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Development of Technical Design Process for a Manufacturing Company

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Abstract

The objective of the thesis was to get acquainted with and study the current technical design process and to find out the development and improvement points. The purpose was to create a product library and pilot series of parts for its content while utilizing the PDM system and principles.

The work was carried out in sequence, first finding out the relevant publications and material while creating an overview of the current situation. A pilot series of parts and assemblies was then developed for the new product system, which created the framework for the upcoming product library. Finally, the designed, developed, and manufactured parts were tested to ensure compatibility and functionality in practice.

As a result of the work, it was possible to increase the efficiency of technical design activities and to create a system that is easy to utilize and guaranteed to function. Uniform operating methods and an easy-to-use product library reduced lead times in technical design, as well as streamlined production operations and generally harmonized the operation.

Key words
PDM, product development, product library, SolidWorks, technical design

CONTENTS

REFERENCES

LIST OF SYMBOLS AND TERMS

2D	Two-dimensional
3D	Three-dimensional
Add-in	Additional part
BOM	Bill Of Materials
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
ERP	Enterprise Resource Planning
PDM	Product Data Management
Solid modeling	Computer modeling software for creating three-dimensional solids based on mathematical principles and computer modeling.
SolidWorks	Solid modeling program (CAD & CAE)

1 INTRODUCTION

The case company of the thesis is TJT-Kaluste Oy, which is a Finnish company that manufactures made-to-measure fittings and furniture business-to-business. Company was established in 1999, and have been growing steadily, today having around 50 employees, while being a respected operator on its business sector. Company operates mainly in Finland but does trading also abroad on occasion. Company has specialized on made-to-measure fittings and provides comprehensive service from design to local manufacturing and unto installation.

The company focuses on serving retail trade- and service sector operators, as well as design- and architecture offices, construction companies and other relevant business-to-business operators.

Company offers deep knowledge of different materials, experienced manufacturing with up-to-date machines and means, innovative design, and prominent cooperation and interaction with clients. Company also offers product development and prototyping, which will help clients to acquire brilliant products for their demand. A brilliant product will correspond to the functional properties set by the customer, while being visually ambitious and cost-effective to manufacture. (TJT-Kaluste, 2021.)

Picture 1. TJT-Kaluste Oy logo and slogan.

1.1 The purpose of the thesis

The purpose of the thesis is to review the current technical design process of the company and to create a groundwork for “product library” to the use of the company.

Development of the product library means creating a pilot series of parts, components, structures, and assemblies that could be utilized in daily design operations on standard-like manner.

The purpose is also to create a more determined operational principles and methods for technical design department, and thus improve the process, as well as decrease the amount of waste that lose time, resources and ultimately money.

Another important purpose is to further utilize the use of the Product Data Management (PDM) system to streamline the design process and prevent additional or overlapping work.

Company's technical design department have been running satisfyingly for several years utilizing 3D-CAD software, but the process development has lagged the daily operation. The streamlined principles in technical design will enable faster lead-times and more efficient operation as wholeness throughout the company. The new solutions, that are easy to utilize, will make the design phase faster and more efficient, but also serve the rest of the company's internal and external value chain, since products are strictly perfected to serve the warehousing, manufacturing, and assembly operations, as well as the customer in functionality manner.

1.2 Boundaries of the thesis

The boundaries of the thesis are set to concern the technical design process and department. The development work and advanced methods in technical design will certainly apply and affect other parts of the company's operation as well, but to prevent excess expansion such definition have been made and such boundaries are set. The thesis does not specifically address other parts of company's operation or supply chain, than the technical design department but will present examples of impacts on operational wholeness.

Therefore, the aim is not to create a textbook-like design or product development process, but to study the current model, and make it more efficient with the methods suitable for the company. Such methods are in example productization, modularization, and scalability.

2 TECHNICAL DESIGN

Whenever a product is produced industrially, it should be designed prior to manufacturing. This order and procedure ensure that critical qualities and features for product success can be noted. The product should be functional, suitable for manufacturing, cost-efficient to manufacture and use in the long run, as well as visually preferable. After the engineering and design, the technical drawings are made for professionals to manufacture the product. (Pere, 1997, s. 1.)

A technical drawing of an object will state the object in clear and unambiguous manner. A technical drawing will present the shape and dimensioning in such thorough way not possible otherwise. The technical drawings are essential for many manufacturing companies and industries, and modern engineering wouldn't exist without this skill and technical drawings. (Pere, 1997, s. 1.)

Obviously, the engineers and authors of such documents must master reading and interpreting them in correct way, but also does the professionals like turners, milling machine and press brake operators, and welders who are the people executing the manufacturing according to the designs.

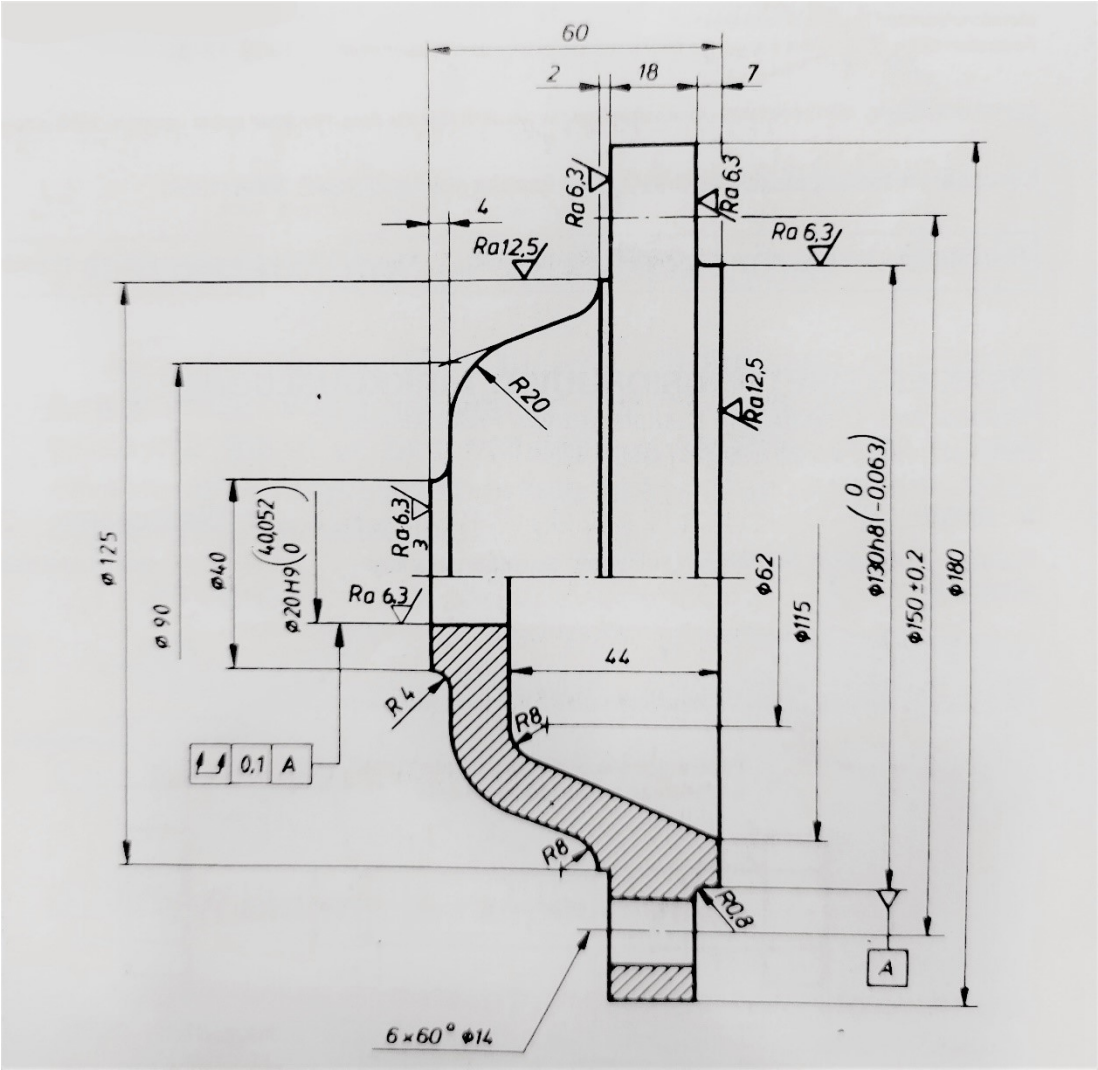
It is crucial that the drawing unambiguously states the object, part, model, or equipment it presents. The technical drawing should always follow certain standards, as well as markings should be made explicitly to achieve two basic requirements:

- clarity
- unambiguousness

(David & Madsen, 2016, s. 8.)

Even seemingly small mistake or wrong interpretation can lead to uncertainty and costly or dangerous outcome (Pere, 1997, s. 1).

A technical drawing of an object (picture 2) contains enough projections, dimensioning, and markings for manufacturing. These drawings must include such detailed information of the object that misinterpretation is not possible, and that professionals can manufacture the object as the designer had intended without more clarification and uncertainties. (David & Madsen, 2016, s. 8.)



Picture 2. Technical drawing of an object (Pere, 1997, s. 1).

Technical drawings will contain the following information (without being limited to these options):

- geometry
- dimensioning
- tolerances
- material
- finish

2.1 Standardization

Standardization is the endeavoring to decrease the technical and commercial insignificant differences in products, as well as ensure that definition of constructs and dictions are globally uniform (David & Madsen, 2016, s. 29). The idea is to restrain the number of product types into sufficient, but as small as possible quantity. Standardization is an important and constantly expanding segment of rationalization. Standardization is made on international, national, industry, and company level (Pere, 1997, s. 2).

International Organization for Standardization (ISO) is the central organization and operates mainly on general and mechanical sector (Pere, 1997, s. 3).

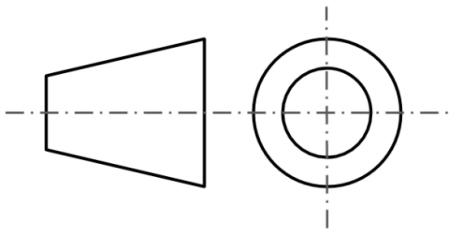
European Committee of Standardization (CEN) strive to advance the European standardization (Pere, 1997, s. 3).

Finnish Standards Association (SFS) is a member of ISO and CEN organizations (Pere, 1997, s. 3).

2.2 Projections

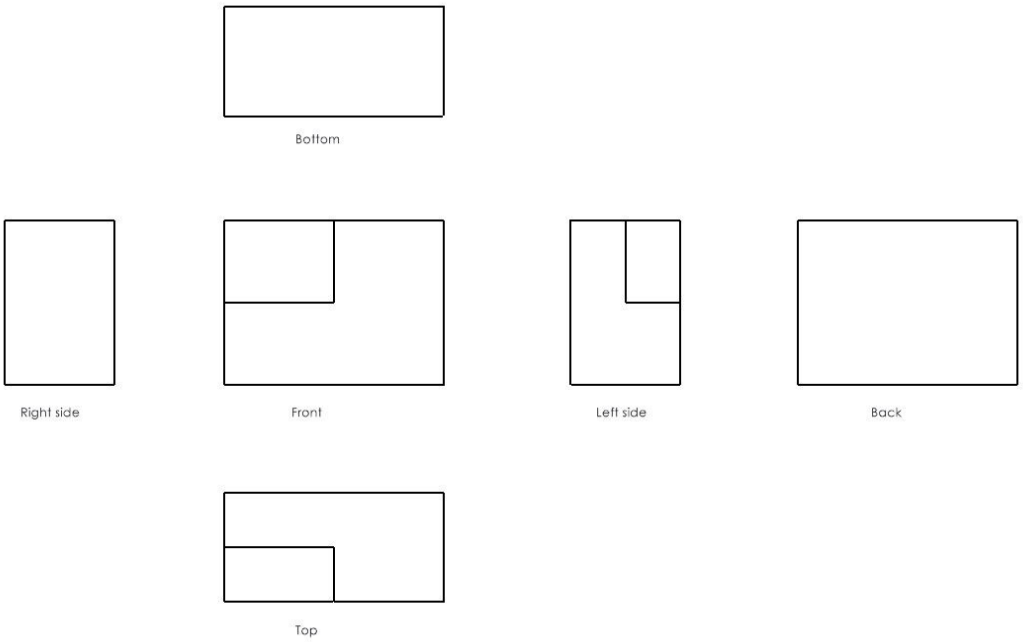
Projection means a standardized way to present 3D object in 2D plane. There are two different projection methods that are in use. The first-angle projection according to ISO standard (picture 3) and third-angle projection. These projection techniques are clearly distinguishable, and even though both do the same “job” the way the results are reached vary substantively.

In the first-angle projection, the right view is left of the front view and the top view is under the front view (David & Madsen, 2016, s. 234). The first-angle projection is used in Europe.



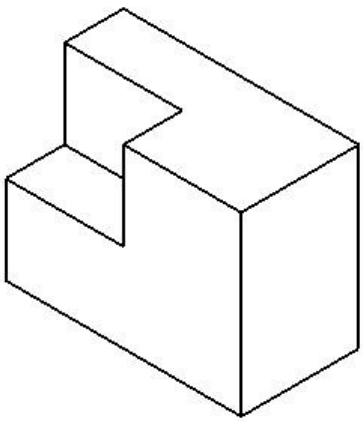
Picture 3. First-angle projection icon.

There are six main orthographic views: top, bottom, right, left, front, and back view. These views can be used to present a 3D model in 2D projections (picture 4) (David & Madsen, 2016, s. 229-231).



Picture 4. First-angle projection example and orthographic views.

Isometric view can be used to present a 3D model on 2D, as three faces are shown simultaneously (picture 5), while the angle between x-, y-, and z-axes is 120 degrees. Isometric projection is an illustrative projection in technical documents.



Picture 5. Isometric projection.

3 SOLIDWORKS

SolidWorks is a solid modeling software for Computer Aided Design (CAD) and Computer Aided Engineering (CAE). It is mainly used on Microsoft Windows operating system and has millions of users worldwide. The software was developed by Dassault Systèmes, a French software corporation in the mid 90's (Dassault Systèmes, 2021). It is the world's most popular 3D CAD software (AIPWorks, 2021). A new version of SolidWorks is released annually, generally containing some improvements and potentially new features. After the new version, for example SolidWorks 2022, released in the autumn 2021, a series of service packs are released to stabilize the program. The software is used to design very different machines and devices as well as singular pieces and parts as well as 2D drawings. The software can be used to create anything from a simple part like a bolt to large entities like a decorticator.
SolidWorks offers encompassing tools and possibilities for mechanical and engineering design, industrial design, operational verification, product data management, as well as motion simulation and testing (Dassault Systèmes, 2021).

3.1 Basic principles

Solid modeling can be done with computer modeling software for creating three-dimensional solids based on mathematical principles and computer modeling. SolidWorks is a solid modeling software, which utilizes a parametric feature-based method. With the program three types of basic design files can be created: parts (SLDPRT), assemblies (SLDASM), 2D drawings (SLDDRW) (Lombard, 2019, s. 10). A part is basic 3D model component and file type. Parts are used to create assemblies, which consists of two or more parts or sub-assemblies. Drawings are created from the parts or assemblies and signify 2D documentation. (Lombard, 2019, s. 8.) All the files are interconnected, meaning that when a part is changed in the configuration, the actual part file also changes simultaneously, as does the drawing file, or vice versa**.** (Lombard, 2019, s. 24).

3.1.1 Solid modeling rules

Solid modeling relies strongly on mathematical and geometrical information completeness and boundaries. The solid modeling CAD software enables the model to meet all the requirements that is required of the physical object it correlates with (Hietikko, 2009, s. 21). Various representations of the model can be created, and the representation will still be consistent and the part data in synchronization; as if the model is changed, the changes will automatically update the drawing views **(**Lombard, 2019, s. 24).

Solid modeling technique ensures that the created object is geometrically correct, and that all surfaces meet properly without colliding with each other. In example, an interference detection-tool enables testing that two or more objects are not occupying the same space. (Hietikko, 2009, s. 21.) Models can also be tested for e.g., stress and strength, finite element analysis (FEA), or other engineering attributes (Pere, 1997, s. 79).

Attributes, such as center of gravity, volume, or mass of geometrically complex 3D model, can be quickly calculated, since CAD software is based on mathematical principles, and can comprehend such geometrically determined models (SolidWorks, 2021).

Solid modeling technique enables carrying out a series of demanding engineering calculations automatically within the design/modeling process. Machining and assembly processes can be simulated, planned, and verified in the design process.

Since the program is based on solid modeling and mathematical principles, the features are updated constantly, thus the software requires much computing power when doing complex or large-scale models containing a great number of components.

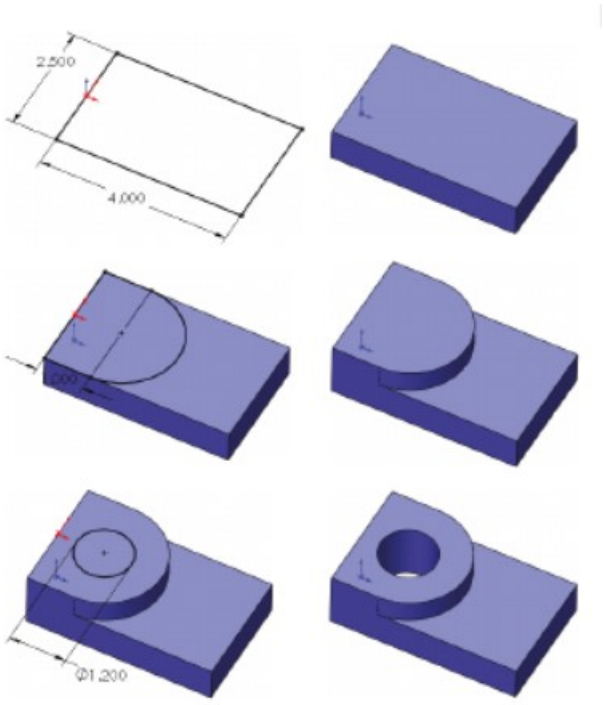
3.1.2 First steps of modeling

The modeling is usually started by drawing a 2D sketch of the desired shape on X, Y plane. After this, the sketch can be extruded into third direction or revolved around an axis. (Lombard, 2019, s. 16-17.) It is also possible to make a 3D sketch using three planes to create a model if convenient (Lombard, 2019, s. 19). The previous 3D-sketch technique is useful e.g., in case of creating a model of bend axle or tubular structure.

A solid model is based on parameters. Parameters that are used to create a solid model part can be e.g., dimensions of features, or formulas used to create and control features (Hietikko, 2009, s. 21-23). A solid model part usually consists of various features, which are added one at a time, until the desired model is created, as shown in picture 6. The features that are added one at a time, generally consists of a 2D sketches, that are extruded, cut, or swept along a path to become 3D. (Lombard, 2019, s. 15.) Parts can be created to be fully independent, or dependent of other entities, such as other parts.

The object created with SolidWorks will have volume, boundary surface, holes, hidden voids and possibly suppressed features etc. The created model can be spun around the screen to have a complete look of the model, as well as sectioned to expose the internal features and structure.

There are two different ways of creating assemblies, which are clearly distinguishable. So called bottom-up and top-down. As the name implies, in the first, the parts of the product are first modeled, and these are used to create a larger entity, an assembly. In the latter, new parts are modeled into even a completely empty assembly. (Dassault Systèmes, 2021.)



Picture 6. A part created in SolidWorks (Lombard, 2019, s. 17).

An example: a metal tube can be created by creating a 2D sketch on a desired plane. After this, the extrusion feature can be used to create a 3D model of the sketch. The tube can in example have a diameter of 50 mm and wall thickness of 2 mm. After this, a hole can be made into the model using an extruded cut feature. The hole can be made also with creating a 2D sketch on desired plane or surface. Designer sets parameters to determine the hole size and location on the model. Such parameters can in example be hole diameter, depth, and distance in example from the origin, or at the end of the tube. When the parameters are edited, the model will update, meaning synchronized updates into in example mass properties, corresponding BOM rows and drawings.
The metal tube used in the example can also be used in an assembly, and the hole in the part can be linked to another part in the assembly, meaning that when the other part is changed, the hole in the first part follows.
The dimensions of the parts or assemblies can also be linked with equations, meaning that when a part is changed, the other parts follow the dimensions of the changed part accordingly.

3.2 Advantages of 3D-CAD software

By leveraging the possibilities and benefits of 3D-CAD software, product development can be streamlined, design and product quality improved and productivity increased. All of which will jointly reduce manufacturing and product costs, thus enabling greater operating income. (Hobbs, 2018.) Basically, 3D-CAD software enables moving quickly from idea to production while creating better and more functional products with less costs.

Advantages an organization will achieve by utilizing 3D-CAD software:

3D-model is realistic, illustrative, and informative.

> Products can be visualized easily, from the final product to constituent parts. Visual representation will give the customer a polished outlook of the final product. This can be advantageous when bidding etc., as customer can move on more quickly with purchase decision with the help of proper reference picture and realistic visualization of the product. (Aspinall, 2018.)

SolidWorks will enable faster product development and detailing.

Efficient CAD software will help designers to reduce costs, since they can work faster and smarter, which will lead to quicker design phase and project completion. Efficient design teams will help the company to produce high-quality yet low-cost products in lesser time. (Hobbs, 2018.)

Possibility to utilize modeled parts and machining in the CNC manufacturing process.

CAM data of 3D solid model can be automatically generated for NC/CNC machines and rapid prototyping equipment (Pere, 1997, s. 79-80).

Design quality will improve.

Quality of the design can be controlled during the creation, even within a team. Problems, faults, or errors can be recognized, investigated, and solved before the product enters the prototyping or manufacturing phase. (Hobbs, 2018.)

Design, product functionality and performance can be assessed before manufacturing.

Individual components can be analyzed, tested, or modified without harming a larger entity or assembly. With solid modeling and digital prototyping, the created model can be described in detailed manner. The object's features can be analyzed and tested before manufacturing. The specifications of the part or assembly can be verified, this will include in example how the part withholds applied force, the impact of heat and fluids and performance with other parts. The design, and ultimately the final product is made right the first time, without spending resources on adjusting the product after it has entered the next phase in the manufacturing process. (Hobbs, 2018.)

Documents can be reused and changed easily.

A previously made document can be used as a base for an upcoming one. In example, a kitchen cabinet can be designed once, and utilized later by simply changing measurements or materials without needing to start from scratch, as the model and all associated components compose the base.

Design cycle is easy to manage.

Revisions can be made easily, while leaving proper trail of the made changes. Changes and amendments made into the model will automatically reflect and update to the drawing, since the drawing is generated from the model. This ensures that the drawing always automatically reflect the model within the drawing. (SolidWorks, 2021.)

Comprehensible technical documents and drawings.

Drawings and technical documents made with CAD-software tend to be easy to read for comprehensive parties, since technical drawings are organized and standardized. CAD-software also enables various perspective, cross-sectional, layout, detailed and dimensional images. (Hobbs, 2018.)

Utilization of all product related data.

Dimensions, scale, material, weight, engineering, and product data available. Accurate BOM can be created. (Grant, 2020).

3.3 Bill of Materials (BOM)

Bill of materials (BOM) is an extensive and crucial list of information used to manage, construct, manufacture, or repair a product. A BOM will contain part number, part name, quantity, dimensions, raw materials, components, and additional information. An accurate BOM is crucial since it serves as a complete list of all items and quantities of such needed to create a certain product. It will ensure that all necessary items are available for the manufacturing or assembly process. (Watts, 2012, s. 93.) A BOM can be integrated into company's enterprise resource planning (ERP) or material requirement planning (MRP) systems to ensure efficient operation and availability of resources, raw materials, and components. An inaccurate BOM could lead to mistakes in production or production stoppage, both of which will increase operating costs, since resources and time is needed to make corrections, locate missing parts, or start another production order.

Below is an example of BOM for case company's actual product (picture 7). The BOM-template the company is using consists of following columns, in following

order: Number, Part number, Name, Length, Width, Material thickness, Quantity, Material, Edge band quantity (length), Edge band quantity (width), Edge band (material), Surface 1, Surface 2, Notice 1, and Notice 2.

Nro.	Nimike	Nimi	L	[P]ituus	[L]eveys	S	Kpl	Materiaali	RP	RL	Reunanauha	Pinta 1	Pinta 2	Huom 1	Huom 2
1	27740-006	Reunalippa		2445	22	12	2	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM							Sahataan pitkänä
2	27740-007	Reunalippa		841	22	12	2	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM							Sahataan pitkänä
3	27740-021	Reunalippa		2505	22	12	2	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM							Sahataan pitkänä
4	27740-002	Tasolevy		2445	195	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
5	27740-003	Tasolevy		2445	96	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
6	27740-004	Tasolevy		574	140	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
7	27740-005	Tasolevy		574	331	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
8	27740-010	Tasolevy		2505	143	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
9	27740-011	Tasolevy		2505	242	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
10	27740-012	Tasolevy		480	880	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
11	27740-013	Tasolevy		480	80	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM						CNC	Työvarat +4mm, tapit, huullos
12	27740-024	Tukilevy		840	45	12	1	00023584 < HI-MACS G009 BLACK SAND 12X760X3680 MM							
13	27740-008	Tasovaneri		837	2406	18	1	KOVANE18B < KOIVUVANERI BB/WG 18MM 1500X3000						CNC	Uran jyrsintä, aukot
14	27740-014	Tasovaneri		837	2466	18	1	KOVANE18B < KOIVUVANERI BB/WG 18MM 1500X3000						CNC	Uran jyrsintä, aukot
15	27740-016	Maskilevy		2021	720	17,50	1	LALE16 < 3045 X 1290	1	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	CNC	
16	27740-022	Maskilevy		2021	720	17,50	1	LALE16 < 3045 X 1290	1	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253		
17	27740-019	Ovi		395	715	17,50	1	LALE16 < 3045 X 1290	2	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	CNC	
18	27740-019MIR	Ovi MIR		395	715	17,5	1	LALE16 < 3045 X 1290	2	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	CNC	
19	27740-018	Peitelevy		842	720	17,50	1	LALE16 < 3045 X 1290	1	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253		
20	27740-017	Päätylevy		790	860	17,50	2	LALE16 < 3045 X 1290	2	2	2110 ABS MUSTA 22/2<AHO0216	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253	F2253 MUSTA DIAMOND BLACK 3050X1300 0,7<LAM_F2253		
21	00026161	Ilmankiertosäleikkö					1	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
22	00026006	Linjaston hyllytaso		570			11	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
23	00028614	Linjaston hyllytaso		370			6	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
24	00026096	Linjaston runkopukin sisälevy					5	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
25	00026002	Linjaston runkoputki					11	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
26	00026004	Linjaston sokkeliprofiili - alumiini					6	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
27	00026005	Linjaston väliputki		570			24	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
28	00028644	Linjaston väliputki		370			12	Material <not specified>				Maalaus työmääräimen mukaan.	Maalaus työmääräimen mukaan.		
29	00028958	Pisarasuoja 1700mm					1	Material <not specified>							
30	00026273	Pisarasuoja 2100 mm					1	Material <not specified>							
31	AHC9625	Ponnahdussalpa					2	Material <not specified>							Tilus

Picture 7. Example BOM of company’s product.

The BOM can be exported from SolidWorks and synchronized into company’s ERP-system, for creating precise product structures and to ensure correct inventory management and costing.
The case company has increased the utilization of BOM in its operation in the last few years. Nowadays, it’s important to put all the components that will be used in the finished product into BOM. This is crucial for the operational success and costing. The completeness of the BOM will have direct correlation with the following stages after technical design. A precise and well defined BOM will lead in lesser confusion and stoppage within the manufacturing and ensure purchases can be made appropriately.

3.4 SolidWorks add-ins

On top of the powerful basic functions, SolidWorks offers the most comprehensive complementary add-ins on the market (AIPWorks, 2021). SolidWorks itself offers a great deal of add-ins, but there is also several third-party software, that can be integrated into SolidWorks. SolidWorks software can be expanded extensively with optional add-ins that extend the software's usability.
Add-ins can be used, for example, to assess the durability of parts and their behavior as a finished product. Alternatively, additional programs can be used to reduce human-performed routines that the program user repeats. SolidWorks also provides lightweight tools for the aforementioned steps in its basic version, but complex

automation of operations often need to be done with separate add-ons. (Dassault Systèmes, 2021.)

3.5 CustomTools add-in

The most important add-in the company uses is CustomTools. CustomTools is fully integrated with SolidWorks and thus practical and safe to use. With the help of this add-in, designers can automate some of the daily routines, and use the released time to be more productive and to find the best solutions and ideas instead of those routine tasks. (CustomTools, 2021.)

CustomTools has many capabilities that organizations can use in their operation to cut those non-profitable routines, and to focus on the important issues, that cannot yet be automated. For the case company the most important capabilities are the batch processing and file management.

Batch processing enables a batch conversion, which means that parts, assemblies, and drawings can be converted to several file formats at once. This is highly advantageous when creating in example DXF-files of parts of a large assembly.

File management offers automated file naming. This offers sequenced numbering for parts, which previously was a manual task, taking time and relying only on user accuracy. Competent file management and correct data are crucial for the manufacturing process. Wrongfully determined file numbering causes unnecessary harm in manufacturing process, as A CNC or NC program might already be made on such number.

3.6 Computer-aided manufacturing

Solid modeling is commonly used by industries and companies for computer-aided manufacturing. With the solid modeling technique and software professionals can form their ideas into solid models and thus into “life”, into comprehensive and clearly visual format. Many products or objects seen in the everyday life can be simulated in solid-model format. Many of those products have already been solid modeled before

manufacturing. With the help of CAD-software accurate and precise concepts, models and designs can be created.

Computer-aided manufacturing is contiguously integrated on software and computer-controller machinery in the manufacturing process; thus, its operability and success is based on crucial factors. Such factors are software, machinery, and post-processing. (Velling, 2021.)

Basically, toolpaths that are generated with the software, tell the machinery how to make the products. In example a cutting trajectory or drilling patterns can be created and determined with the software. The machines will do the defined operations and machining to convert the raw materials into finished products.

Postprocessor is a type of compiler that translates a CL file, Cutter Location-file, that contain machining operations e.g., paths, tools, and machining speeds generated by the CAM software into NC code/G code, which the machinery will understand and is thus able to execute operations.

3.7 Meaning for the case company

The company have been using SolidWorks for approximately ten years now. Basically, all the company's products are first designed, modeled, and drawn with SolidWorks, since that enables the use of CAM in the manufacturing process, while creating crucial draft-files for more manual production and assembly phases. With the use of SolidWorks, a 3D solid model is first created to have a realistic model of the piece about to be manufactured and finished. The model is created to represent the product just as it will be in the finished real model.

The created solid model will include all parts, components, sub-assemblies, devices, mounting hardware etc. that a certain product will include when applicable. The 3D model containing all the relevant parts and information for CAM and manufacturing process, can be used to create a 2D drawings with many useful properties, such as orthographic projections, isometric projections, detailed views, and section views, to name a few. The drawing will contain all relevant information of the product and present the model in easily readable and interpreted way according to technical drawing principles. The designs and drawings can be used for documentation and manufacturing work as well for work done be a sub-contractor.

An important part of the drawing is the BOM that list all the materials and components of the product for a table that will be integrated into company's ERP system and used for activities like purchasing operations, inventory and material management and production planning.

In a nutshell SolidWorks is a crucial software for the company. As said, almost all of the products designed, manufactured, assembled, and installed by the company have firstly gone through 3D-modelling phase. With such process, the functionality of the product can be verified and accurate BOM created. Detailed technical drawings for the manufacturing department are essential to ensure the phase will all necessary information available for the process. When the drawing is easily readable and contain all the relevant information, measures, and illustrations the worker can use his/her professional skills for manufacturing accurately, efficiently and without misinterpretation and delays. When the drawing is e.g., missing out an important measure, it can be easily added, since the fully defined solid model is the base for the drawing, and employee's valuable time does not go to waste.

4 PRODUCT DATA MANAGEMENT

Product data generally means any data and information related to a certain product. Product Data Management (PDM) is a centralized software system, where all product related information can be stored. PDM can typically contain following information: CAD data, models, parts information, manufacturing instructions, technical specifications, requirements, notes, and other documents. (Hietikko, 2009, s. 107.)
Product data management has constantly grown importance in product development. It is of great importance, that product data management principles are carefully considered, and guidelines are set for the reusability of components and data management purposes to be efficient. (Hietikko, 2009, s. 107). The increasing utilization of digital solutions, computer aided design and technologies in product development and manufacturing operations emphasizes the product data since the processes rely on the data.

The efficient management of product design and manufacturing data is a challenge that many companies face. The challenge is not faced just on product development and manufacturing departments, but on wider in the manufacturing organizations as well. Efficient management of the data has impact on the company's ability to grow while maintaining and extending the competitive edge (SolidWorks, 2021b.)

4.1 Function and fundamentals of PDM system

PDM system is a centralized vault for design file management. All the documents are stored and administered in the data vault. (Hietikko, 2009, s. 107). Everyone in the organization, or a selected team of professionals can access the most current data in a consistent way. Only one person at a time can edit the specific file, and the files are saved according to version- and revision control rules. This reduces file redundancy and clutter. Files can also be secured or granted access to, meaning that only selected people can access and modify the files whenever necessary.

All the documents are instantly available throughout the organization. Version history is completely traceable: who did what and when.

Data in the PDM is indexed, and right files can thus be found fast and easy. With the intelligent versioning and revisioning files stay reliable and up-to-date, and reverting to previous design is possible.

Since the data is stored in one centralized place, the backup is effortless to implement. Even though files can be modified by only one person at the time, the files stored in the PDM system can be used simultaneously by various users in the organization. This makes collaboration easier and increases productivity, since a project containing same files can be worked by several people in the organization at the same time.

Product data can contain:

- Part number
- Part name and description
- Supplier or vendor
- Supplier or vendor part number and description
- Unit of measure
- CAD-files

- Material data
- Tooling and manufacturing specifications
- Cost

4.2 Benefits of PDM system

The efficient use of PDM and improvement of the data management signifies several upgrades for the company's operation: reliable and correct data can be found quickly, improve product quality, decrease amount of development errors, mistakes and thus costs, ability to better meet business and regulatory requirements, facilitate more efficient collaboration, enhance organizational agility and flexibility, increase productivity and reduce cycle times, improve value-chain orchestration, optimize organizational resources, and provide visibility and better decision making. (Siemens, 2021.) (SolidWorks, 2021b.)

PDM system will reduce the unproductive and unprofitable time wasted on finding files that are misplaced, overwritten, or deleted.

4.3 PDM in Case Company

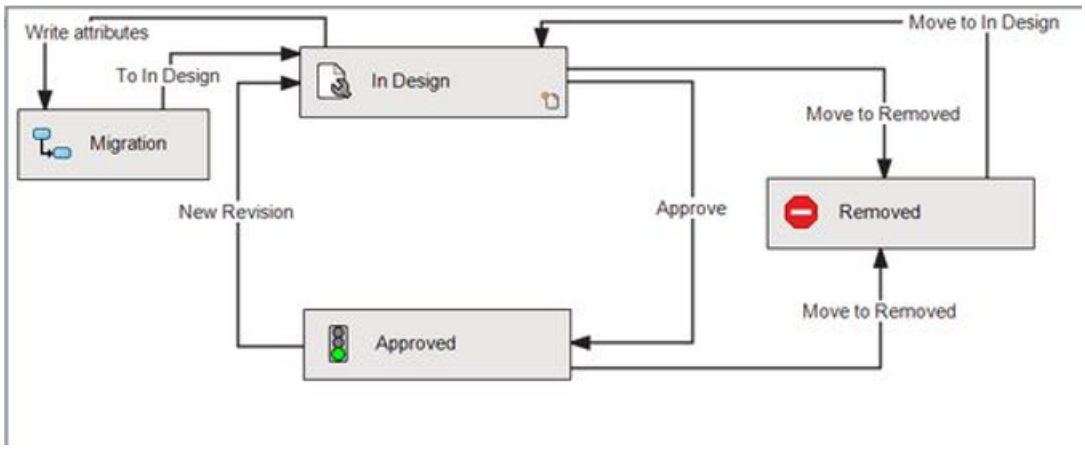
The company has been using SolidWorks PDM-system for a few years now. The use has been ongoing, but vague and ineffective, since a clear set of instructions, rules, and purpose has been missing. Content of the PDM has not been administered successfully, and this had led to clutter and disorder.

PDM-system has contained a decent number of files, but not in a consistent manner. Files, in example parts or assemblies can be inconsistent with reality or set product structures in ERP-system, include incorrect meta-data, or lie on incorrect planes or include other wrongful design-intents. All the issues cause inefficiency in the design phase, and could lead to be harmful for production, inventory management, and calculation of costs.

The newly defined workflow (picture 8) will help to administer the PDM. A file that is on "In Design" or "Approved" state can and should be used and contain the most

recent version. Files that are in “Removed” state are still available for use, as the files cannot be deleted for existing references to stay intact but should not actively used.

When a file is saved into PDM, the meta-data must be confirmed accurate, as well as the 3D-model, meaning that model must match the reality (in example a product manufactured by the company or a mounting hardware). Also, it’s crucial that the modeling is done properly (in example planes and mates are correctly set). After the file is saved into PDM, and checked for the previous issues, it must be verified with “Check In” command that changes the state into “In Design” or “Approved” and the file is available for other users. A file that has been checked in cannot be modified unless it’s first checked out and thus available to be modified. After the modification, the file must be checked back in.



Picture 8. TJT-PDM workflow.

The main goal of the use of PDM in the case company is to decrease the number of reclamations caused by technical design, and simultaneously facilitate and expedite the design process. This will be achieved when the parts are modeled correctly, contain all relevant features, meta-data is correct, and functionality is tested and guaranteed in practice.

The most important feature for the use of PDM is the fast and effortless way to find SolidWorks 3D-model parts etc., which are modeled to match and be consistent with reality. Assemblies can also be stored in the PDM, which enables utilizing existing assemblies or models further.

The upside of PDM-system; the boundaries and structure are also the downside if guidelines or workflow are neglected. People might see the use and guidelines too bureaucratic and cut corners, which could be beneficial one time, but cause obscurity

in the long run. In example a wrongfully modeled part might not be interchangeable with the future designs, which will lead to additional work and corrective action.

5 CURRENT STATE OF THE TECHNICAL DESIGN PROCESS

Companies that operate on business field of production must be able to identify the needs of customers, and react to those needs accordingly, by constantly evolving and developing new products. The challenge lies within the product development process, since in the beginning of such process's organizations are dealing with unpredictable and unknown issues. As the situations are not predictable, accurate plans cannot be created. (Hietikko, 2009, s. 11.)

The created product will obviously contain the main idea, ergo invention, but also the organizational know-how; the ability to refine the idea into value-adding product that the customer is willing to pay. Strategically, product development is one of the most important issues in industrial organizations. (Hietikko, 2009, s. 11.)

Product development and product design can be mixed up, although those are two different concepts**.** Product development is the wider process, that comprehend everything from customer demands to production start-up. Product design can be a part of the product development process. The product design process can start in example after the concept generation phase and include generation of CAD models based on a few selected drafts. (Hietikko, 2009, s. 12.)

5.1 Process description

The main objective of product design is to create such documents of a certain product, that the production can unambiguously manufacture the necessary, right, and compatible parts and subassemblies. (Hietikko, 2009, s. 12-13).

Product design rarely focuses on creating a completely new product, that has no similarities to existing ones. Usually, an existing product is modified or used as a model to create a new one, or a variant is made for a certain product family.

Product design is a crucial part of company's operation, since the functional and successful products are manufactured based on the designs and technical drawings. Most of a product's costs are determined in the design phase, in example with material choices and by manufacturability. Product design has also impact on how the markets evaluate the product, and are willing to pay for it, which translates directly to contribution margin.

The technical design department creates 3D models and manufacturing drawings of products desired by the customer. Projects and products vary a lot, but the main segment is fixtures for retail stores. Another notable segment is the public spaces, construction companies, and personnel restaurants.

The desired products can be anything from a simple fastener to an entire shop including floors, ceilings, electrical works, without overlooking the actual fixtures. Technical design creates the 3D model and ensures the functionality and appearance of the product. The 2D manufacturing drawings are made from the 3D model and serve the production department professionals as an important document with the necessary dimensioning and information for manufacturing.

First thing is the impulse to create something. Usually, that means a sales agreement between company and a client. After the sales department has made a deal with a customer, the project moves to the next phase, technical design-phase. The projects differentiate by business segment and by customers within the same segment.

Some projects are explicit from the beginning, in example public sector projects. Those usually have architectural plans or designs, that set the boundaries for technical product design. The specifications might include materials, precise dimensioning, appearance, and suggestion of structure. In these cases, the company's technical design department creates models and manufacturing drawings for in-house production, based on the specifications, considering functionality and manufacturability.

On the other hand, some projects are very confusing from the beginning and explicit specifications are not available. In these cases, the project is an ongoing interaction between the design-, sales-, production-, and project coordination officials. These projects consume a lot of resources but are frankly quite common on retail-sector. The projects are crucial for the company despite of the need of resources. The operating model on this business sector has over time shaped to be generally as such, and as the

company offers made-to-measure fittings, the orders and specifications tend to be a bit confusing and require further investigation.
The initial information and specifications for a project bear great impact on the design phase. With proper specifications, and all other relevant information, the design phase can run smoothly, and with certainty that work is done within boundaries and with appropriate issues. The lack of such information correlates directly with the design phase efficiency and success. It is possible that the designer and the customer have a completely different idea of the product visually or functionally if there are open questions or possibility for misinterpretation.

5.2 Issues to be improved:

Overlapping work:
People within the design department are developing similar solutions simultaneously versus discussing with each other and utilizing existing, functional solutions. The knowledge and solutions that are proven good and functional are not shared, which lead to unnecessary, duplicate work without certainty of manufacturability and functionality.

Lack of communication:
Communication within the design team call for more interaction and sharing ideas and expertise. Manufacturing perspective and workable solutions should be discussed in earlier stage of the project with supervisors and professionals, to ensure manufacturability, and the identified solutions to be practical. Sales- and design department should have more interaction about the project deliverables and about the requirements set by the customer. Specifications must be pointed out more clearly.
Generally, communication within the organization should be better to ensure efficient and reliable operation, value-adding operational procedure, and ensuring the customer receive right kind of product at desirable quality at the agreed schedule.

Quality issues:
Absence of the quality paradigm and management. Occasionally things are thought or designed only 90% through, thus the last missing piece causes a lot of harm in

functionality, and in assembly and installation phase. Monetary impact of internal and external reclamations is extensive. Ideally every employee should ensure his/her effort is desirable and quality on every step meet the requirements.

Unused potential and expertise:
Possibility to further improve use of software and applicable tools. Utilizing the product library and PDM system presented in this thesis, as well as project management tools. Utilize the expertise that lies within the organization and the professionals, in example brainstorming sessions, to regard all essential perspectives for value-adding and successful products.

5.3 Assets:

Organization possesses much know-how:
Company has been operational for 22 years and has over the years gathered a tremendous amount of experience and know-how. Company has done several demanding projects and has excellent experience on practical solutions and production methods. Company has had own design and manufacturing from the start, which has proven to be an advantage concerning competition. The in-house design-, metal-, wood-, and assembly departments possess much expertise.

Urge to strive forward:
Process development has been ongoing process, which has been strongly invested in in the last year or so. Management has offered the support and conditions for the process and efficiency improvement operations. Customership objectivities and significance have been determined to support the customer-oriented approach in the organization. Also, calculation of costs has been invested in, which offers valuable data of profitability.

Management of reclamations:
Company has recently established a working committee for quality management and reclamations. The idea of the committee is to go through example cases, that include both excellent and poor issues. The objective is to find and determine the root causes

of the issues, to ensure similar issues can be avoided in the future. The objective is also to present functional solutions, that could be utilized more, as well as to form reliable procedures. Both internal and external reclamations can be addressed in the committee. Monetary significance of the external reclamations or quality issues can be major, which support the idea to strongly investigate the cases and the find the underlying root causes.

Up-to-date resources:
Design department have excellent CAD software with the suitable add-ins for the company. SolidWorks enables doing everything the company's design and manufacturing needs and much more.

5.4 Improvement ideas:

Invest and develop productization:
The goal is to create and implement cooperative procedures in design, as those are crucial for interchangeable designs and manufacturability. Clear guidelines and procedures will steer the operation in the department to be more uniform and efficient. The development and utilization of the PDM-system will favor and steer using determined components that are most suitable for the company, and most importantly, functional.
The catalogue for reference objects and solutions will help in brainstorming, offering and tendering situations.
Cooperative procedures throughout value-chain and rules will help to avoid mistakes and ambiguous issues.
Quality definition and management should be addressed correctively; what is sufficient and what excessive quality. This should be considered for each customer.
The aim is to offer special fixtures made with standard components:

- Scrutinize and trim the component- and raw material inventory to best match the production and products as well as decrease the amount of inventory and monetary excess.

Management of assignments and orders:

Support and invest on the project's initial information to ensure the best possible information is available. Invest in project startup and review to ensure people recognize what is to be made. Use and utilize project management tools and software. Create distinguish and suitable project phases for the company:

- In example phases introduced in Project Management Body of Knowledge, PMBOK: initiating, planning, execution, monitoring and controlling, and closing.

Improve cooperation and communication:
Between design team personnel and within department to ensure uniform procedures in design, as well as to introduce notable issues. Interaction between departments (design and sales, metal-, wood-, assembly-, and installation) to ensure smooth operation.

Utilize power of teamwork:
Share the workload between designers in extensive projects. Include manufacturing professionals in earlier stage of work. Use more teamwork - no one can do the things only individually. Everybody's effort matters for operational success.

Improve feedback organization:
Introduce good and functional solutions and examples. This will steer choosing functional solutions in the future, considering manufacturability and operations throughout the entire value-chain. It's also highly important to introduce the reclamation products with issues as well as possible improvement ideas.

To summarize the main topics:

- "A special fitting made with standard components".
    - Customers are willing to pay for the functionality and outstanding, visually preferable looks, but products can still be based on standard solutions and components, adjusted to the specific needs and regulations of a customer.
- The goal is to ensure efficient and more definite operating with lesser issues with quality and functionality.

6 PRODUCT LIBRARY

The product library is an upcoming system to help the company's relevant employees at different departments (sales, design, purchase, metal- and wood production, and warehousing) to manage and explore finished products and solid and functional solutions. The product library is an intra-net-based product catalogue where company's parts, components, structures, assemblies, finished products and other related information is available in easily findable, clear, and visual format.

The product library is a catalogue-like place where designers, purchasers, project managers and salespeople can find predefined, tested and fully functioning components and elements. The products that are available in the product library can be stand-alone entities, or smaller parts that can be used individually or to create a larger assembly. User can see a picture of the model piece he/she is looking for. The library also shows the main measures and other relevant specifications and information. The product library will help users to find and visualize the elements they are looking for.

For the sales department and salespeople, it's important to have some reference pictures of products and visualization with them on tour, that way they can show the potential customer some reference products and pictures and push the sale forward. With the use such product library, the salespeople can also steer the customer toward solutions most suitable for the company manufacturing-wise. Since the customer might not have precise idea for the product he or she is desiring to buy, it's important to guide the decision towards something that benefits the company, and simultaneously offers a good product.

The utilization of such product library will decrease the custom to redesign the same or similar things repeatedly, and will offer functional solutions, and ultimately lead to more efficient utilization of suitable solutions throughout the value-chain.

The premeditated and efficient use of PDM and the product library will save time in both design and production, while enabling the utilization of modular and standards-compliant production.

The material choices and structures of the parts, components, and products found in the product library will be considered from different perspectives to be production-

friendly, but also to have first-class technical, functional, and cost-effective properties. In the future, well-proven solutions could be utilized even better and more efficiently.

6.1 Development / pilot series of parts

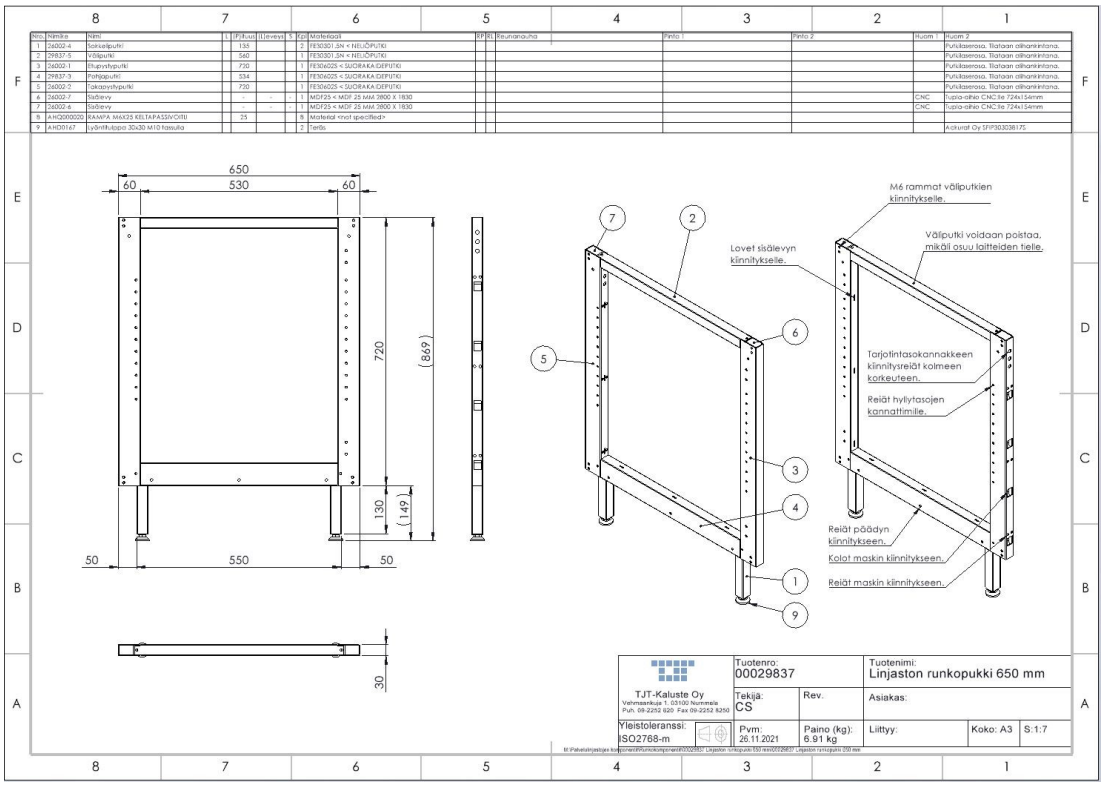
The idea to develop the products for product library has come from urge to offer better solutions with decreased lead time and with more functionality and manufacturability. The vaster idea is to create and collect components and products from many sections, structures, and product families into one clearly visual catalogue. The idea is scalable, and content can be added in the future as seen fit or necessary.

The work has been started from a section called “structures for counter”, loosely translated. This section consists of components and products that can be used in various counters and fixtures. The section is currently divided into four sub-sections:

- frame-components
    - This section includes all components used to create in example a counter. There are components like: frames, shelves, and frame tubes. The main idea is to use and utilize modularization and predefined components. Dimensioning have been made on modularization principles, which offers flexibility and possibilities, as components can varied to create different size of frameworks.
- air-circulation grills
    - This section includes all the grills used in fixtures, that have equipment installed into. In example when installing refrigerated equipment into fixtures, air circulation must be assured.
- droplet screens
    - This section includes droplets screens on various sizes. The suitable size screen can be adapted into fixture in the designing phase. The selected screens can be adjusted to match the needs of specific customer. The dimensioning follows food industry and catering equipment, that follows Gastronorm (GN) standard.
- friezes and logos
    - This section includes friezes for selected line of counters in lineal meter, to ensure smooth manufacturing and installation operations.

The below (picture 9) presents a component called “Linjaston runkopukki”, a certain component found under “frame-components” and to be used to construct various frameworks and counters. The component has been tested and proven to be functional and suitable for different kind of end-products.

The idea was to create a “universal” solution that can be utilized vastly in counters and suitable fixtures. The component will replace the need, and more importantly habit, to create an exact solution for each counter. Previously the habit and procedure were for every designer to design a specific framework for each product or counter. Obviously, there is a lot of work, which could be decreased or eliminated by utilizing this standard-like component and product family.



Picture 9. Page of technical drawing of a component placed in product library.

6.2 Development / catalogue

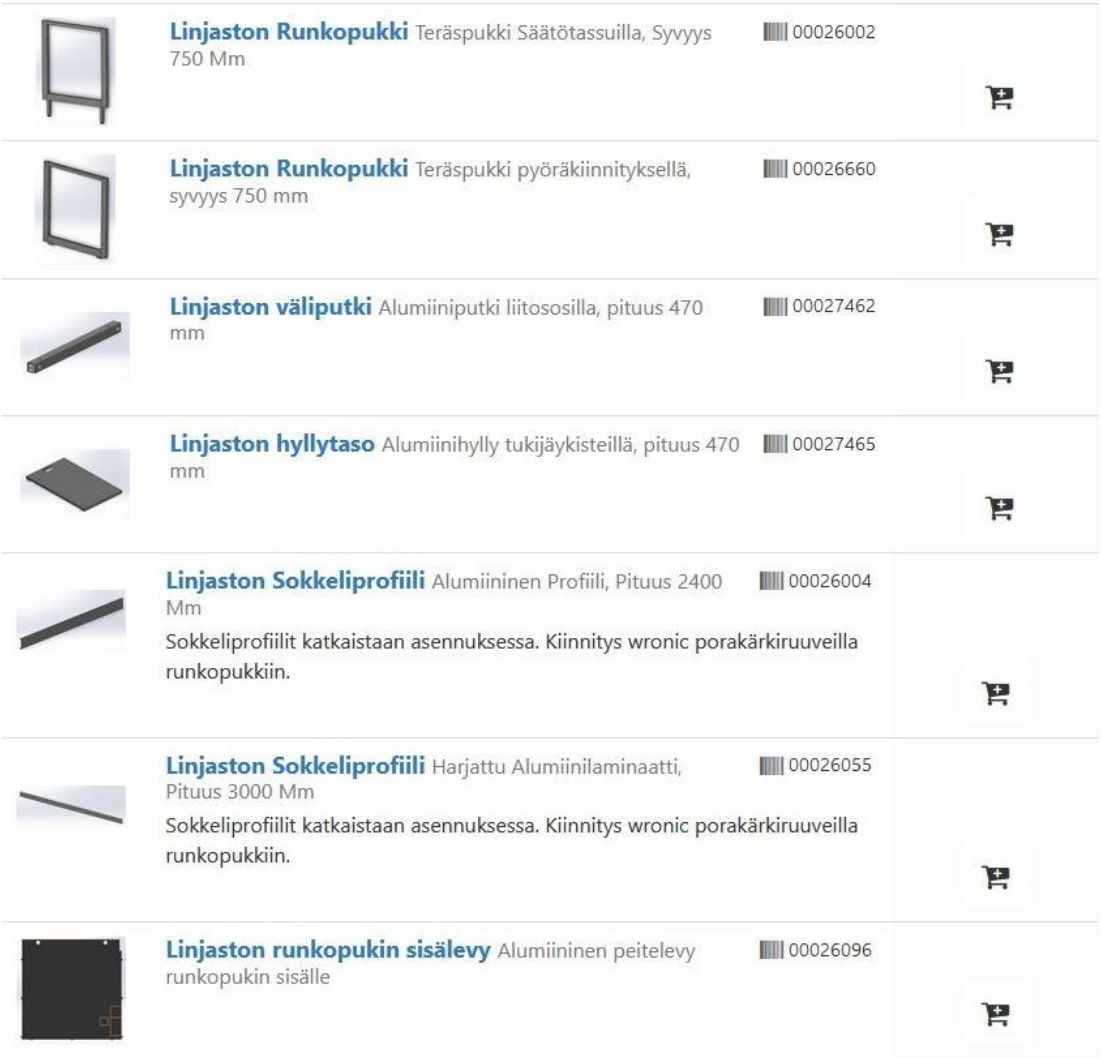
The product library catalogue will be posted into company’s intranet. The product library catalogue will only include parts, components and products that are tested and

fulfilling the set demands, such as manufacturability, functionality, and cost-effectivity.

The catalogue can be seen and utilized by company employees with username and password. The catalogue will be most likely in use by salespeople and designers. The salespeople can “steer” the client toward same solutions when convenient. The designers will have a clear visual representation of parts, components and products that have tested and proven to be suitable for manufacturing, functional and cost-efficient.

Utilizing the product library will decrease lead times in design phase, as well as delivering a high-quality, functional design to manufacturing phase.

In the below (picture 10) is an example of product catalogue. In the example there are a few items presented, that contain a picture for visuality, name and short description, and a part number.



Picture 10. Example view from the product library.

7 CONCLUSION AND DELIBERATION

Product library and PDM were selected to be the foundation for improvements and enhancements of technical design process. Discussions with upper management were conducted after studying the technical design process in the company and generating a general overview of the process and situation. Product library was a desire for the company because it was seen to bring out much needed fundament for uniformity and efficiency. The product library was seen to avail the idea: “Create and offer a special fitting made with standard components”. Advisable use of the PDM-system is the base for utilization of selected and specified mounting hardware, components, parts, assemblies, and products.

The upsides are undeniable according to design phase/department lead times, that have gotten shorter when utilizing new procedures, approaches and the created and enhanced system and product library. As significant matter concerning the improvements is the fact that designs and fittings are fully functional and does not need fixing and adjusting in the manufacturing or installation phase. This saves both time and money, while giving a better and more professional image of the company.

Quality of the design and quality of the final product have gotten better. Design quality signifies more efficient operation throughout the organization, since work can continue and be carried out without misinterpretation, obscurity, and interruption. Quality of the final product saves money and time, as corrections and rework can be eliminated. A high-quality, fully functional, and visually preferable product strengthens the imago of the company and increases customer confidence for the company.

7.1 Test of functionality

A test assembly was done after completing the design phase and development of the components (picture 11). In the test-phase the components were tested to be fully manufacturable, compatible, practical, and robust.

The pilot assembly was stated to match all the qualities set earlier and determined to be easy to assemble and modify when necessary, according to the assemblers. There were some notes concerning the shelving solution, which were presented as constructive feedback, including improvement ideas about the issue. The shelving solution was reviewed on modeling software, and the improvement ideas were discovered to streamline the assembly process even more.

The improvement ideas and generally notifications in the test-phase are essential since it's very hard to consider all possible details and variables in the design phase. In the test-phase insight, opinion, and notifications were gathered from relevant parties: sales, design, purchases, production, and assembly and installation. It was very rewarding to gather the insights of such many parties before "locking" the components with certain specifications. The test-phase also offers a great possibility to share the knowledge and introduce the new product family for many department representatives simultaneously, which makes it easier to collect feedback and form a conclusion.

Picture 11. Test assembly of the created parts.

7.2 Sales point of view

With the help of the product library, it’s faster, easier, and more efficient to offer products and make deals the with possibility to show a library of reference products and pictures. It’s also possible to steer the customer on choosing a product/solution that is proven to be functional and suitable for the company to design, manufacture and install. The product library also works as an inspirational source when generating

ideas with customer. Fully determined product system with reliable specification will help in tendering. Costing and cost-base are easier and faster to determine with more accuracy.

7.3 Design point of view

Clear, standard-like uniform procedures, components and product families will save time and resources in the design phase. When the components/solutions/parts or products are fully thought out and easy to utilize, the design works will run more smoothly and efficient. Designer can simply take a component and place it to the assembly without having design it from the beginning. Designer can focus the available time on productive and exceptional design work rather than creating similar solutions over and over.

7.4 Manufacturing point of view

When the product library and PDM -tools are utilized efficiently, the manufacturing department will receive work orders and designs that are suitable for the company to manufacture. In example material solutions in the products to be manufactured are thought out to match the inventory and set base materials negotiated with suppliers. Components and solutions are suitable for manufacturing with company's machinery and personnel expertise. Manufacturing department can adjust the operation according to familiar products. These procedures will eliminate too challenging solutions from manufacturing perspective or excessive use of resources.

7.5 Economical point of view

The newly set procedures and PDM and product library tools will save money and resources throughout the operation. In the design phase money will be saved as the lead time decreases and resources can be allocated faster and more efficiently on new projects. The design quality will also improve, as the functional solutions are easy to utilize. This saves rework and internal reclamations that consume money.

Manufacturing specified products that include specified components will decrease the lead time in manufacturing phase. The material choices that respect the determined inventory will save money in purchases and in inventory management.

Assembly work will run more smoothly, and lead time will be decreased. The assembly works can be carried out as planned, since the solutions are compatible.

Installation phase can execute the work as planned and without unnecessary delays, since the solutions are compatible and functional. This will cut rework and unprofitable adjustment work in the customer's premises.

All the above will improve the operation and decrease costs. Costs will be saved within the process but also in form of external reclamations. External reclamations and quality issues will be eliminated to a great extent as the solutions are fully thought and designed and manufactured with professionalism.

REFERENCES

AIPWorks. Referred 20.10.2021. https://aipworks.fi/

Aspinall, C. (11.6.2018). Top 5 Benefits of using 3D CAD Software. https://www.cadspec.co.uk/blog/top-5-benefits-of-using-3d-cad-software/

CustomTools. Referred 18.11.2021. https://www.customtools.info/

David, M. & Madsen, D. (2016). Engineering Drawing and Design (6th edition). Cengage Learning.

Dassault Systèmes. Referred 20.10.2021. https://www.3ds.com

Grant, M. (10.10.2020). Bill of Materials (BOM). https://www.investopedia.com/terms/b/bill-of-materials.asp

Hietikko, E. (2009). Tietokoneavusteinen suunnittelu (3. painos). Savonia-ammattikorkeakoulu.

Hobbs, J. (10.10.2018). The Advantages of CAD (Computer-Aided Design). https://www.cadcrowd.com/blog/the-advantages-of-cad/

Lombard, M. (2019). Mastering SolidWorks (1st edition). Sybex.

Pere, A. (1997). Teknisen piirustuksen perusteet (5. painos). Kirpe.

Siemens. Referred 8.9.2021. https://www.plm.automation.siemens.com/global/en/our-story/glossary/product-data-management/13214

SolidWorks. Referred 14.10.2021. https://www.solidworks.com

SolidWorks. (2021b). The Top Five Reasons for Manufacturers to Improve Data Management. https://www.solidworks.com/sites/default/files/2019-08/The%20Top%20Five%20Reasons%20for%20Manufacturers%20to%20Improve%20Data%20Management%20Whitepaper_FINAL_US.pdf

TJT-Kaluste Oy. Referred 18.9.2021. https://www.tjt-kaluste.fi/etusivu

Velling, A. (15.4.2021). What is Computer-Aided Manufacturing (CAM)?. https://fractory.com/what-is-computer-aided-manufacturing-cam/

Watts, F.B. (2012). Engineering Documentation Control Handbook: Configuration Management and Product Lifecycle Management. (4th edition). Elsevier.