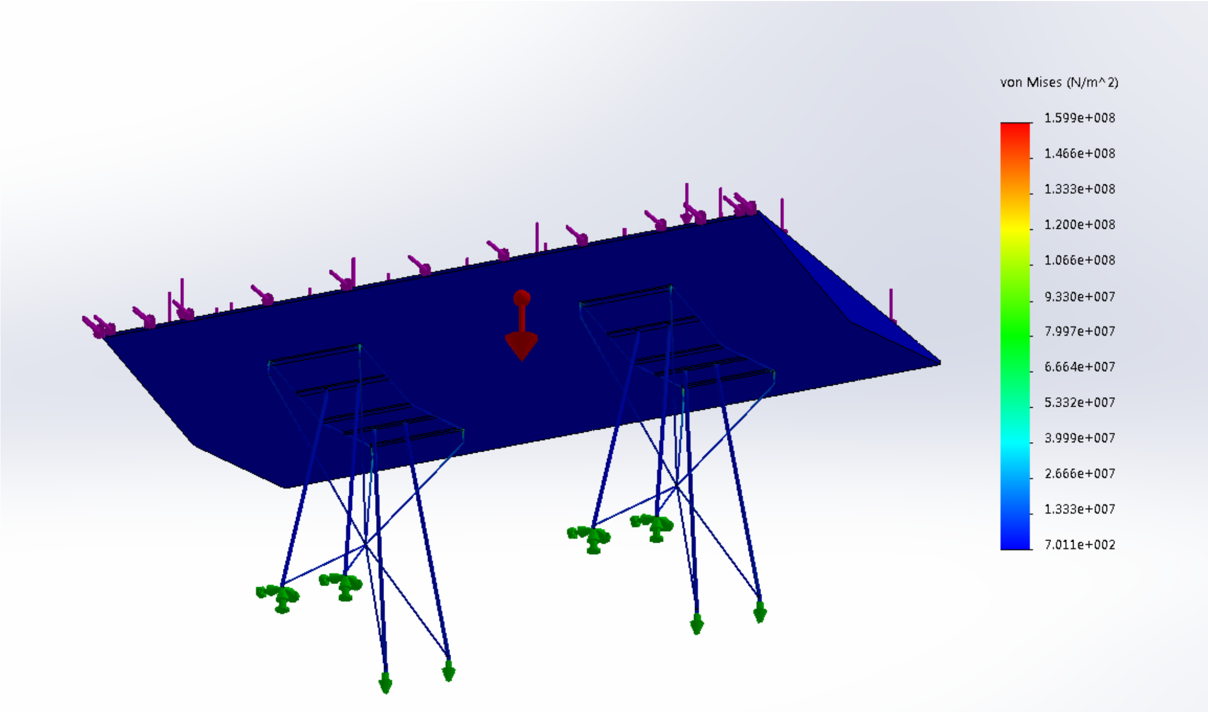
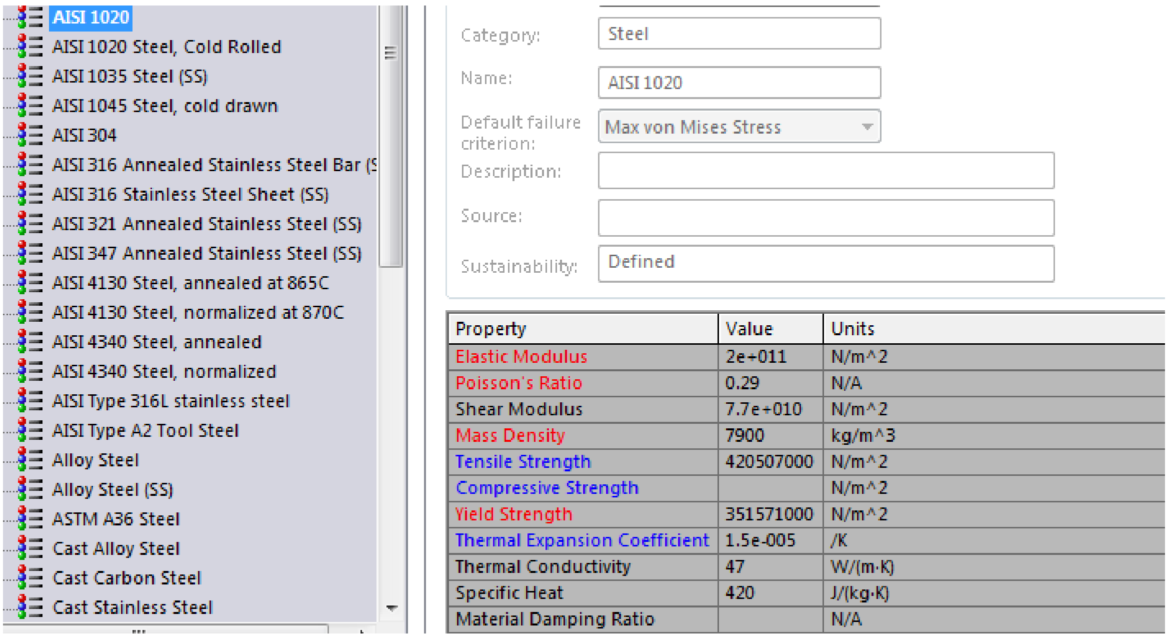


Figure 61. Horizontal static load. Force 3. Direct stress.

Yield strength of material used (AISI 1020) was 351MPa (Figure 62). If reserve factor was for example two, the maximum stress allowed would be 175.5MPa. Which is almost ten times bigger than the stress defined by the Force 1 simulation.



Property	Value	Units
Elastic Modulus	2e+011	N/m^2
Poisson's Ratio	0.29	N/A
Shear Modulus	7.7e+010	N/m^2
Mass Density	7900	kg/m^3
Tensile Strength	420507000	N/m^2
Compressive Strength		N/m^2
Yield Strength	351571000	N/m^2
Thermal Expansion Coefficient	1.5e-005	/K
Thermal Conductivity	47	W/(m·K)
Specific Heat	420	J/(kg·K)
Material Damping Ratio		N/A

Figure 62. Horizontal static load. Material properties.

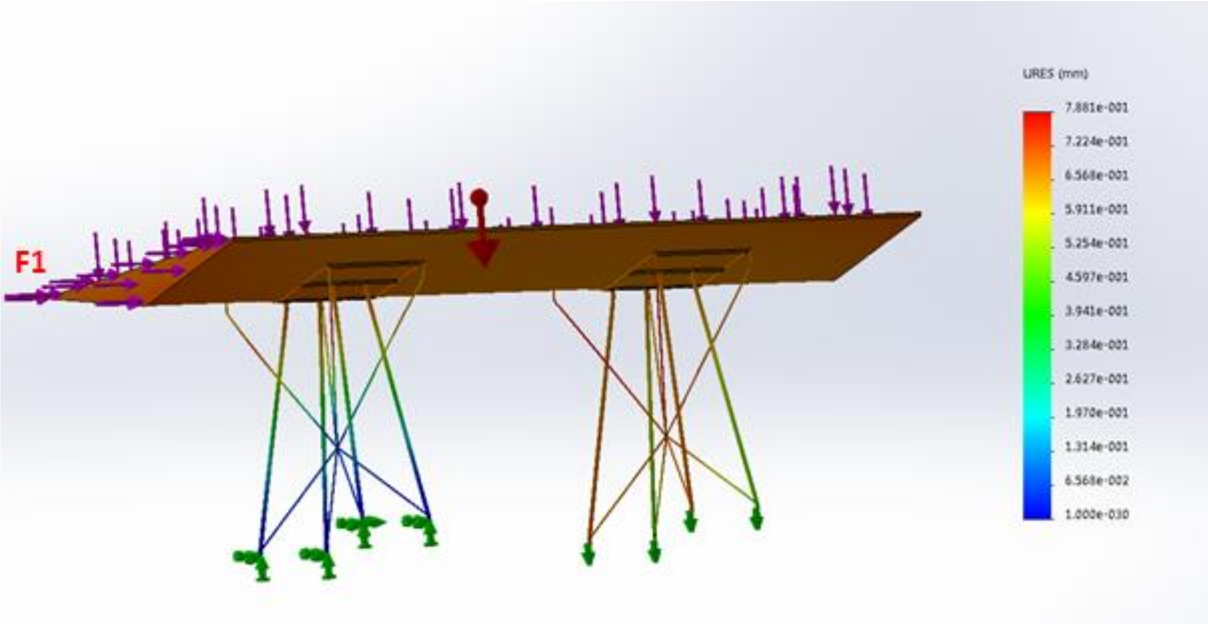


Figure 63. Horizontal static load. Force 1. Total deformation.

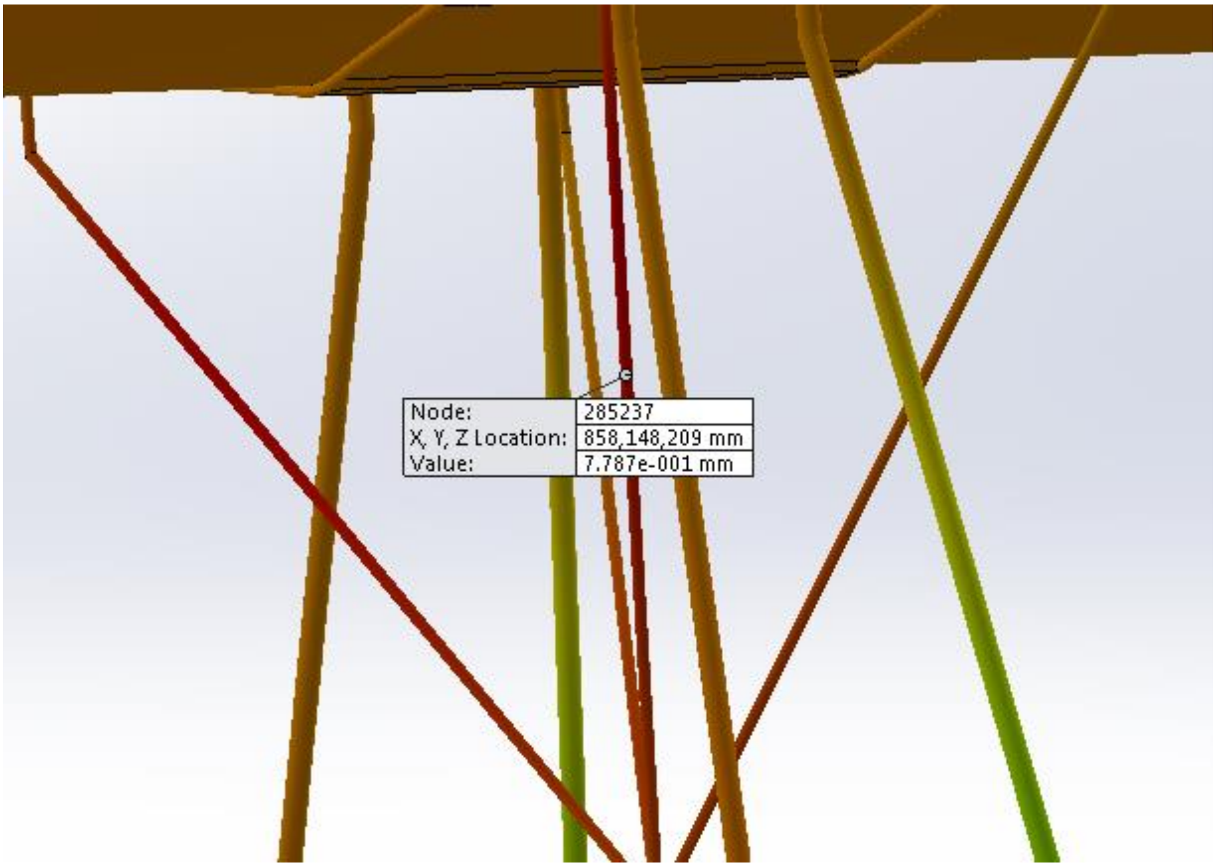


Figure 64. Horizontal static load. Force 1. Total deformation weak point.

Figures 63 and 65 indicated the deformation weak points. Blue areas had barely any deformations and as an opposite red colour showed the biggest fragility. Based on Force 1 the table top moved 0.706mm, making it impossible to see with human eye. Force 3 moved the table top 0.275mm (Figure 59). The biggest deformation occurred in the Ø6mm rods. Force 1 had 0,778mm (Figure 64) and force 3 0.706mm deformation (Figure 66).

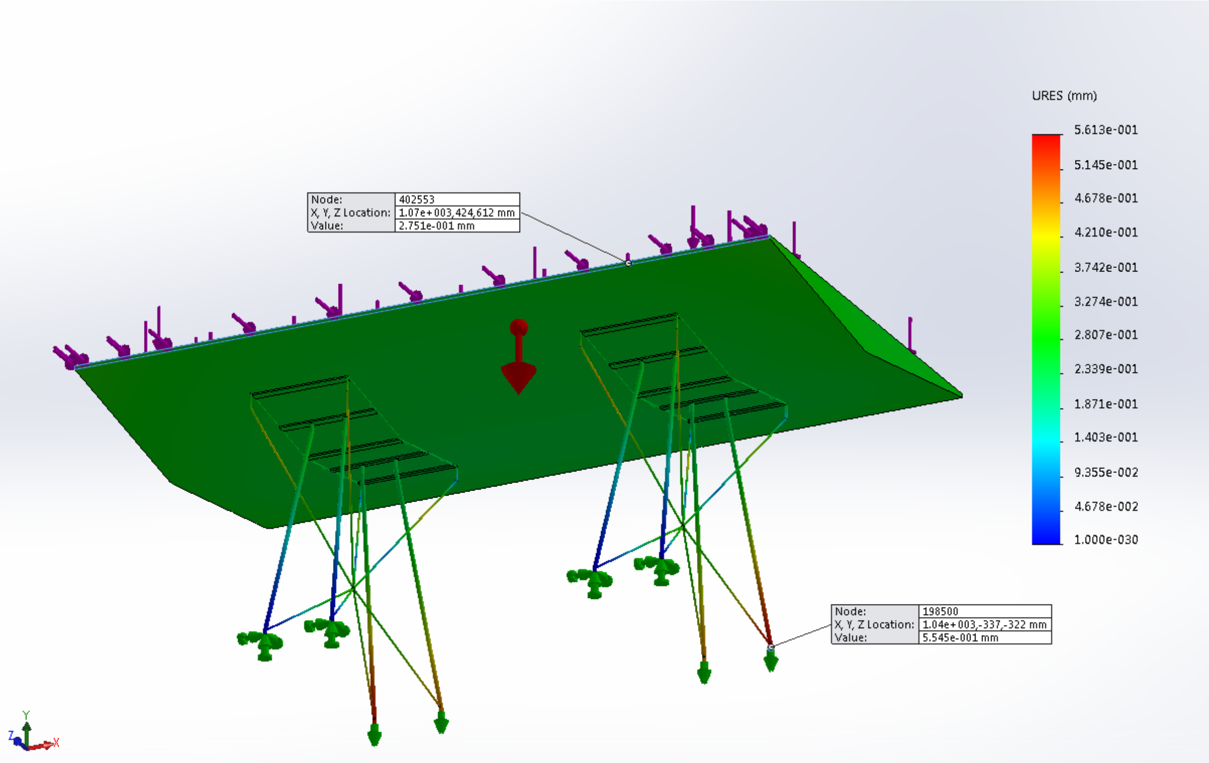


Figure 65. Horizontal static load. Force 3. Total deformation.

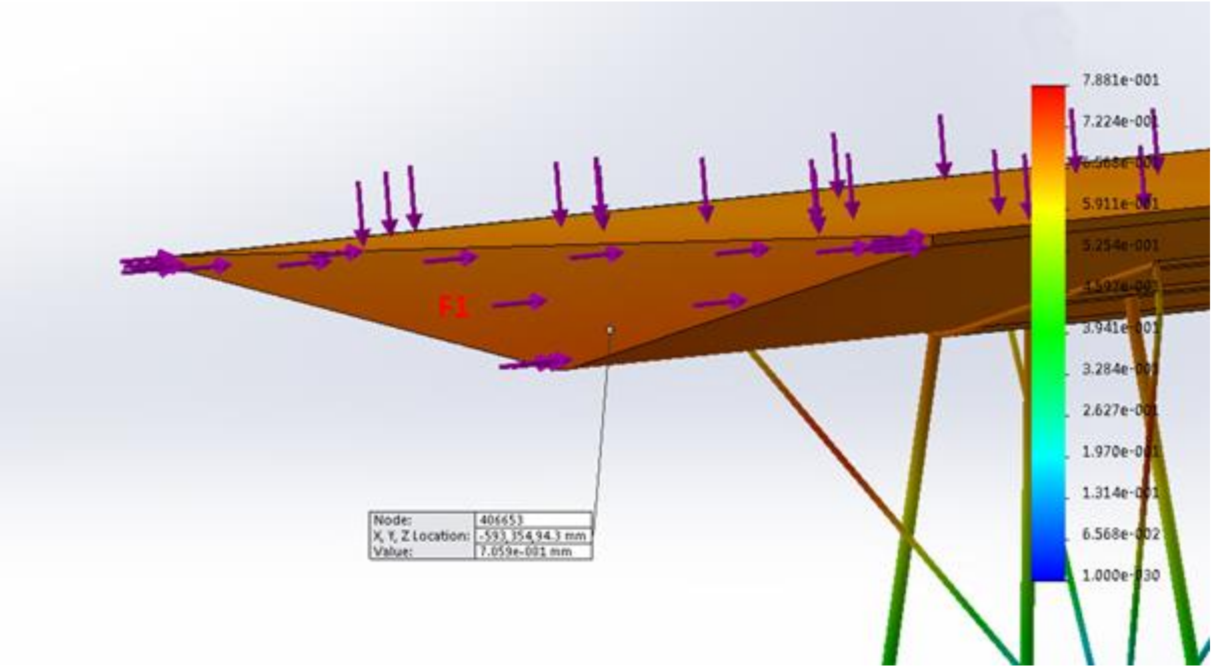


Figure 66. Horizontal static load. Force 1. Table top moving.

Horizontal durability test

Durability test made small impact on table construction. Similarly to static load test the stress was biggest in the place where metal legs were fixed onto sandwich panel. The maximum stress came out to be 11.2MPa (Figure 67) and 10.9MPa (Figure 68).

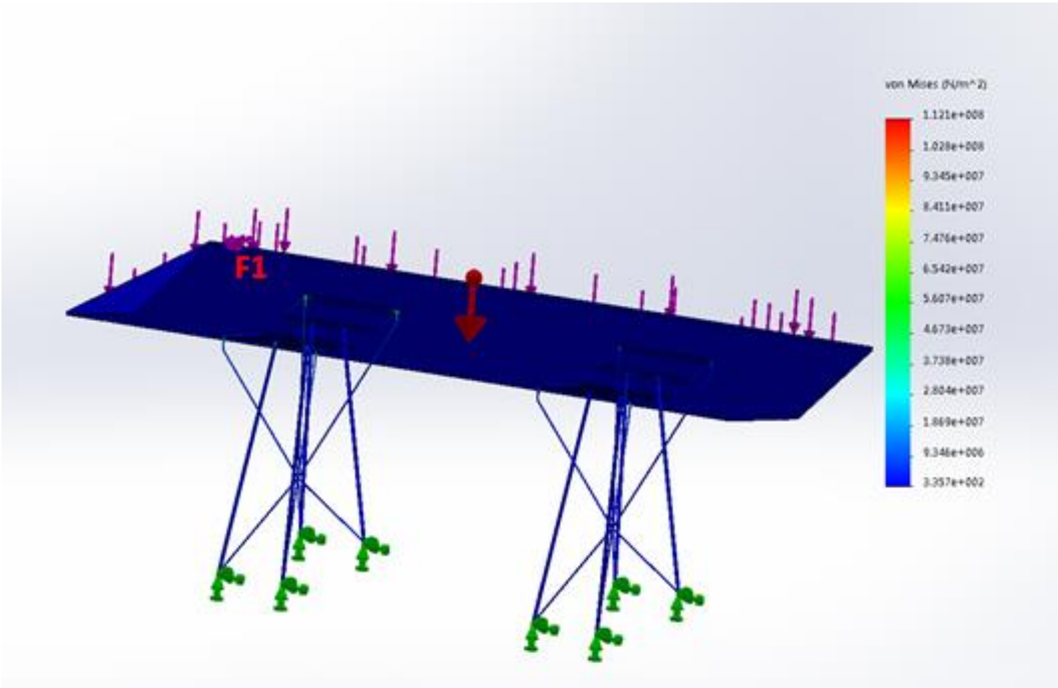


Figure 67. Horizontal durability test. Force 1. Direct stress.

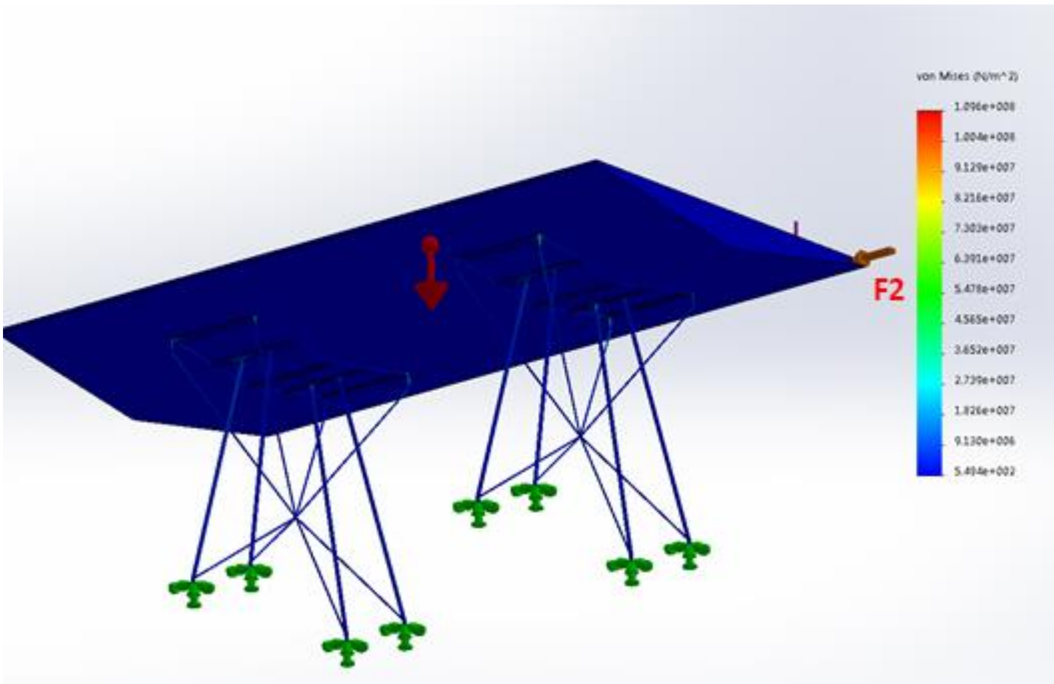


Figure 68. Horizontal durability test. Force 2. Direct stress.

Total deformations from both sides came basically the same. Metal leg deformed after applying Force 1 (Figure 69) 0.413mm and after Force 2 (Figure 70) 0.414mm.

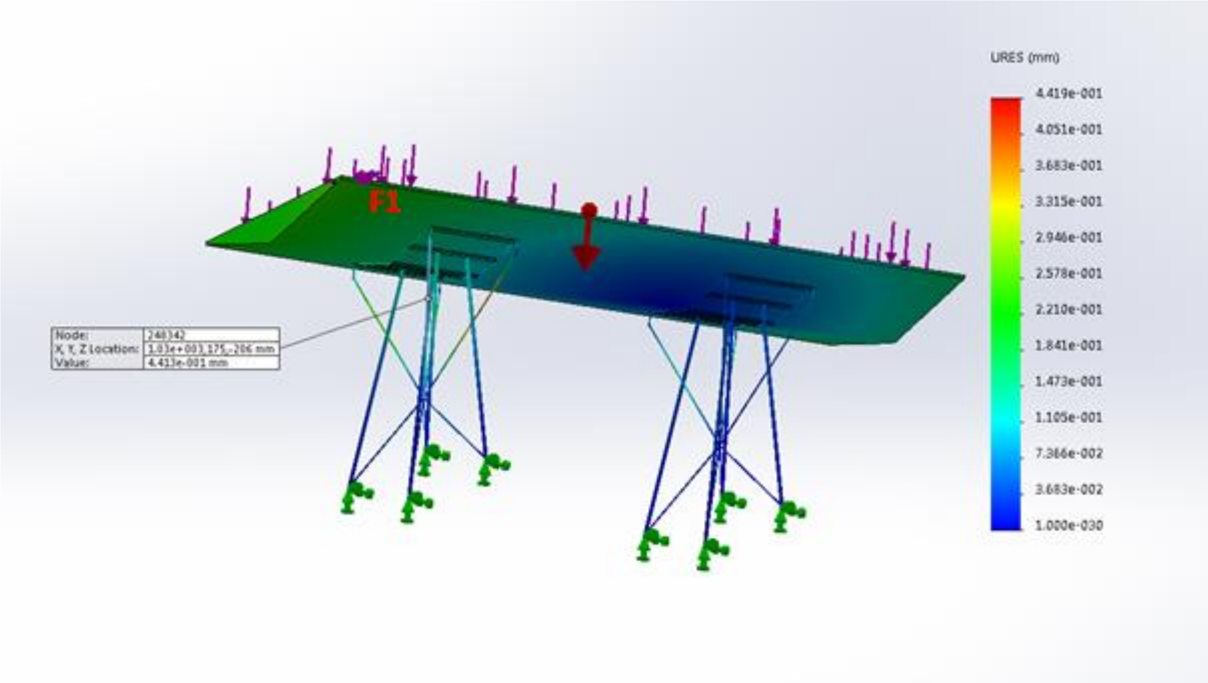


Figure 69. Horizontal durability test. Force 1. Total deformation.

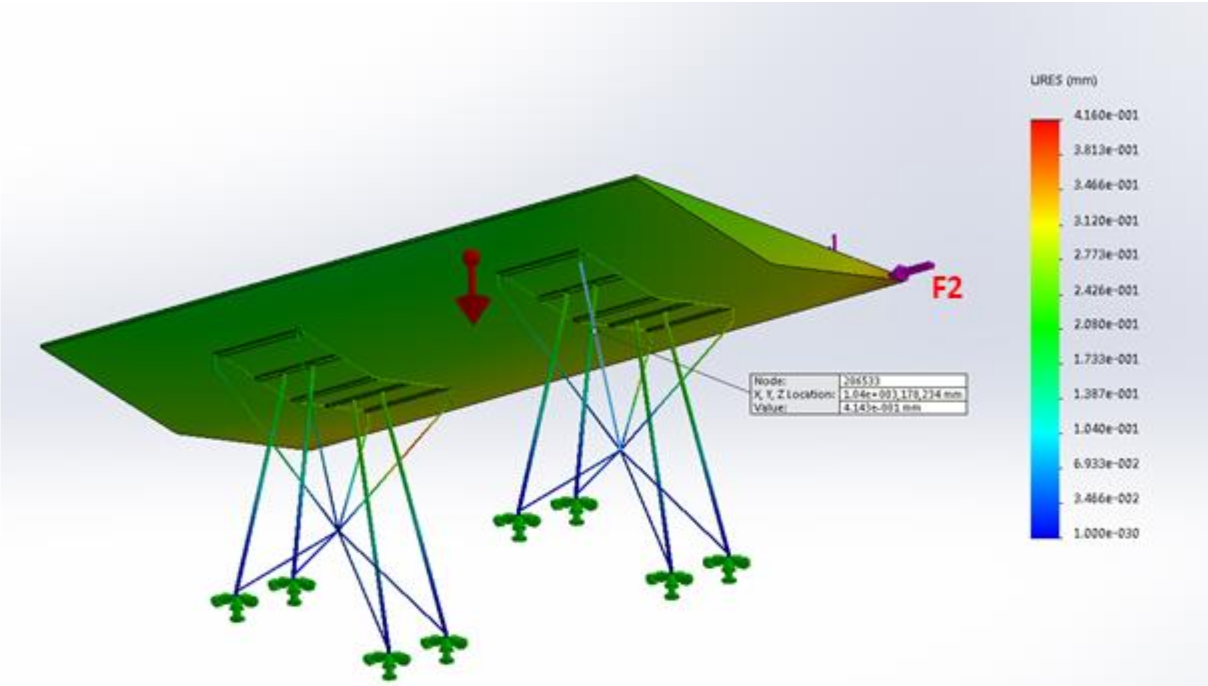


Figure 70. Horizontal durability test. Force 2. Total deformation.

4.3.3 Further decisions regarding dining table product design

Conclusively it can be said that using simulation program for virtual testing the products was essential phase while prototyping, because of relatively same results. Compared to laboratory tests positive aspect of simulation was that the results were accurately measurable and gave proof that the dining table metal legs can resist to applied load according to test procedure.

Considering the fact that programs may not be able to simulate all situations that may occur in reality, further testing in laboratory needs to be carried out regarding dining table. Aside from metal construction, sandwich panel requires thorough laboratory testing to assure if it withstands the testing conditions.

CONCLUSIONS

Investigating target market gave understanding that strong and sustainable design were the key factors for entering Northern and The Netherlands market.

Furniture tests in Laboratory for Furniture and Wood Materials Testing indicated that being present during testing procedure was as important as examining the results. While the testing rig applied relevant pressure, it was clearly seen how it temporarily influenced the whole construction. Even if nothing broke, the understanding of how the product deformed was vital for making improvements.

Already during seat static load test it was clear that Bar stool_2 seat plate had wrong wood grain direction. This was a major flaw in product design and this mistake has to be prevented in the future. While in the first tests the seat plate deformed when pressure was applied, during seat impact test first cycle the plate was broken along glue connection of boards.

Foot rest static load test had another interesting result. While in first glance using tube instead of rod material should have given it bigger strength, the result was opposite. Although applied pressure had unrealistic value, it showed clearly how important was the selection of materials. This result could not have been predicted without laboratory testing and therefore played an important role in product development.

Program based simulations were created form bar stool and dining table. While dining table prototype did not get ready on time it was possible to compare the virtual test results to real test according to the test standards using bar stool. The simulation came out to be very accurate, in some cases the deformations were even bigger than what was defined in Laboratory for Furniture and Wood Materials Testing.

Dining table was tested for horizontal cycling load using Solid Works simulation. The importance was to see how the legs will deform and as a result no major distortions were pointed out. Nevertheless dining table needs to be tested in the furniture testing lab, because wood cannot be defined using simulation and therefore table top needs additional analysis.

Case studies implicated the importance of furniture testing. How accurate can program simulation be to real situation and what are the weak points of product design. Hence it is important to use simulation programs like ANSYS Workbench and Solid Works in product development and in the final phase make the expense to test the products in Laboratory for Furniture and Wood Materials Testing to get the products certificated.

SUMMARY

The idea of this work was to investigate what international furniture market demands from design and how to add value to a small sized furniture exporter. This paper was mainly written for Tallinn University of Technology for thesis but will be used in the future for the development of design furniture company. It will give an insight of the overall importance of furniture testing in Estonian creative industry. This in turn can provide designers with valuable information regarding product development and testing the furniture.

Specific target market was chosen to investigate the demand factors. The countries were chosen based on their location and design awareness. In general Northern countries and The Netherlands became target market.

Investigation of competitors and target market, gave data about this segment demands sustainable design with witty details. Customers from these countries had higher expectations in quality and they were willing to pay more for designer furniture in order to add value to their lives.

Target market research gave a platform for starting product development, based on gathered information. The idea was to produce product line and test all items in furniture testing laboratory. In the end only two items were designed due to limited time resources.

All products were designed based on same aesthetics, implicating that they had to be strong, sustainable and lightweight. X-shape in the middle became the distinctive look for both bar stool and dining table. After sketching and model making the products were visualised by using 3D program to redefine all possible constructional mistakes. After completing previous phases, technical drawings were made.

Before testing the products, manufacturers had to be found, in order to produce the prototypes. Companies were chosen based on their productivity rate and readiness for export. Several agreements were made but declined due to various reasons, leading to production of only one product - bar stool.

Bar stool development involved changing of materials and properties on the run. At the end two prototypes were created and tested in the furniture testing laboratory. The results defined overall design to be ready for production, although minor details needed changing.

As dining table prototype did not get ready in the timeframe of this thesis, program based simulation about leg deformations was created. It was essential to use computer program for testing due to high price level of prototyping. Deformations occurred were almost non-existent, but additional prototype testing in laboratory must be carried out in the future.

After completing product development based on EU standards, it can be said that testing designer furniture in laboratory plays important role in product development, thereby helping designers to understand product design limits, regarding strength and durability.

RESÜMEE

Antud lõputöö eesmärk oli uurida, millised on rahvusvahelise mööblituru nõuded disainmööblile ning kuidas lisada väärtust ekspordile keskendunud väikeettevõttele. Eelkõige on see valminud Tallinna Tehnikaülikooli magistritöö raames, kuid leiab tulevikus kasutust mööblifirma asutamisel. Antud töö näitab mööblitestimise olulisust Eesti disainivaldkonnas, mis omakorda võiks pakkuda disaineritele kasulikku informatsiooni toodete arendamisel ja testimisel.

Mõistmaks välisriikides valitsevaid trende ning nõudeid toodetele sai välja valitud sihtgrupp. Riigid valiti vastavalt lokatsioonile ning disaini teadlikkusele. Üldisemas mõistes moodustasid sihtgrupi Põhjamaad ja Holland.

Läbi sai viidud põhjalik analüüs uurimaks sihtgruppi ja otseseid konkurente. Kogutud informatsiooni põhjal võis järeldada, et antud turg eelistab jätkusuutlikku disaini ühes hoolikalt planeeritud detailidega, mis on sertifitseeritud ja testitud vastavalt ülemaailmsetele standarditele. Eelpool nimetatud riikides esines kõrgem ootus kvaliteedi suhtes ning disainmööbli eest oldi nõus rohkem maksma, tõstmaks oma elukvaliteeti.

Põhjalik turuuuring andis platvormi alustamaks tootedisainiga. Eesmärk oli valmistada tooteseeria ning testida kõiki tooteid mööblitestimislaboris. Tänu limiteeritud ajale valmisid kokkuvõttes vaid kaks toodet – baaripukk ja söögilaud.

Mõlema toote disain põhines samadel alustaladel: kvaliteet, kergus ning aegumatu disain. Geomeetriline x-vorm toote keskel kujunes nii baaripuki kui söögilaua äratuntavamaks jooneks. Visandamisele ning maketeerimisele järgnes 3D programmeerimine, elimineerimaks tehnoloogilisi vigu. Pärast eelpool nimetatud protsesse, valmisid antud toodete kohta tööjoonised.

Mööblitestimisele eelnes koostööpartnerite leidmine, kes oleksid nõus valmistama vajalikud prototüübid. Tootjapõhine valik sai tehtud vastavalt firma tootlikusele ning ekspordi valmisolekule. Sõlmitud sai mitmed kokkulepped, kuid erinevatel põhjustel lükati need tagasi, mistõttu valmis vaid baaripuki prototüüp.

Baaripuki tootearendus kätkes endas materjalide ja proportsioonide vajaduspõhist muutmist. Protsessi käigus valmisid kaks prototüüpi, mida testiti mööblitestimislaboris. Antud katsete tulemusena võis tõdeda, et toode on tootmiskõlbulik, kuigi mõningad muudatused tuleb sisse seada.

Kuna söögilaua prototüüp ei saanud antud töö raames valmis, koostati programmipõhine simulatsioon defineerimaks deformatsioone, mis võivad lauajalgades ilmneda. Laua testimine läbi arvutiprogrammi oli majanduslikult oluline, kuna prototüübi omahind oleks tõusnud võrdlemisi kõrgeks. Testimise käigus tekkinud deformatsioonid olid silmale nähtamatud, kuid vaatamata sellele on lauda tarvis testida tulevikus ka mööblitestimislaboris.

Pärast tootearendusprotsessi, mis põhines EU standarditel, võib järeldada, et disainmööbli testimine laboritingimustes, mängib olulist rolli tootearendus protsessis, aidates disaineritel mõista materjalide ja proportsioonide limiite, mis mõjutavad toote vastupidavust ja tugevust.

REFERENCES

1. The University of Birmingham (2004) *“Collins Cobuild advanced learner's English dictionary”* HarperCollins Publishers, Glasgow, Great Britain
2. Jobber, D. (2007), *“Principles and Practice of Marketing (5th Edition)”*, McGraw-Hill Education, United Kingdom
3. *“Business Dictionary”* http://www.businessdictionary.com/ (20.04.2015)
4. *“The free Dictionary”* http://www.thefreedictionary.com/ (20.04.2015)
5. Mr.Johan Jonkers (2006), *“CBI market survey. The Domestic Furniture Market in the EU”*, CBI, Netherlands
6. International Trade Centre (2005), *“International Wooden Furniture Markets. A review”* Geneva, Switzerland
7. Natalia Abramovich (2014), *“The image and perception of Scandinavian products in the minds of British consumer in Britain in relation to the consumer in Scandinavia.”* Aalborg University
8. *“Design forum Finland”* http://www.icsid.org/members/listing/member_list112.htm (23.11.2014)
9. Ornamo (2013), *“Finnish design sector in numbers”* Finland, Helsinki
10. CBI (2008), *“The bedroom furniture market in Finland”* Ministry of Foreign Affairs, Finland
11. *“Furniture”* http://www.tukes.fi/en/Branches/consumer-safety/Safety-requirements-for-products-/Furniture-/ (15.04.2015)
12. Design Forum Finland (2006) *“Branding Finnish Design”* Finland
13. Pisa, C. (2008), *“Furniture industry in Norway”* CSIL Milano scrl, Milano, Italy
14. *“Möbelfakta furniture standard”* http://www.mobelfakta.no/?lang=en_GB (23.11.2014)
15. Solum, N.H. (2004), *“Country report: Norwegian design industry”* Nordic Innovation Centre, Oslo
16. *“Marketing a Business in Norway”* http://www.startupoverseas.co.uk/starting-a-business-in-norway/marketing-a-business.html (23.11.2014)
17. *“Market and export”* http://www.tmf.se/bransch/mobler/marknad (23.11.2014)
18. *“Design”* http://www.studyinholland.co.uk/design.html (23.11.2014)
19. Buruma, H. (2012) “Guide to doing business in the Netherlands” In-house council practical guide
20. *“Artek homepage”* http://www.artek.fi/ (05.05.2015)
21. *“Swedese homepage”* http://www.swedese.se/ (05.05.2015)
22. *“Furniture company Fjordfiesta homepage”* http://fjordfiesta.com/ (05.05.2015)
23. *“HAY homepage”* http://hay.dk/ (05.05.2015)
24. *“Moooi homepage”* http://www.moooi.com/ (05.05.2015)
25. “*EVS-EN 15372:2008 Furniture - Strength, durability and safety - Requirements for non-domestic tables”* Eesti Standardikeskus (2008)
26. *“EN 1335-1:2000 Office furniture - Office work chair - Part 1: Dimensions - Definition of dimensions”* Eesti Standardikeskus (2000)
27. *“EVS-EN 16139:2013 Furniture - Strength, durability and safety - Requirements for non-domestic seating”* Eesti Standardikeskus (2013)
28. Ashby, M. & Johnson, K. (2014) *“Materials and design : the art and science of material selection in product design”* Elsevier Butterworth-Heinemann, Amsterdam
29. Kula, D. & Ternaux, É. (2014) *“Materiology. The Creative Industry's Guide to Materials and Technologies”* Birkhäuser Basel, Amsterdam
30. “Angle grinder” http://www.makitatools.com/en-us/Modules/Tools/ToolDetails.aspx?Name=9005B 19.05.2015
31. Thomson, R. (2011)“The manufacturing guides Product and furniture design” Thames & Hudson, United Kingdom
32. Thomson, R. (2011)“The manufacturing guides Prototyping and low-volume production” Thames & Hudson, United Kingdom
33. Bergman, R. (2010) *“Wood Handbook, Wood as an Engineering Material”* Forest Products Laboratory, U.S.

34. *“Wooden materials”* http://www.mass.ee/ (04.05.2015)
35. *“MDF Manual”* http://cbt.eu-gateway.jp/wp-content/uploads/2014/04/MDF-manual-ENG-LOW-RES.pdf (04.05.2015)
36. *“Hydraulic veneer press”* http://www.directindustry.com/prod/langzauner/veneer-press-hydraulic-21879-306618.html (04.05.2015)
37. *“Felder Group homepage”* http://www.felderusa.com/us-us/products/saw-shapers/sawshaper-new-kf-700-s-professional.html (5.10.2014)
38. *“Makita tools”* http://www.makita.ee (09.05.2015)
39. *“Banding machine” http://homag.fm.alibaba.com/product/108339515-101510722/Edge_banding_machine.html 19.05.2015*
40. *“Tikkurila Unica Super Laquer”* http://www.tikkurila.ee/ehitus-_ja_remontvarvid/tooted/tooted_tahestiku_jarjekorras/lakid/unica_super_laikiv_-_puidulakk_sise-_ja_valistoodeks.2012.shtml (09.05.2015)
41. *“Flat socket bolt”* http://www.fmwfasteners.com/products/Flat-Socket-Cap-Screws-Metric/Class-12-9-Flat-Socket-Cap-Screws-DIN-7991-Alloy-Metric (09.05.2015)
42. *“Beech dowel”* https://www.festool.com/Products/Accessories/Pages/Variations.aspx?pid=495661&ppid=574325&cat=ol_duebelfraese_df_500_3675 (09.05.2015)
43. *“Standardisointi”* http://www.puusepanteollisuus.fi/standardisointi/ (16.04.2015)
44. *“Testing machines and measurement technology”* http://www.hegewald-peschke.com/ 24.05.2015
45. *“EVS-EN 1728:2012 Furniture - Seating - Test methods for the determination of strength and durability”* Eesti Standardikeskus (2012)
46. “EVS-EN 1730:2012 Furniture - Tables - Test methods for the determination of stability, strength and durability” Eesti Standardikeskus (2012)

APPENDIX 1

NORTHERN COUNTRIES AT GLANCE

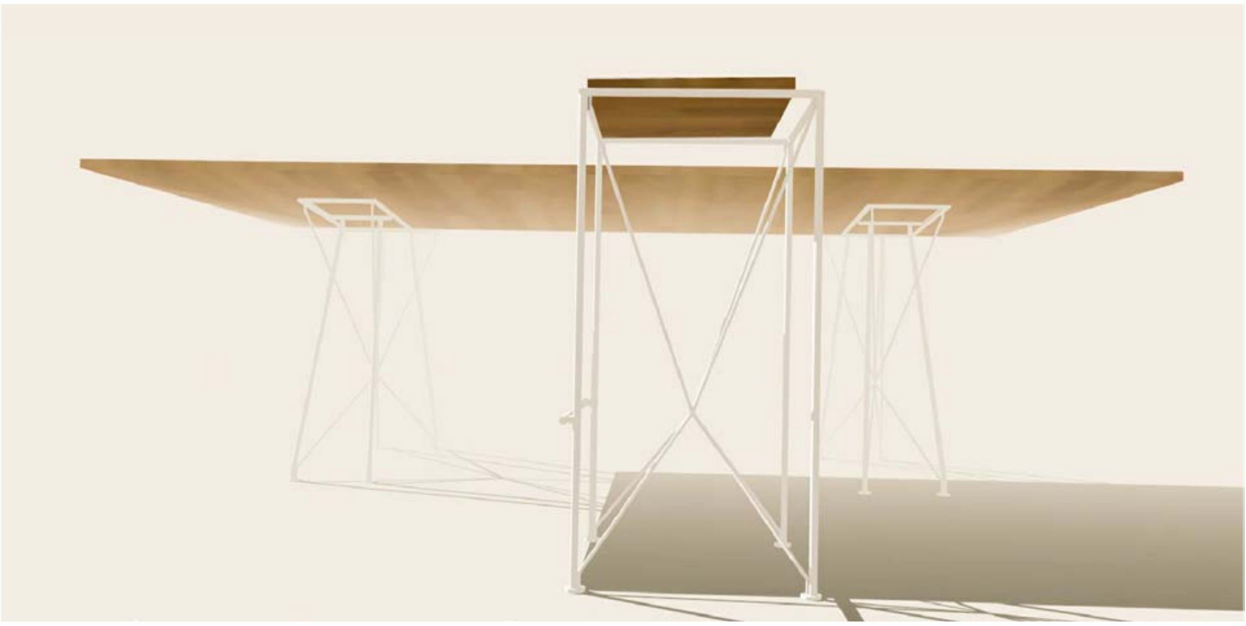
	Denmark	Finland	Norway	Sweden	The Netherlands
Government	Liberal-conservative coalition. Parliamentary election in 2011	Majority coalition formed by the National Coalition Party, the Social Democratic Party, the Left Alliance, the Swedish People's Party in Finland, the Green League and the Christian Democratic Party.		The Moderate Party	Constitutional monarchy with a parliamentary system. The Dutch parliament consists of the Second Chamber and the First Chamber
Constitution	Monarchy with multi-party parliamentary democracy. Queen Margrete II	Republic with a multi-party, parliamentary democracy. President Ms Tarja Halonen	Monarchy with a multi-party, parliamentary democracy. King Harald V	Monarchy with a multi-party, parliamentary democracy. King Carl XVI Gustav	Constitutional monarchy with a parliamentary system.
Population	5.5 million	5.4 million	4.6 million	9.4 million	16.8 million
Number of households	2.9 million	2.5 million (2009)		4.6 million (2008)	
Population density	126 inhabitants per km²	15.8 inhabitants per km²		22.8 inhabitants per km²	
Area	43,095 km²	338,424 km²	385,155 km², incl. Svalbard 61,020 km²	449,664 km²	41,526 km²
Climate	Temporate climate. Four distinct seasons: Spring: March, April, May Summer: June, July, August Autumn: September, October, November, Winter: December, January, February	Four distinct seasons. Great contrasts – cold winters and fairly warm summers. Average temperature and precipitations: Helsinki: January –4.2°C and 47mm, July 17.2°C and 62mm. Jyväskylä: January –8.5°C and 43mm, July 16.0°C and 79mm. Sodankylä: January –14.1°C and 35mm, July 14.3°C and 63 mm	Four distinct seasons and large local variations	Four distinct seasons with large variations between south and north. Average temperature and precipitations: Stockholm: January –3°C and 30–40mm, July 18°C and 80mm. Malmö: January 0°C and 50mm, July 18°C and 70mm. Kiruna: January –16°C and 30mm, July 14°C and 80mm.	41,526 km²
Language	Danish	Finnish and Swedish	Norwegian	Swedish	Dutch and Frisian
Business language	English	English	English	Swedish and English	Dutch and English
Weight and measures	The metric system	The metric system	The metric system	The metric system	The metric system
Currency	Danish krone (DKK) (linked to the Euro)	Euro (EUR)	Norwegian krone (NOK)	Swedish krona (SEK)	Euro (EUR)
Capital	Copenhagen	Helsinki	Oslo	Stockholm	Amsterdam
Time zone	Central European Time zone: One hour ahead of GMT. From the end of March to the end of October two hours ahead of GMT.	Eastern European Time zone: Two hours ahead of GMT. From the end of March to the end of October three hours ahead of GMT.	Central European Time zone (see Denmark)	Central European Time zone (see Denmark)	Central European Time zone. One hour ahead of GMT.
Business hours	Monday to Friday 9 a.m. to 5 p.m.	Monday to Friday 8 a.m. to 4 p.m.	Monday to Friday 8 a.m. to 4 p.m.	Monday to Friday 8 or 9 am to 5 p.m.	Monday to Friday 10 a.m. to 6.30 p.m.
Banking hours	Monday to Friday 10 a.m. to 4 p.m.	Monday to Friday 9.15 am to 4.15 p.m.	Monday to Friday 9 a.m. to 3 p.m., Thursday until 4.30 p.m. except in the summer	Monday to Friday 10 a.m. to 3 or 4/5.30 p.m. (banks close at 6 p.m. in the bigger cities)	Monday to Friday 9 a.m. to 6.00 p.m.
Public holidays	New Year's Day: January 1st, Easter: (Maundy Thursday, Good Friday, Easter Monday) Great Praying Day Ascension Day Whitsun: Sunday and Monday Constitution Day 5 June (half-day holiday) Christmas: 24 (half-day), 25 and 26 December	New Year's Day January 1st, Epiphany: 6 January, Easter: (Maundy Thursday, Good Friday, Easter Monday) Labour Day: 1 May Ascension Day Midsummer's Eve: Friday between 19–25 June Independence Day: 6 December Christmas: 24–26 December New Year's Eve: 31 December	New Year's Day: January 1st, Easter: (Maundy Thursday, Good Friday, Easter Monday) Labour Day: 1 May Constitution Day: 17 May Ascension Day Whitsun: Sunday and Monday Christmas: 25 and 26 December	New Year's Day January 1st, Twelfth night: 5 January, Twelfth day: 6 January, Easter: (Maundy Thursday, Good Friday, Easter Monday) Walpurgis Night: 30 April Labour Day: 1 May Ascension Day National Day: 6 June Midsummer's Eve: Friday between 20–26 June Christmas: 24–26 December New Year's Eve: 31 December	New Year's Day January 1st, Good Friday 18 April, Easter, Easter 20-21 April, King's 27 April, Liberation Day 5 May, Ascension Day 29 May, Pentecost, 8-9 June, Christmas, 25-26 December

APPENDIX 2

VIEW 1

VIEW 2

VIEW 3



-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer. These drawings will be approved by the Client and the Designer.

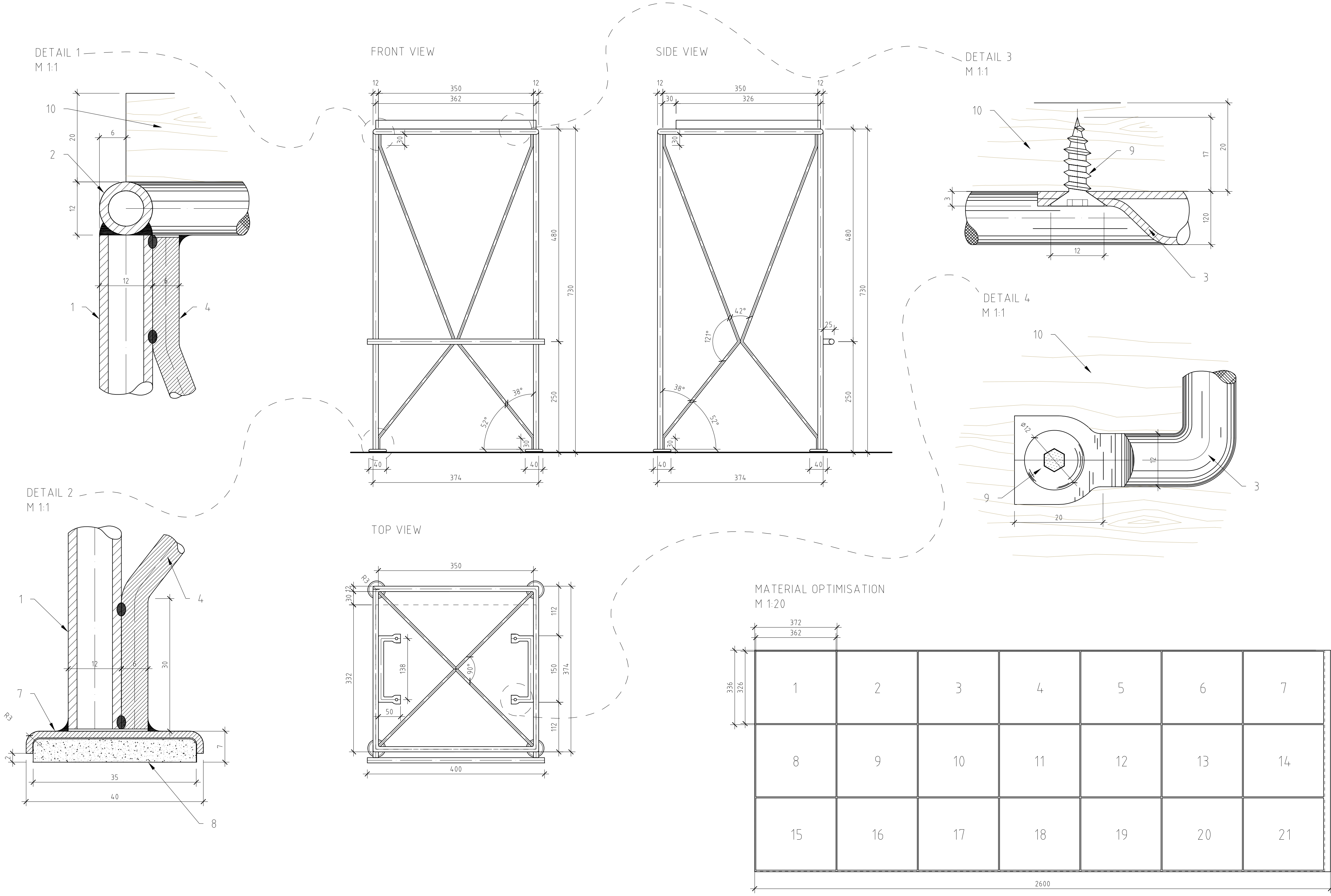
Project: Final Thesis	Client:	Format: A4	Scale: 1:10
Drawn by: Piret Noor	Title: Bar stool. 3D Views		
Date: 01.06.2015			
Stadium: Furniture project			
Tallinn University of Technology Chair of Woodworking	Sheet: 1/1	DWG. No. FP-01.1	

APPENDIX 3

Item	Pos	Description	Part No	QTY
		Documentation		
		Bar stool. Assembly Drawing	FP-01.4	
		Parts		
1		Supporting leg	1	4
2		Leg frame	2	1
3		Seat support	3	2
4		Center leg	4	4
5		Footrest	5	1
6		Footrest fixer	6	2
7		Furniture glide	7	4
8		Seat plate	10	1
		Standard Parts		
9		Leg pad	8 / FP-01.3	4
10		Bolt	9 / M6 / DIN7991 / 20mm	4

Drawn By:	Piret Noor	Title: Bar stool. Parts list	
Date:	01.06.2015		
Stadium:	Furniture project		
Tallinn University of Technology Chair of Woodworking		Sheet: 1/1	DWG No: FP-01.2

APPENDIX 4



MATERIALS:

1./2./5./6. Ø12mm metal tube / powdercoated / RAL9016 (white)
3. Ø12mm bent and hewn metal tube / powdercoated / RAL9016 (white)
4. Ø6mm metal rod / powdercoated / RAL9016 (white)
7. Ø40mm metal furniture glide / powdercoated / RAL9016 (white)
8. Ø35mm felt pad / white
9. M6 bolt / DIN7991 / powdercoated / RAL9016 (white)
10. Glued laminated timber / oak / long lamella / quality A/B
   Cut out from 20x1000x2600mm (21pieces)
   For additional information, see drawing FP-01.4

NOTE! All metal details are welded together.

QUANTITY:

For making one bar stool, one metal leg and seat plate is needed.

COMMENTS:

- All corner details are bent, welding is done aside the corner and sanded.
- Connection of 4 x Ø6mm details is made with a single weld in the center.
- Details 4 and 5 can be traded for standard parts only when looking alike.
- All drilling holes in metal frame are bevelled for M6 bolt.
- For making seat plate, 20mm glued laminated timber plate is cut into shape and bevelled perimetrally 7mm.
- Pre-drilling is done into seat plate for M6 bolts.
- Seat plate is connected onto bent and hewn metal tube and fixed with bolts. For additional information, see Detail 3 and 4.
- The seat plate is placed in the middle section of Ø12mm metal frame.

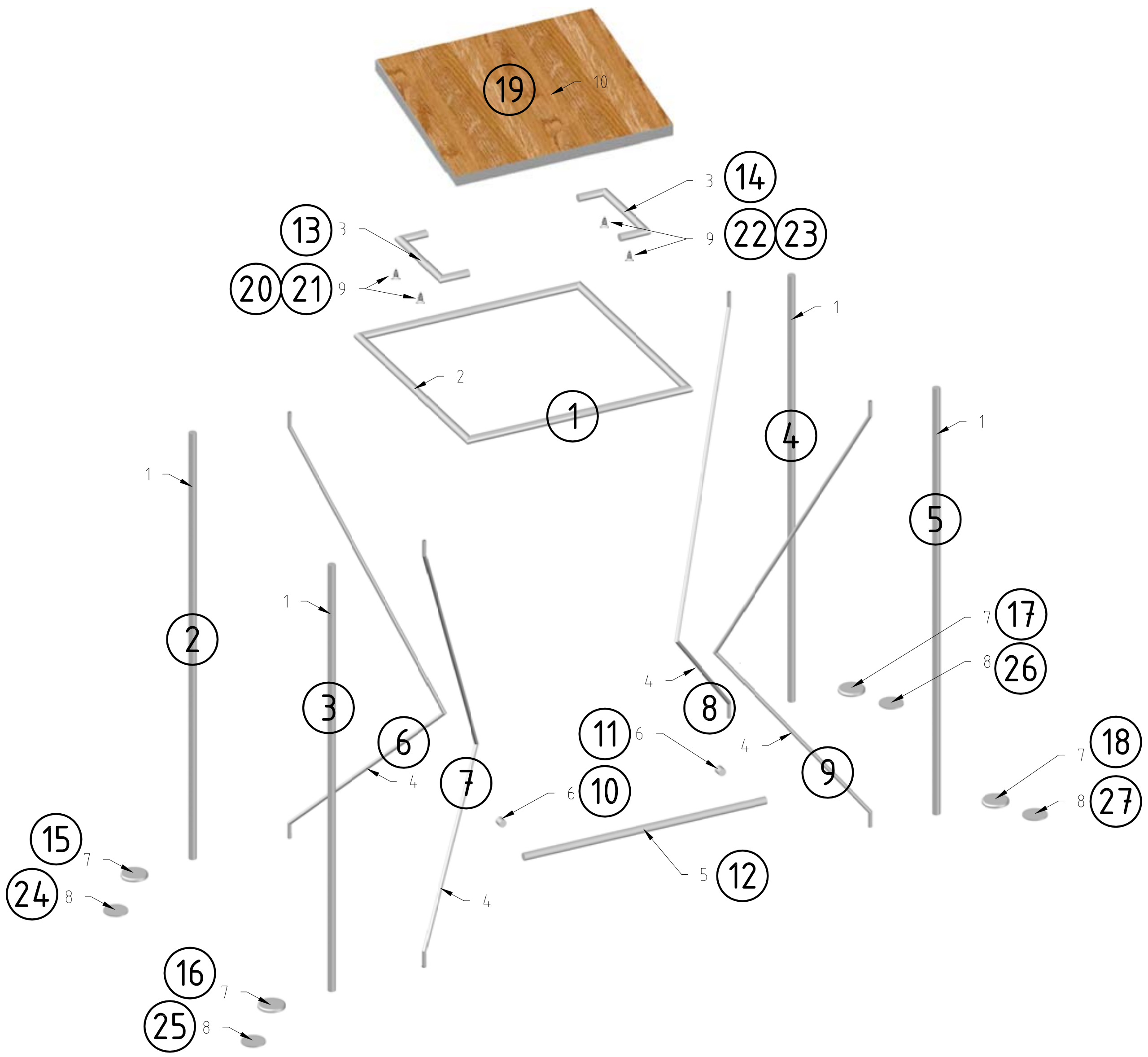
CUTTING OF PLATES:

Seating plates are cut from 20X1000X2600mm glued laminated timber plate.
Making it more efficient for mass production.
From one plate 21 pieces of seats are cut out, with the calculation of 5mm kerf.
By using bigger plate the loss of material is 31096mm²=0,031m²

-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer. These drawings will be approved by the Client and the Designer.

Project: Final Thesis	Client:	Format: A3	Scale: 1:10
Drawn by: Piret Noor	Title: Bar stool. Metal leg assembly drawing		
Date: 01.06.2015			
Stadium: Furniture project			
Tallinn University of Technology Chair of Woodworking	Sheet: 1/2	DWG. No. FP-01.3	

APPENDIX 5



Assembly drawing					
ITEM NO.	PART NO.	DESCRIPTION	MATERIAL	QTY.	DIMENSIONS
1	FP-02.3	Supporting leg	ϕ12mm metal tube	4	710mm
2	FP-02.3	Leg frame	ϕ12mm metal tube	1	1445mm
3	FP-02.3	Seat support	ϕ12mm metal tube	2	225mm
4	FP-02.3	Center leg	ϕ6mm metal rod	4	880mm
5	FP-02.3	Footrest	ϕ12mm metal tube	1	400mm
6	FP-02.3	Footrest fixer	ϕ12mm metal tube	2	13mm
7	FP-02.3	Furniture glide	2mm metal sheet	4	ϕ40mm
8	FP-02.3	Leg pad	5mm felt	4	ϕ35mm
9	M6	Bolt	Metal	4	M6 / DIN7991 / 20mm
10	FP-02.4	Wooden seat	Glued laminated timber	1	20x362x326mm

-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer.
These drawings will be approved by the Client and the Designer.

Project: Final Thesis	Client:	Format: A3	Scale: 1:10
Drawn by: Piret Noor	Title: Bar stool. Assembly drawing		
Date: 01.06.2015			
Stadium: Furniture project			
Tallinn University of Technology Chair of Woodworking	Sheet: 2/2	DWG. No. FP-01.4	

APPENDIX 6

VIEW 1

VIEW 2

VIEW 3

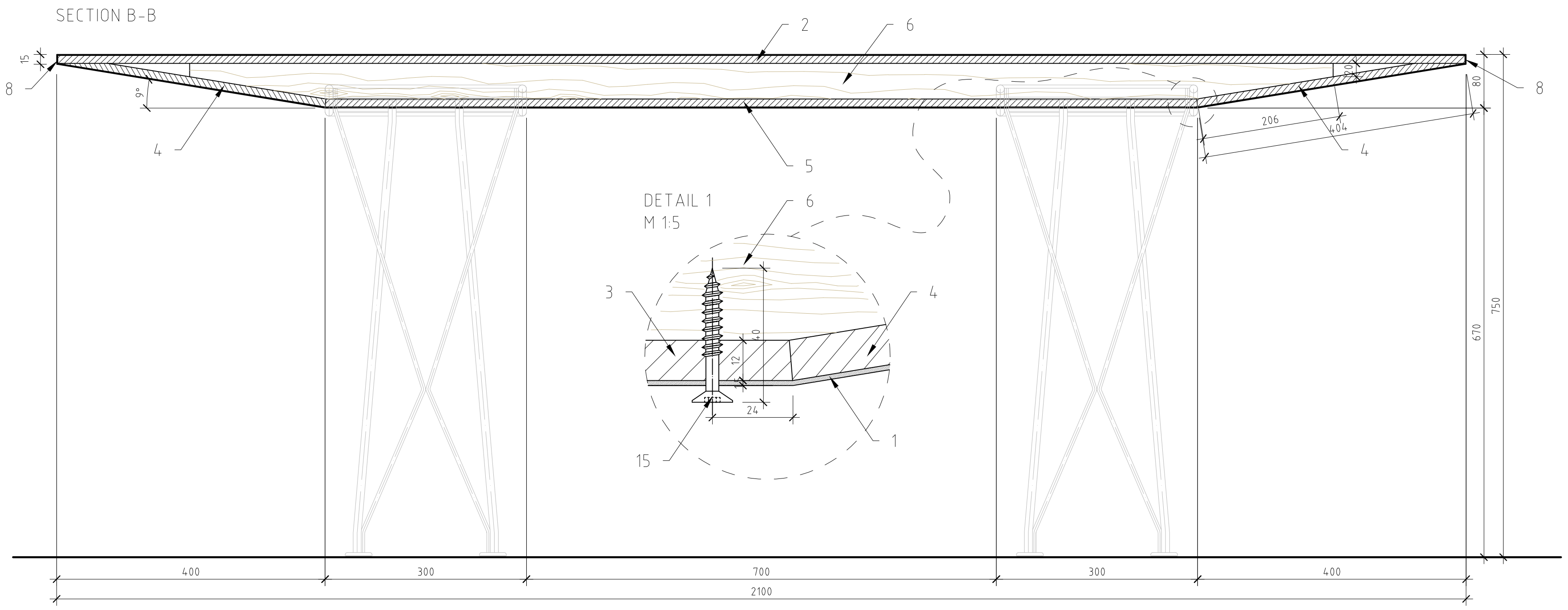
-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer. These drawings will be approved by the Client and the Designer.

Project: Final Thesis	Client:	Format: A4	Scale: 1:10
Drawn by: Piret Noor	Title: Dining table. 3D Views		
Date: 01.06.2015			
Stadium: Furniture project			
Tallinn University of Technology Chair of Woodworking	Sheet: 1/1	DWG. No. FP-02.1	

APPENDIX 7

Item	Pos	Description	Part No	QTY
		Documentation		
		Dining table. Assembly Drawing	FP-02.5	
		Parts		
1		Overlay	1	1
2		Top panel	2	1
3		Side panel, long	3	2
4		Side panel, short	4	2
5		Base panel	5	1
6		Support rib, center	6	1
7		Support frame, side	7	2
8		Edge band	8	1
9		Metal frame	9	1
10		Separator	10	6
11		Supportive leg	11	8
12		Center leg	12	8
13		Furniture glide	13	8
		Standard Parts		
14		Leg pad	14 / FP-02.3	8
15		Bolt	15 / M6 / DIN7991 / 40mm	12
16		Beech dowel	16 / Festool DOMINO DF 500 / 8mm	80

Drawn By:	Piret Noor	Title: Dining table. Parts list	
Date:	01.06.2015		
Stadium:	Furniture project		
Tallinn University of Technology Chair of Woodworking		Sheet: 1/1	DWG No: FP-02.2



APPENDIX 8

MATERIALS:

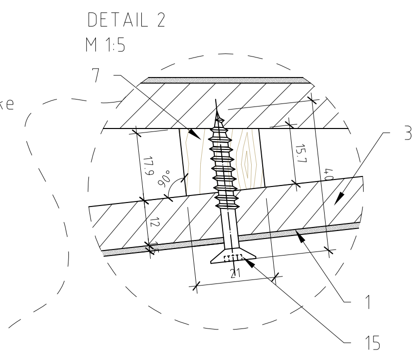
1. 1.5mm Oak veneer overlay.
2. 12mm MDF panel / 1200x2100mm / finish: oak veneer overlay.
3. 12mm MDF panel / 712x2100mm / finish: oak veneer overlay.
4. 12mm MDF panel / 712x1200mm / finish: oak veneer overlay.
5. 12mm MDF / 21x1300mm / finish: oak veneer overlay.
6. 21mm Plywood rib / 53x1700mm / joined onto MDF panels using beech dowels.
7. 21mm Kertopuu rib / 18x1700mm / joined onto MDF panels using beech dowels.
8. 1.5mm Oak veneer edge band / total lenght 6.6m.

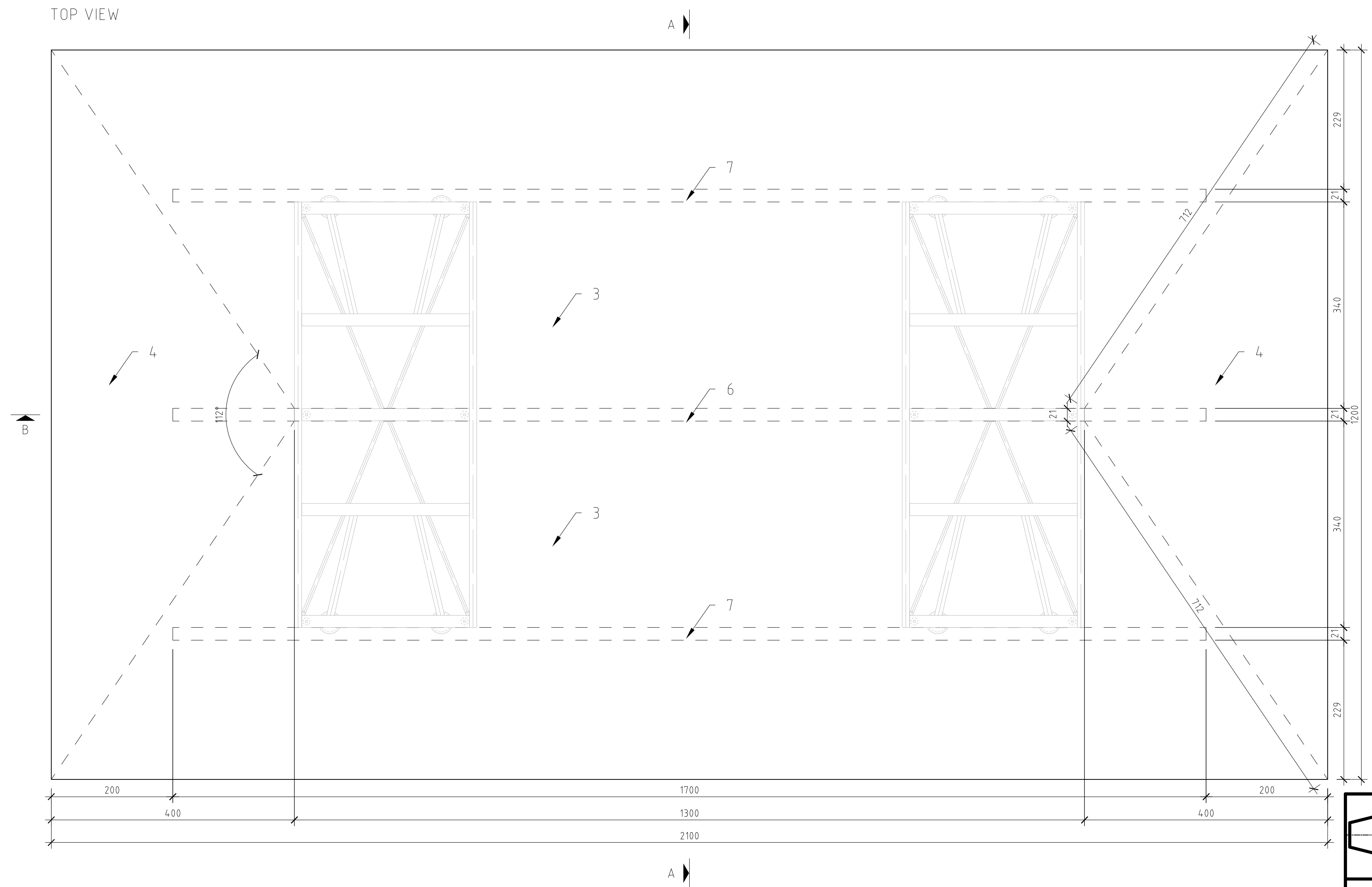
QUANTITY:

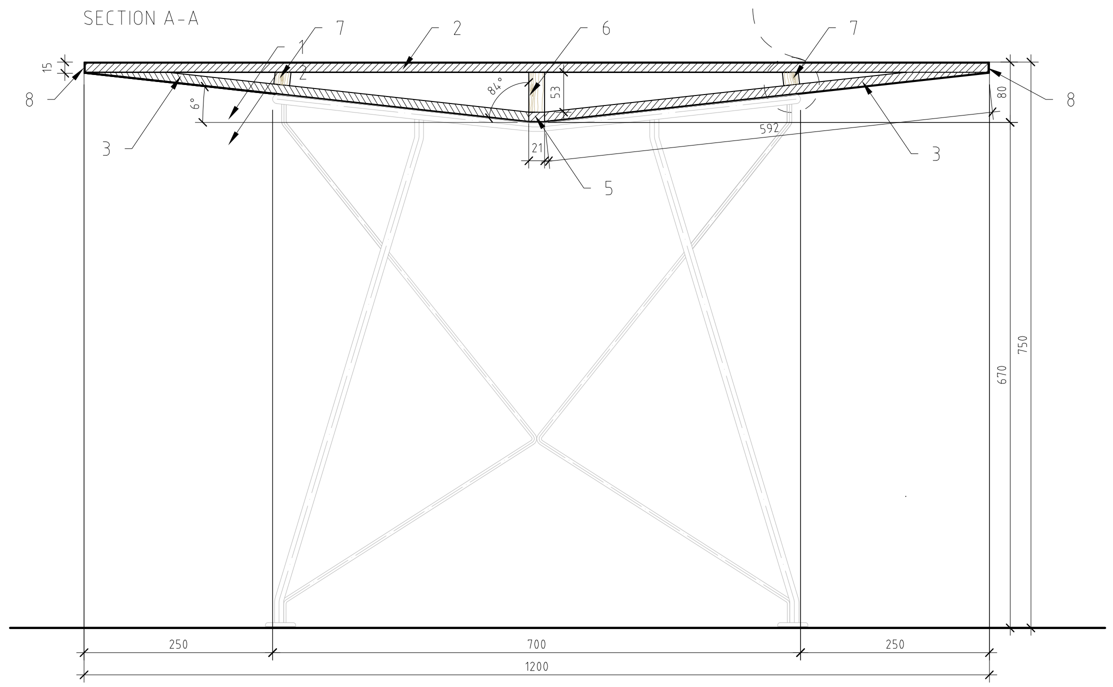
For making one dining table, two sets of metal legs and one tabletop is needed.

COMMENTS:

- All corner details are bent, welding is done aside and sanded down
- Connection of 4 x Ø6mm details is made with a single weld in the center
- Details 13 and 14 can be traded for standard parts only when looking alike
- All drilling holes in metal frame are bevelled for M6 bolt
- Pre-drilling is done into tabletop for M6 bolts
- For making tabletop shuttering is used.
- Tabletop is flat from the bottom (21mm) for fastening M6 bolts.



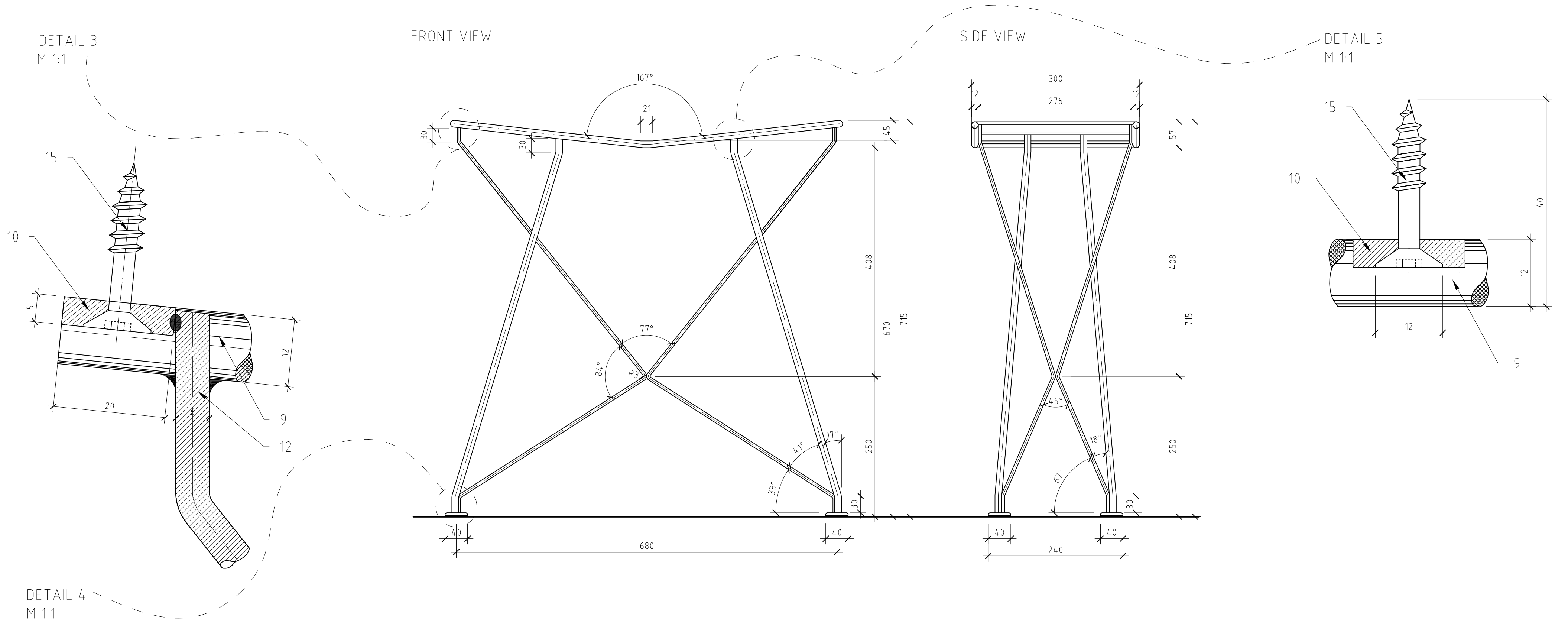


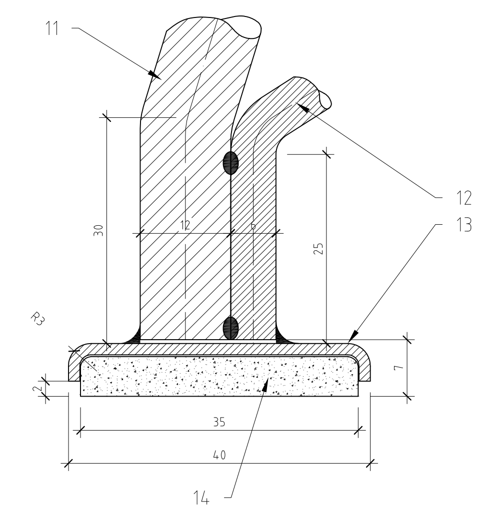


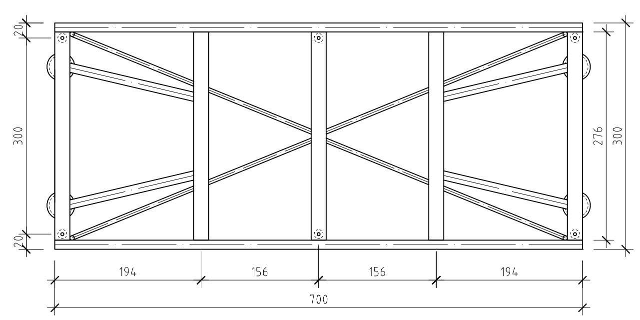
-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer.
These drawings will be approved by the Client and the Designer.

Project: Final Thesis		Client:	Format: A3	Scale: 1:10
Drawn by:	Piret Noor	Title: Dining table. Table top detail drawing		
Date:	01.06.2015			
Stadium:	Furniture project			
Tallinn University of Technology Chair of Woodworking		Sheet: 1/3	DWG. No. FP-02.3	

APPENDIX 9







MATERIALS:

9./11. Φ12mm metal rod / powdercoated / RAL9016 (white)
10. 5x20mm metal sheet separator / powdercoated / RAL9016 (white)
12. Φ6mm metal rod / powdercoated / RAL9016 (white)
13. Φ40mm grooved metal sheet / powdercoated / RAL9016 (white)
14. Φ35mm felt pad / white
15. M6 bolt / DIN7991 / powdercoated / RAL9016 (white)
16. Festool DOMINO DF 500 / 8mm / Beech dowel
NOTE! All metal details are welded together / TIG welding.

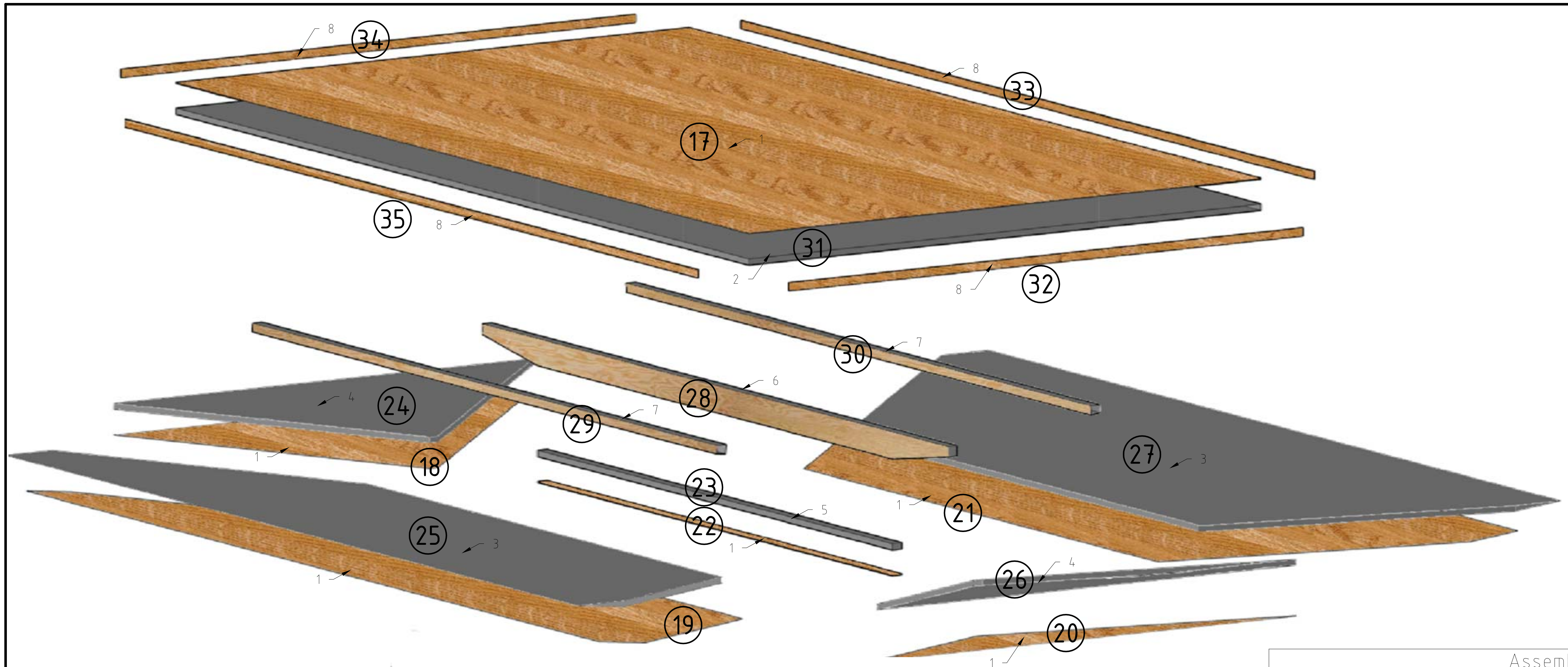
QUANTITY:
For making one dining table, two sets of metal legs and one tabletop is needed.

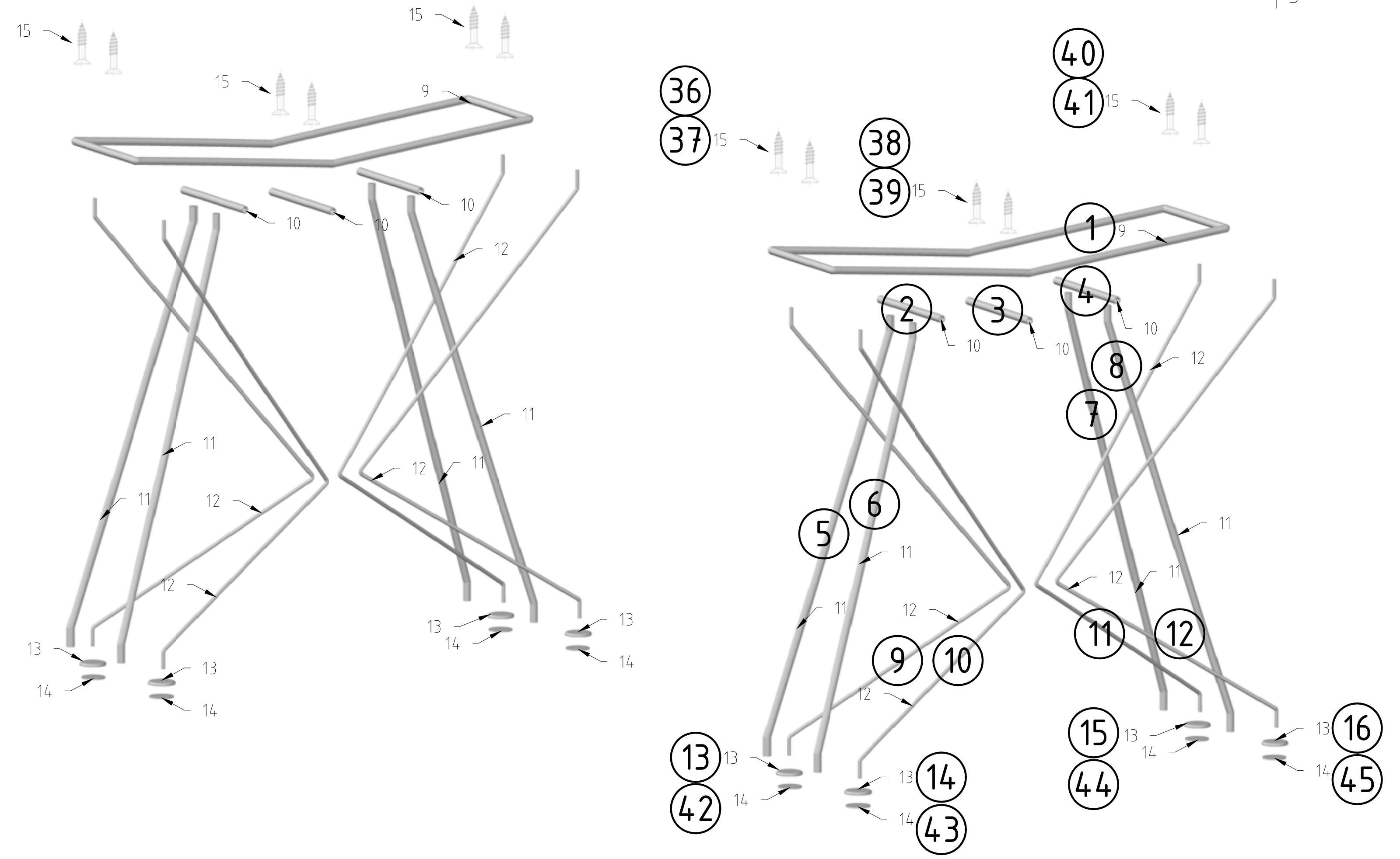
COMMENTS:
- All corner details are bent, welding is done aside and sanded down
- Connection of 4 x Φ6mm details is made with a single weld in the center
- Details 13 and 14 can be traded for standard parts only when looking alike
- All drilling holes in metal frame are bevelled for M6 bolt
- Pre-drilling is done into tabletop for M6 bolts
- For making tabletop shuttering is used.
- Tabletop is flat from the bottom (21mm) for fastening M6 bolts.

-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer. These drawings will be approved by the Client and the Designer.

Project: Final Thesis	Client:	Format: A3	Scale: 1:10
Drawn by: Piret Noor	Title: Dining table. Metal leg assembly drawing		
Date: 01.06.2015			
Stadium: Furniture project			
Tallinn University of Technology Chair of Woodworking	Sheet: 2/3	DWG. No. FP-02.4	

APPENDIX 10





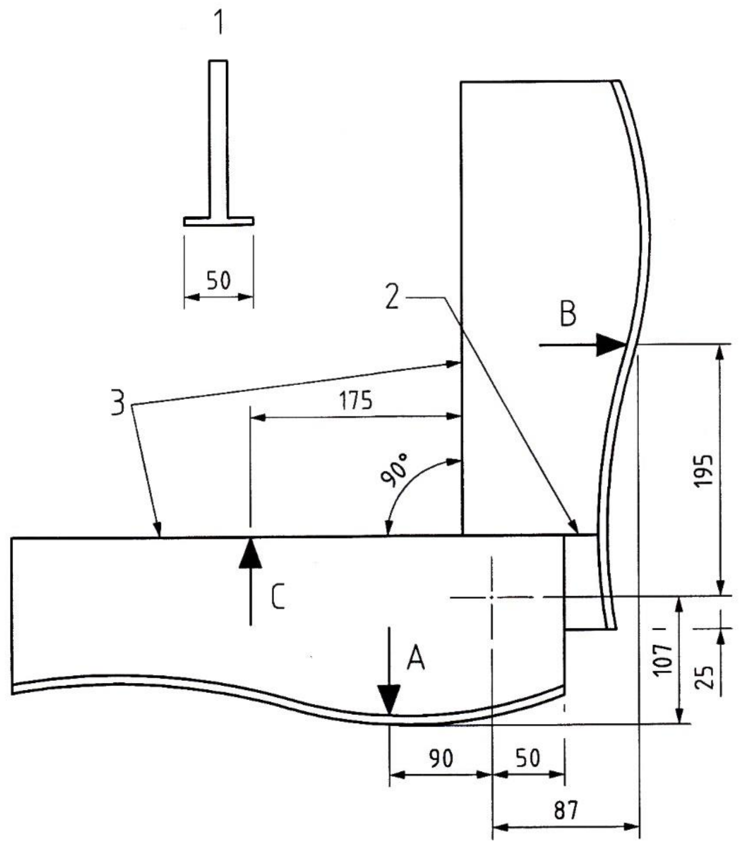
Assembly drawing					
ITEM NO.	PART NO.	DESCRIPTION	MATERIAL	QTY.	DIMENSIONS
1	FP-02.3	Overlay	Veneer	1	$0.012m^3$
2	FP-02.3	Top panel	MDF	1	12 x 1200 x 2100mm
3	FP-02.3	Side panel, long	MDF	2	12 x 712 x 2100mm
4	FP-02.3	Side panel, short	MDF	2	12 x 712 x 1200mm
5	FP-02.3	Base panel	MDF	1	12 x 21 x 1300mm
6	FP-02.3	Support rib, center	Plywood	1	21 x 53 x 1700mm
7	FP-02.3	Support frame, side	Kertopuu	2	21 x 18 x 1700mm
8	FP-02.3	Edge band	Veneer	1	1.5 x 15 x 6600mm
9	FP-02.4	Metal frame	Ø12mm metal rod	1	1760mm
10	FP-02.4	Separator	Sheet metal	5	5 x 20 x 247mm
11	FP-02.4	Supportive leg	Ø12mm metal rod	8	670mm
12	FP-02.4	Center leg	Ø6mm metal rod	8	1005mm
13	FP-02.4	Furniture glide	2mm metal sheet	8	Ø40mm
14	FP-02.3	Leg pad	5mm felt	8	Ø35mm
15	M6	Bolt	Metal	12	M6 / DIN7991 / 40mm
16	FP-02.5	Beech dowel	Solid wood	80	Festool DOMINO DF 500 8mm

-There is a principle solution for the construction shown on the present drawing. Stiffness and strength is given by the manufacturer. In case of need, the exact working drawings will be compiled by the furniture manufacturer. These drawings will be approved by the Client and the Designer.

Project: Final Thesis		Client:	Format: A3	Scale: 1:10
Drawn by:	Piret Noor	Title: Dining table. Assembly drawing		
Date:	01.06.2015			
Stadium:	Furniture project			
Tallinn University of Technology Chair of Woodworking		Sheet: 3/3	DWG. No. FP-02.5	

APPENDIX 11

LOADING POINT TEMPLATE [45]

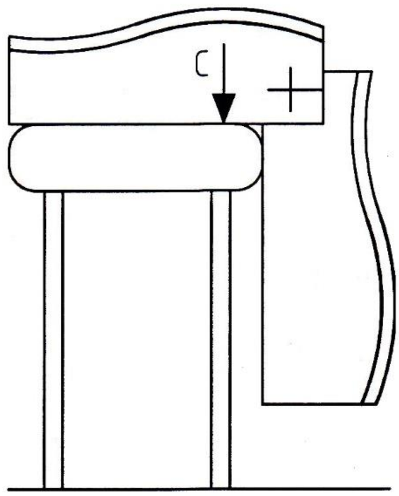


Key

1 Typical section
2 Mark to fix 90˚
3 Straight edge for the determination of seat or back indication
A Seat load (chairs)
B Back load (chairs)
C Seat load (stools)

APPENDIX 12

DETERMINATION OF SEAT LOADING POINT [45]

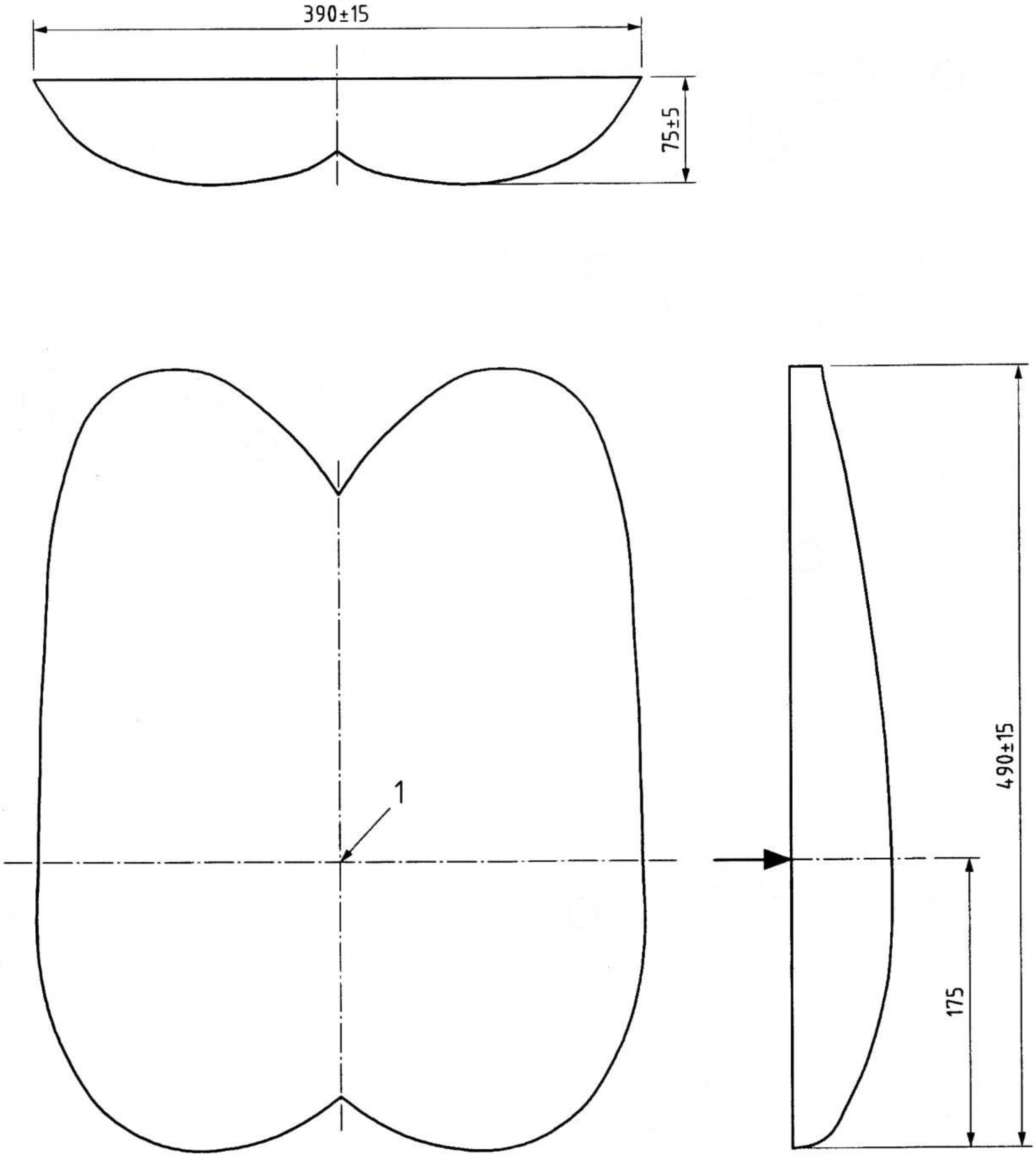


Key

A Seat loading point – seating with backs
B Back loading point
C Seat loading point – seating without backs

APPENDIX 13

SEAT LOADING PAD [45]

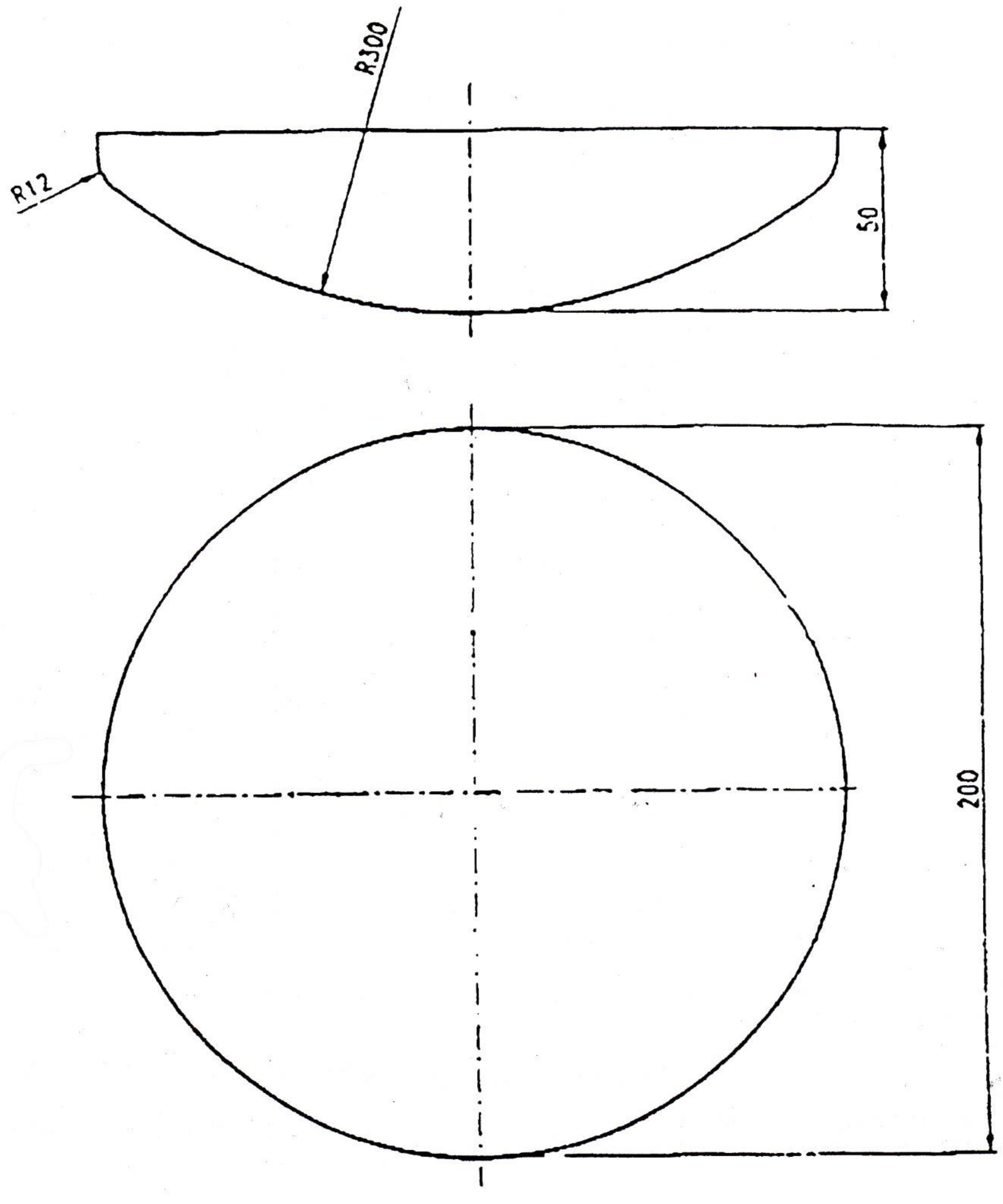


Key

1 Seat loading point

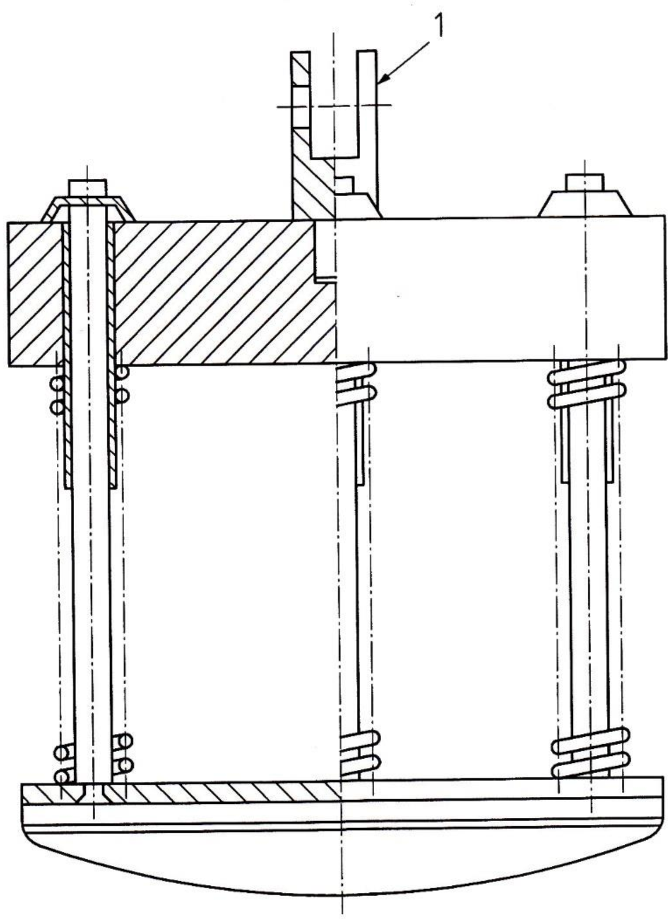
APPENDIX 14

SMALLER SEAT LOADING PAD [45]



APPENDIX 15

SEAT IMPACTOR [45]



Key

1 Joint of lifting device not inhibiting free fall

APPENDIX 16

SAFETY, STRENGHT AND DURABILITY TESTS FOR SEATS [27]

Test	Reference	Loading [a]	Level	
			L1	L2
1. Seat and back static load test	EN 1728:2012, 6.4	Seat: force, N Back: force, N 10 times	1 600 560 (min. force, 410)	2 000 700 (min. force, 410)
2. Seat front edge static load test	EN 1728:2012, 6.5	Force, N 10 times	1 300	1 600
3. Vertical static load on back [b]	EN 1728:2012, 6.6	Force, N Seat load, N 10 times	600 1 300	900 1 800
4. Foot rest and leg rest static load test	EN 1728:2012, 6.8, 6.9	Force, N 10 times	1 300	1 600
5. Arm sideways static load test	EN 1728:2012, 6.10	Force, N 10 times	400	900
6. Arm downwards static load test	EN 1728:2012, 6.11	Force, N 5 times	750	900
7. Vertical upwards static load on arm rests	EN 1728:2012, 6.13.1, 6.13.2	Seat load, N Lift 10 times, during ≥ 10 s	250 or lift stack with max. 8 chairs of max. 25 kg	1 200
8. Seat and back durability test	EN 1728:2012, 6.17	Cycles Seat: 1 000 N Back [c]: 300 N	100 000	200 000
9. Seat front edge durability test	EN 1728:2012, 6.18	Cycles Force: 800 N	50 000	100 000
10. Arm durability test	EN 1728:2012, 6.20	Cycles Force: 400 N	30 000	60 000
11. Foot rest durability test	EN 1728:2012, 6.21	Cycles Force: 1 000 N	50 000	100 000
12. Leg forward static load test	EN 1728:2012, 6.15	Force, N Seat load, N 10 times	500 1 000	620 1 800
13. Leg sideways static load test	EN 1728:2012, 6.16	Force, N Seat load, N 10 times	400 1 000	760 1 800
14. Seat impact test	EN 1728:2012, 6.24	Drop height, mm 10 times	240	300
15. Back impact test	EN 1728:2012, 6.25	Height of fall, mm/° 10 times	210/38	330/48
16. Arm impact test	EN 1728:2012, 6.26	Height of fall, mm/° 10 times	210/38	330/48
17. Drop test (multiple seating)	EN 1728:2012, 6.27.1	Drop height, mm 2 × 5 times	not applicable	450
18. Auxiliary writing surface static load test	EN 1728:2012, 6.14	Force, N 10 times	300	300
19. Auxiliary writing surface durability test	EN 1728:2012, 6.22	Cycles Force: 150 N	10 000	20 000

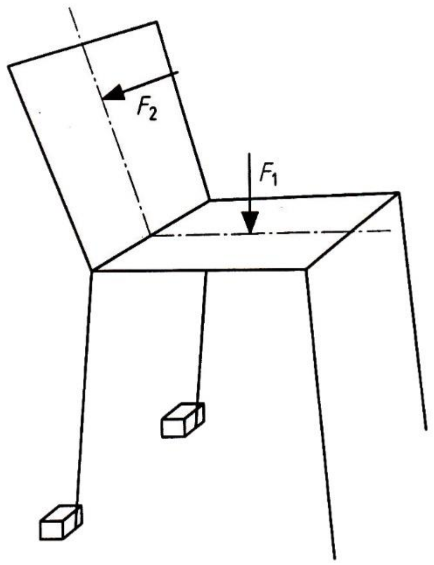
[a] Seat load on parts not undergoing test: 750 N.

[b] The test is only applicable for chairs without head/neck rest and for chairs with a height of the backrest < 1 000 mm above ground.

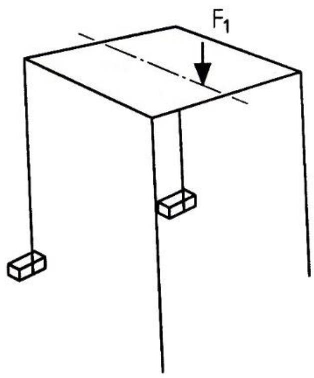
[c] No minimum force defined.

APPENDIX 17

SEAT STATIC LOAD TEST [45]



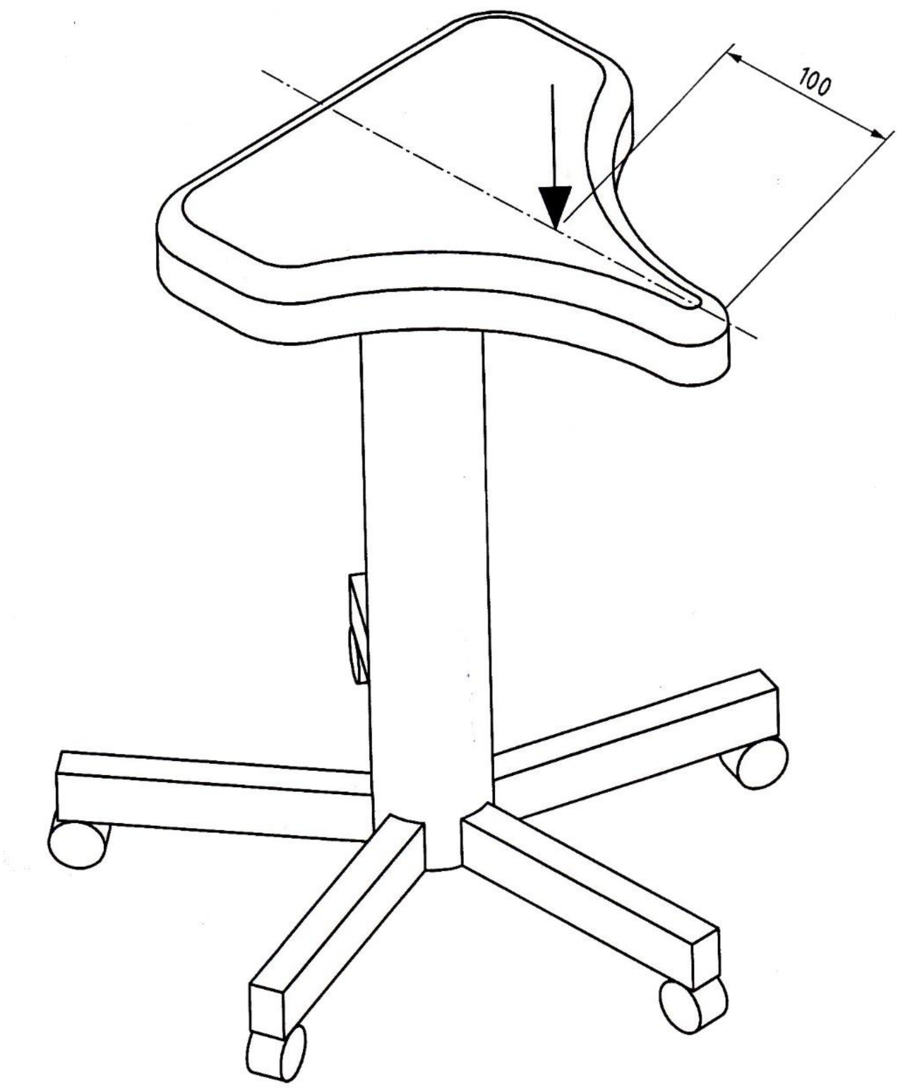
a) Example for chairs



b) Example for stools

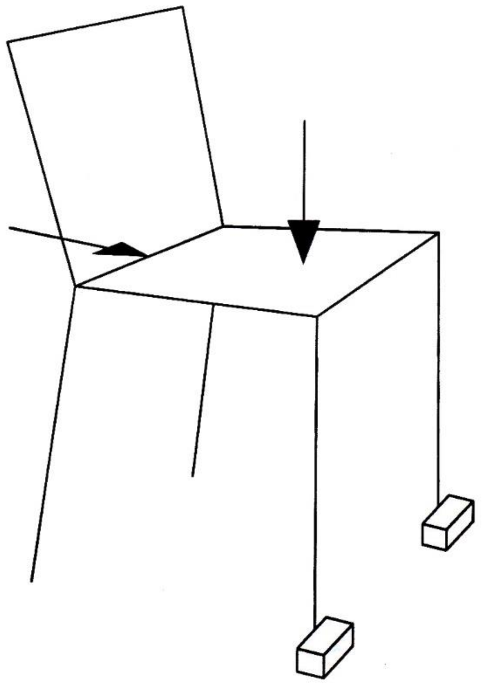
APPENDIX 18

SEAT FRONT EDGE DURABILITY TEST [45]

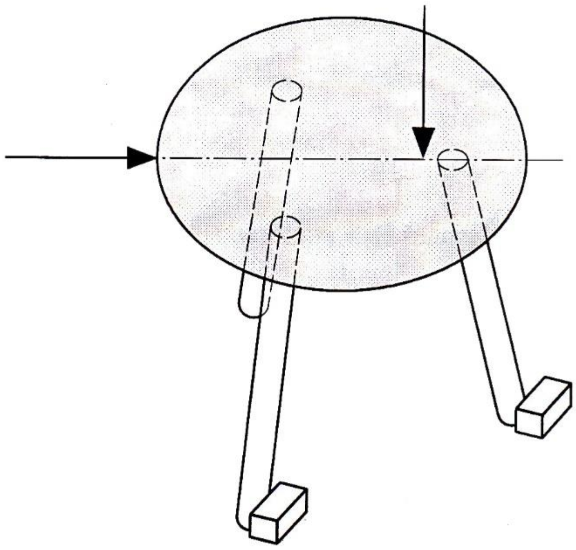


APPENDIX 19

LEG FORWARD STATIC LOAD TEST [45]



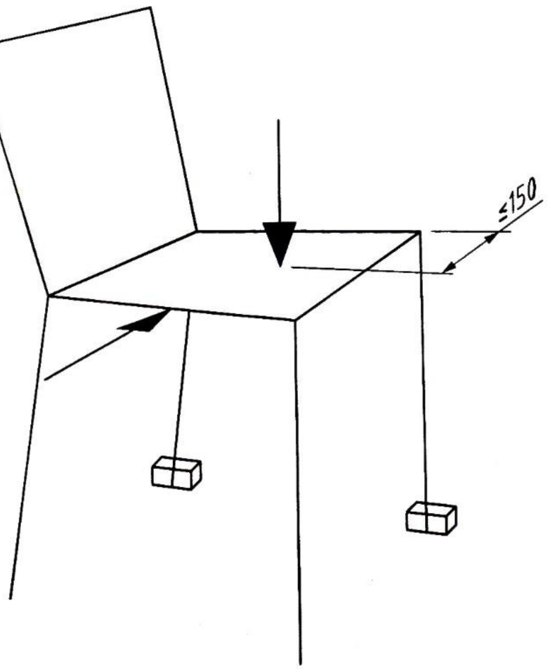
a) Example – four leg chair



b) Example – three leg stool

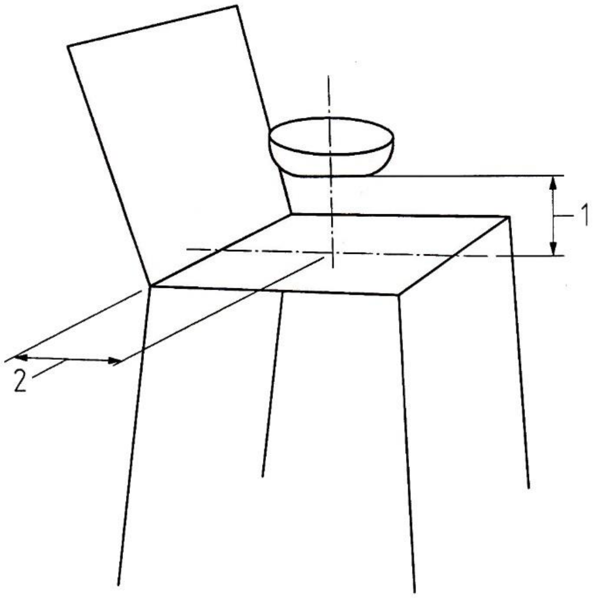
APPENDIX 20

LEG SIDEWAYS STATIC LOAD TEST [45]

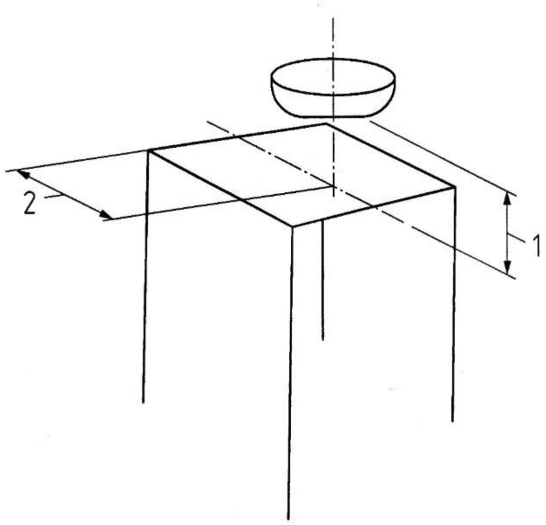


APPENDIX 21

SEAT IMPACT TEST [45]



a) Example - chair



b) Example - stool

APPENDIX 22

TEST SEVERETY TABLE FOR TABLES [25]

Test Severity	Type of Use	Application
1	light	hotel bedroom, church, libraries
2	general	general hotel, café, restaurant, public hall, banks, bars, meeting rooms
3	severe	night-club, police station, transport terminals, hospital public areas, casino, homes for the elderly, sports changing rooms, prisons, barracks

APPENDIX 23

STABILITY, DURABILITY AND STRENGHT TESTS FOR TABLES [25]

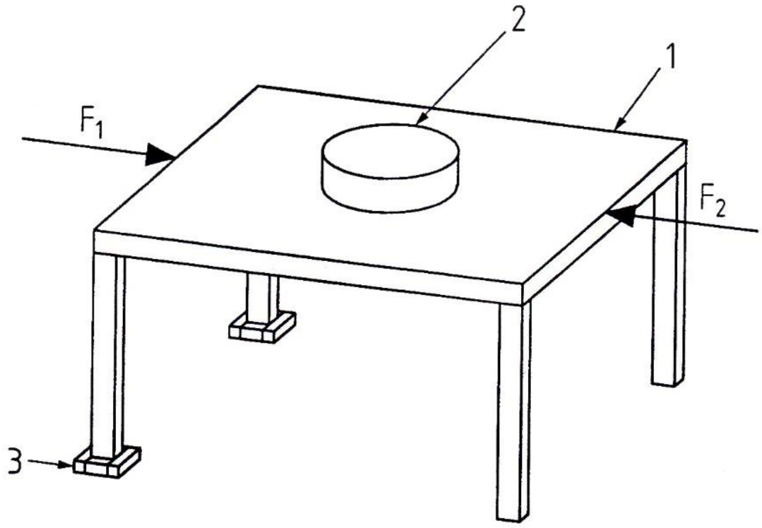
Test	Reference	Loading	1	2	3
1. Stability under vertical load	EN 1730:2000, **6.7**	Test force, N Main surface V_1 V_2 Ancillary surface V_1 V_2	 200 400 100 200	 200 400 100 200	 200 400 100 200
2. Stability for tables with extension elements	**5.3.2**	Test force, N	200	200	200
3. Horizontal static load	EN 1730:2000, **6.2**	Test force, N: high (more than 600) low (600 or less) 10 times	 400 200	 400 200	 600 300
4. Vertical static load	EN 1730:2000, **6.3**	Test force, N a) main surface b) ancillary surface 10 times	 1 000 200	 1 250 300	 1 250 300
5. Horizontal fatigue	EN 1730:2000, **6.4**	Number of cycles: Test force 300 N	10 000	15 000	2 0000
6. Vertical fatigue for cantilever or pedestal tables	EN 1730:2000, **6.5**	Number of cycles: Test force 300 N	10 000	15 000	20 000
7. Vertical impact for tables without glass in their construction	EN 1730:2000, **6.6**	Drop height, mm: 10 times	180	180	240
8. Vertical impact for tables with glass in their construction	EN 1730:2000, **6.6** EN 14072:2003, **6**[2)]	Drop height, mm: 10 times Safety glass[1)] Other glass	 180 240	 180 240	 240 300
9. Drop test for tables weighing more than 20 kg	Annex A	Nominal drop height mm – tables without glass Nominal drop height mm – tables with glass	100 50	100 50	100 50

[1)] Glass is considered to be safety glass if the glass fulfils the requirements in EN 12150-1:2000, Clause 8, fragmentation test; or where the mode of breakage (β) according to EN 12600, is Type B or Type C.

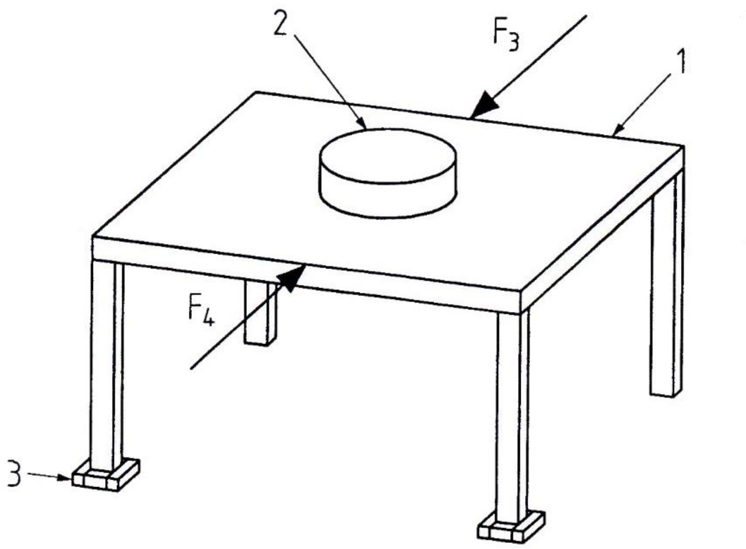
[2)] Impact for the table top in accordance with the positions defined within EN 1730:2000, 6.6.

APPENDIX 24

HORIZONTAL STATIC LOAD TEST. FORCES 1-4. [46]



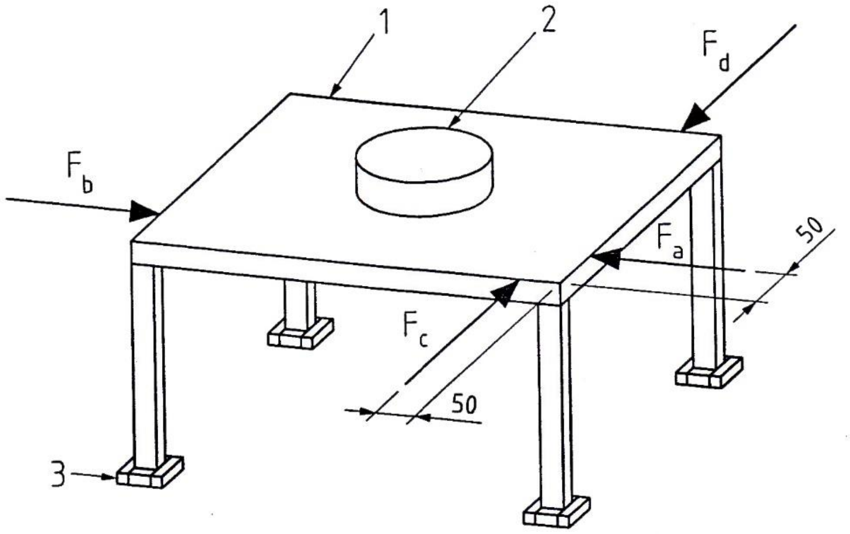
a) Rectangular table – first and second directions



b) Rectangular table – third and fourth directions

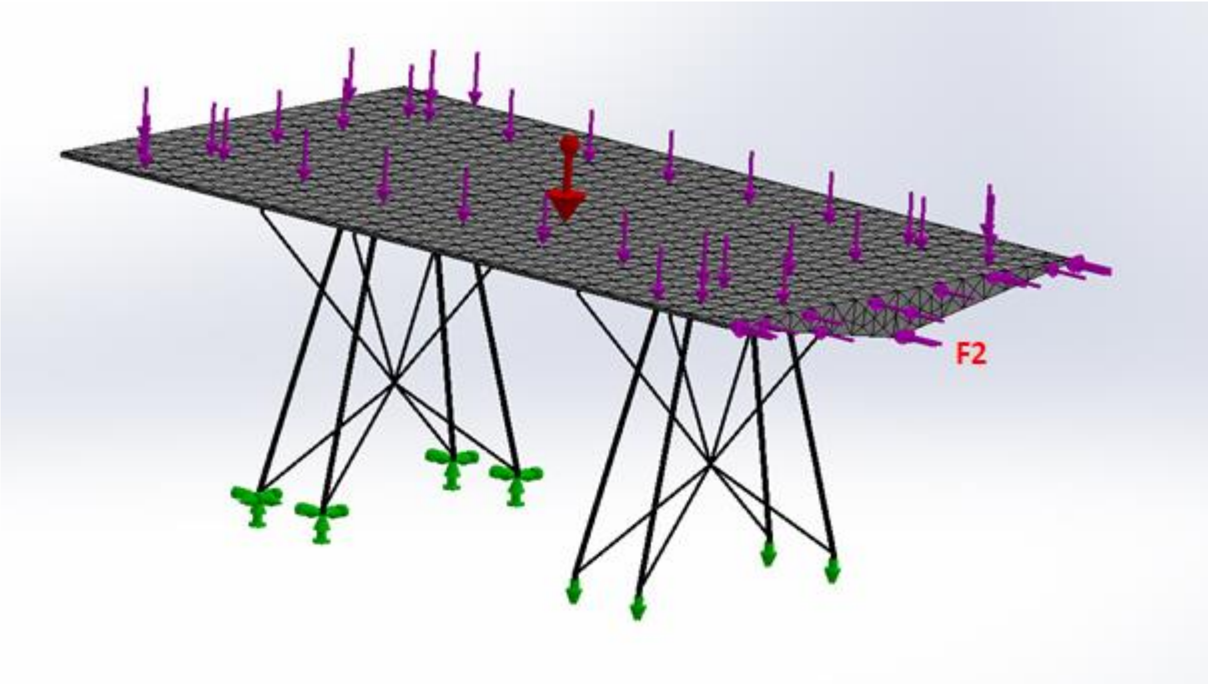
APPENDIX 25

HORIZONTAL DURABILITY TEST [46]



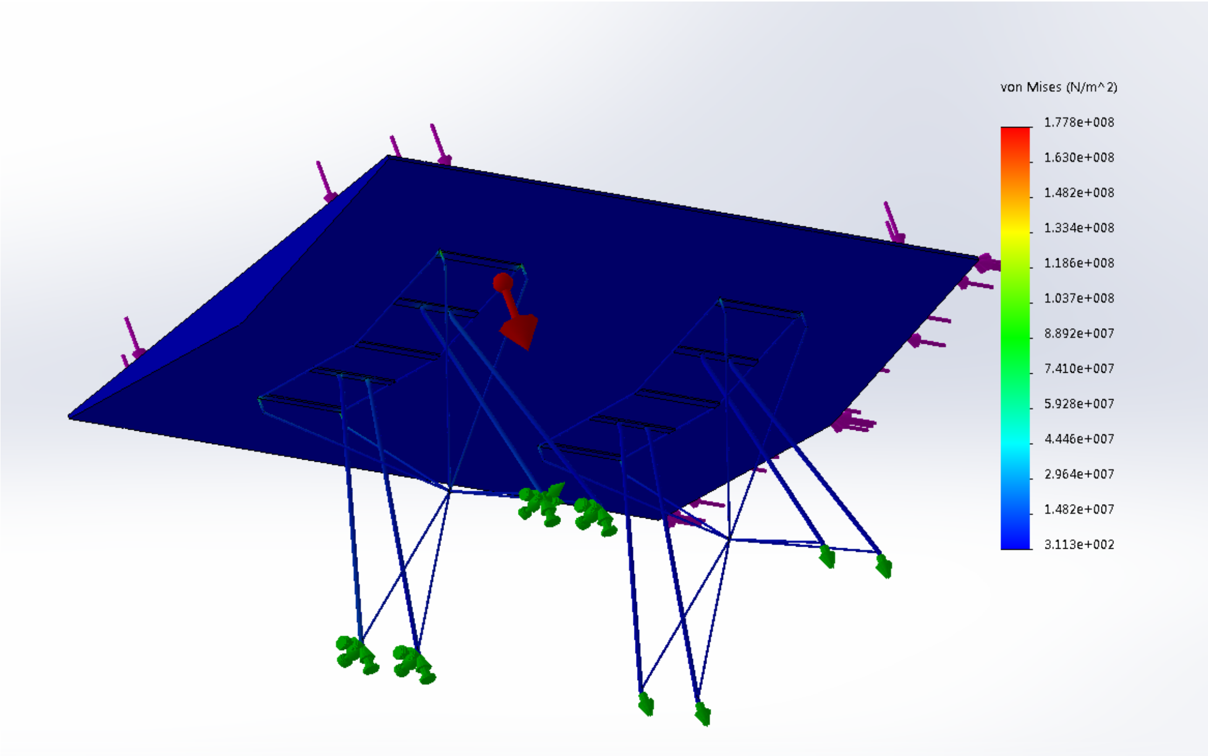
APPENDIX 26

HORIZONTAL STATIC LOAD TEST. FORCE 2 TESTING CONDITIONS.



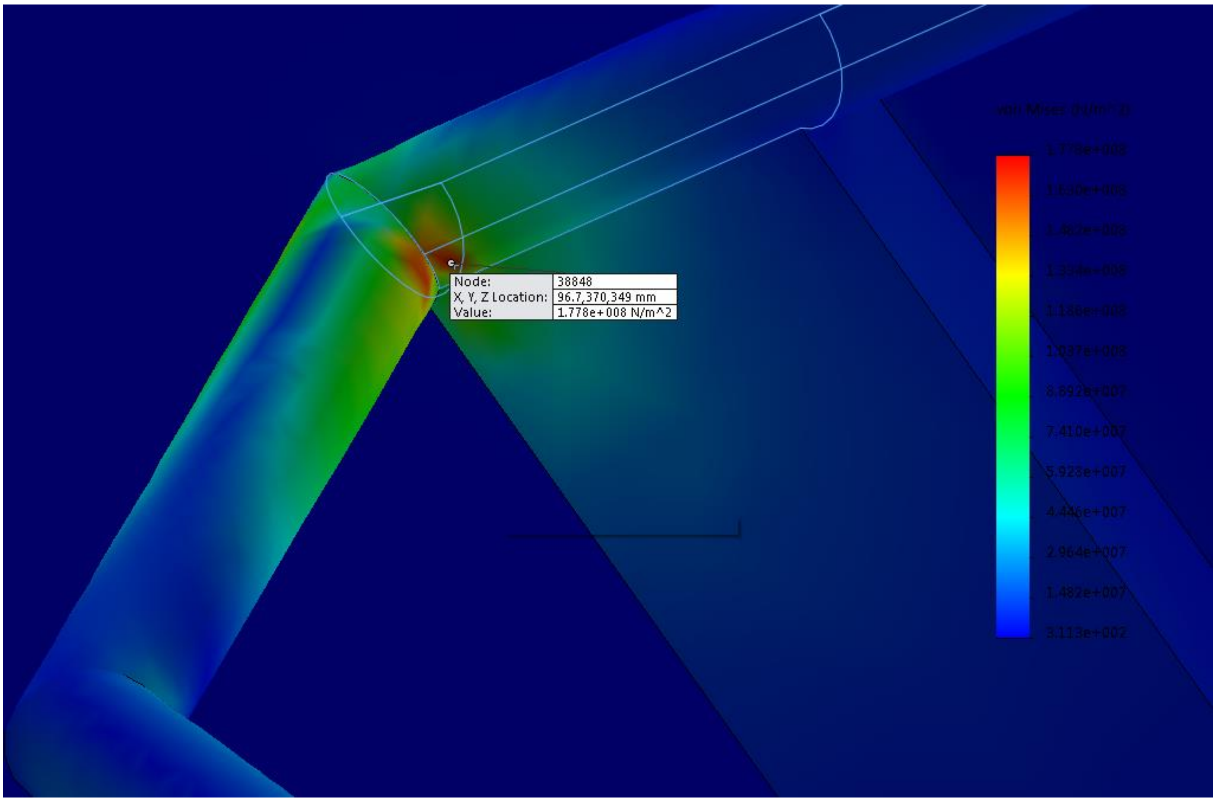
APPENDIX 27

HORIZONTAL STATIC LOAD TEST. FORCE 2. DIRECT STRESS.



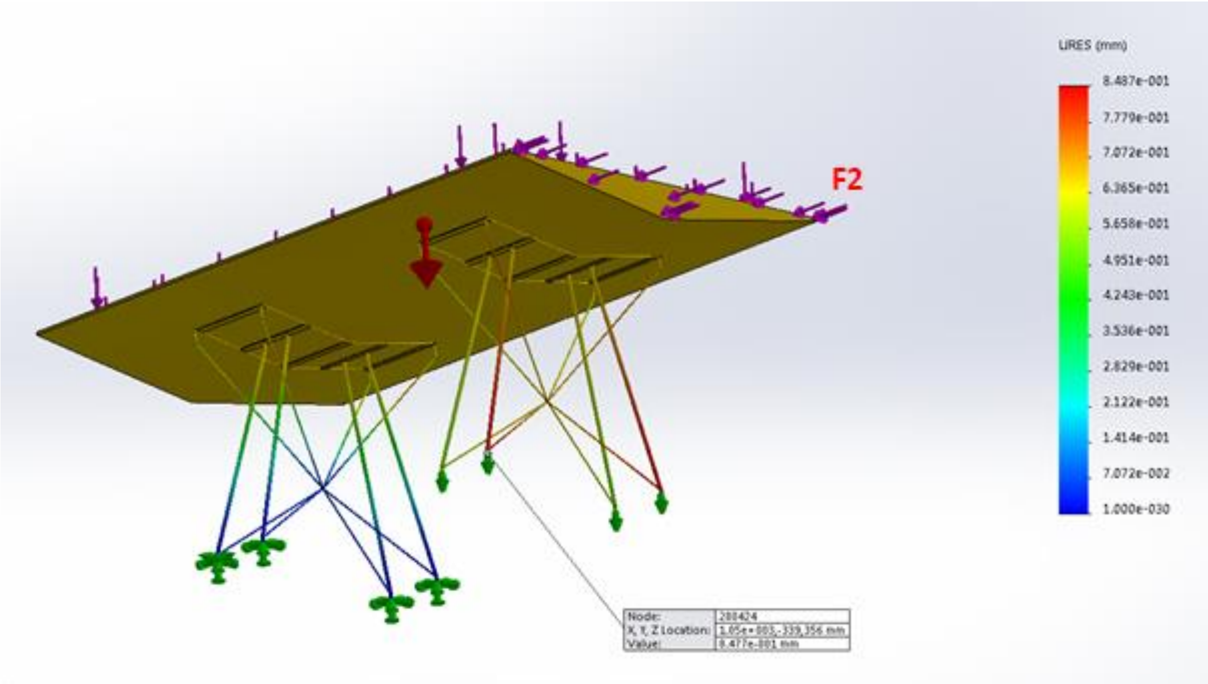
APPENDIX 28

HORIZONTAL STATIC LOAD TEST. FORCE 2. DIRECT STRESS POINT.



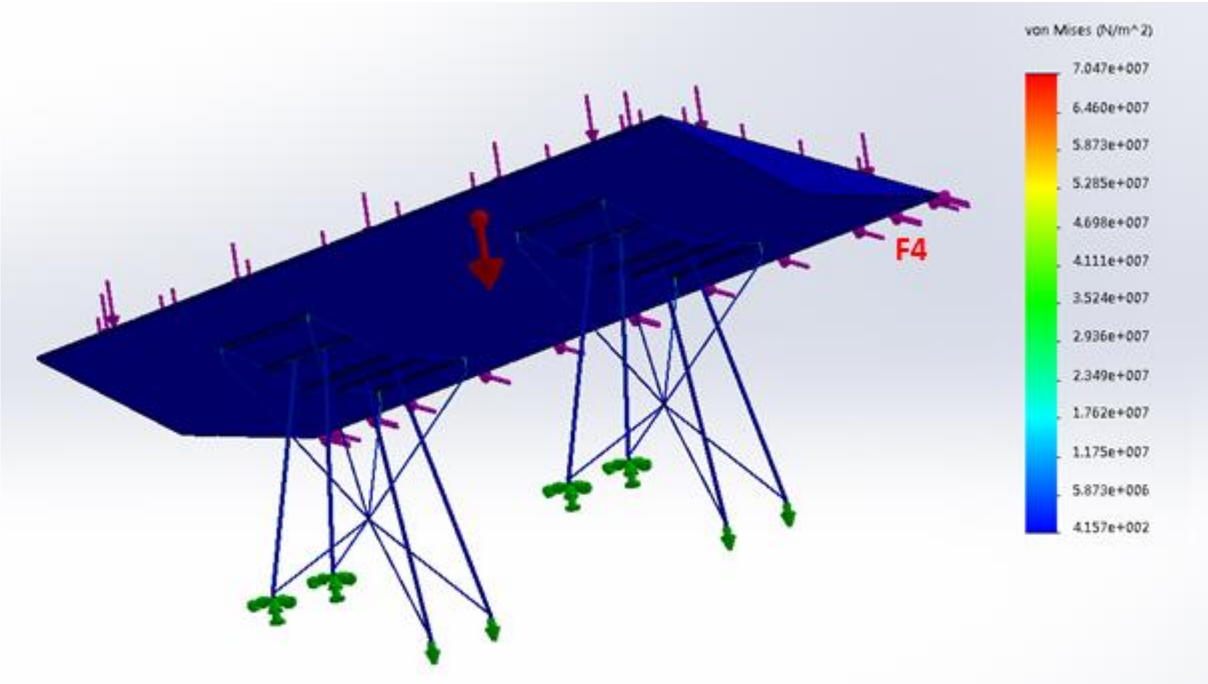
APPENDIX 29

HORIZONTAL STATIC LOAD TEST. FORCE 2. TOTAL DEFORMATION.



APPENDIX 30

HORIZONTAL STATIC LOAD TEST. FORCE 4. DIRECT STRESS.



APPENDIX 31

HORIZONTAL STATIC LOAD TEST. FORCE 4. TOTAL DEFORMATION.