SAVONIA

THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

ROLLER CONVEYOR

Developing a modular conveyor solution with add-ons

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SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

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Abstract

This thesis was a design project of a roller conveyor line. The customer of the project was Vannetukku.fi, a Finnish tire, rim and equipment importer and seller. Vannetukku.fi is a major operator in Finnish tire markets, and it has about 10% of the marketshare with steady growth. Besides tire and rim sales, Vannetukku.fi sells equipment and machines of their own brand. This project acted as a part of their efforts to expand their equipment cataloque and offer better solutions for cheaper price for entreprenuers in this field.

The purpose of the product was to transfer car tires from one work station to another ergonomically, safely and efficiently. The roller conveyor operates on gravity. It has a protective cage for tire inflation, a stand for inflation robots, tool wall and a brake to stop tires from rolling. The product was designed to be modular, transportable in flat packages and easily assembled and dismantled with minimum number of tools. This type of IKEA-inspired design was what the customer initially wished for.

To reach satisfactory results product design was studied and different tools and techniques of product design and -development were utilized. Quality Function Deployment (QFD) and Designed for Manufacturing and Assembly (DFMA) were used to achieve a product that fits the purpose with the voice of customer having the final say on the development to ensure customer satisfaction.

The project followed schedule in approximation and yielded a working prototype for the customer. Testing the prototype would be a natural following step, after which found improvement ideas could be implemented. After this, the product could be outsourced in large quantities and sold in domestic and foreign markets.

Keywords
QFD, DFMA, Roller conveyor, product development, tires

PREFACE

This product design project started in early February 2018 as the first meeting with the project's customer took place. At the time I didn't have any contact to Vannetukku.fi, and approached the company based on my previous experience in the field of business. The CEO Jukka Heiskanen was very positive towards student cooperation, and we quickly found a topic amongst various possibilities that resonated with my personal interests.

The project is now finished, and thinking back I didn't feel bored or forced at any point during the design work. The task was challenging enough to keep interest up, but not overwhelming, and at least for me this subject felt very fitting for a thesis project.

I would like to thank Mr. Jukka Heiskanen, without whom this project wouldn't have taken place, and Mr. Marko Härkönen for his participation and supportive ideas on the prototype design. Both have been important factors in the success of this project.

Hopefully even a bit of my interest in the subject conveys through this report to you.

Juuso Laine
12.6.2018 in Kuopio

CONTENT

1 INTRODUCTION

Work Safety is a very relevant issue in modern markets. Companies drive for safety in many ways: adjusting workers' attitudes to better acknowledge risks, preventing physical traumas by protective gear, or educating personnel on ergonomic work methods. The law demands employers to take care of employees' safety, observe the work environment and act to prevent possible accidents and health risks. In practice, employer must plan the work and methods to minimize the risks, procure necessary safety equipment and guide employees to safe working methods. Work safety is beneficial for both employees and employers. (Anias & Salmivalli 2015, 6.) Accidents and injuries have negative effects on both parties.

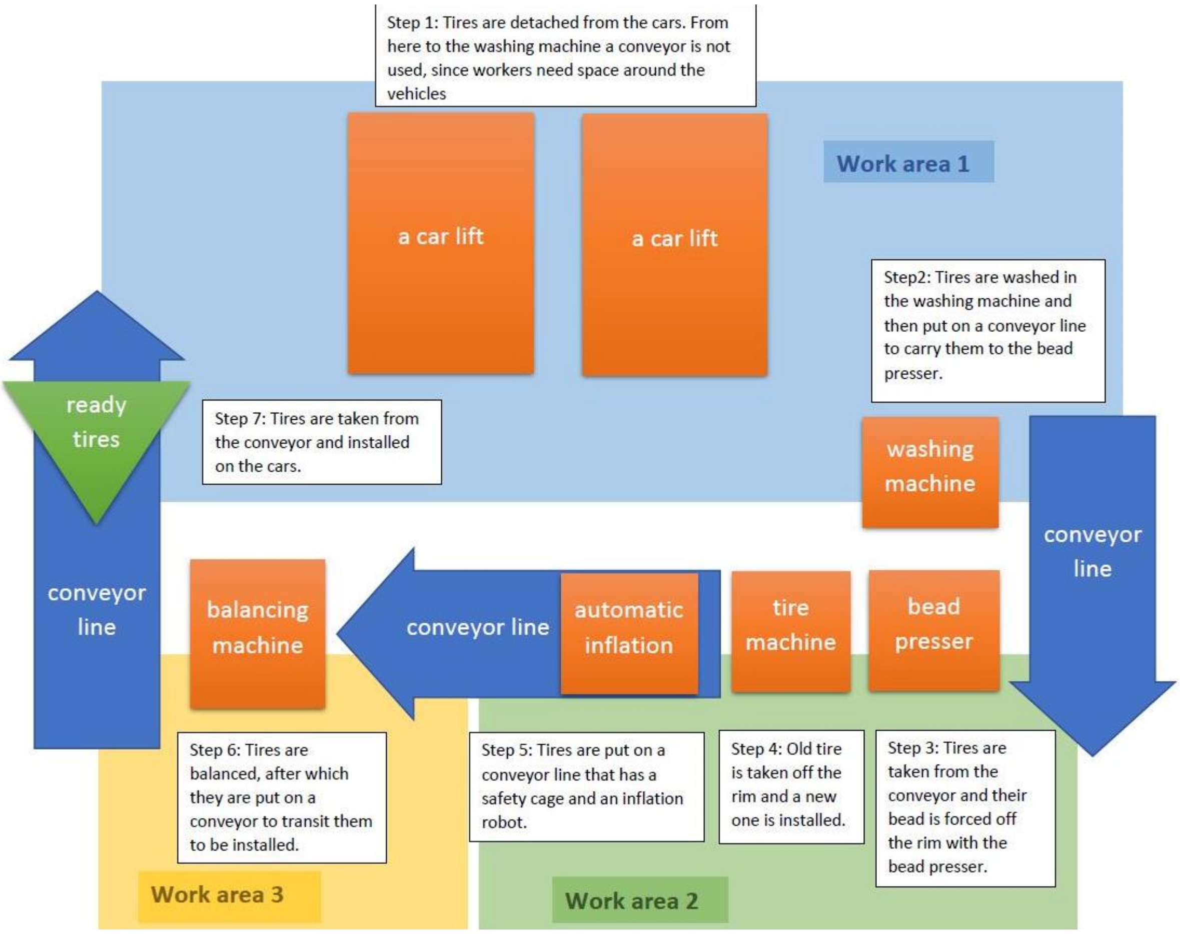
This thesis is made for a tire, rim and equipment importer and wholesaler, and the topic is to design a gravity powered roller conveyor and its modular add-ons to be part of a tire installation line. This is directly related to work safety and efficiency, as using devices like these make working more ergonomic, prevent physical harm and save time. When devices are planned in a way that the operator can work safely without unnecessary movement and difficult positions, efficiency and work satisfaction increase.

In tire business there are many companies with different types and sizes of workshops. When planning a product for this type of market, it is important to be able to offer multiple variations of size and capacity. Also, when designing a product for a target group, one must consider what they want, not only what they need. A designer often assumes a customer to want something else than the customer's real wishes. (Huotari, Laitakari-Svärd, Laakko & Koskinen 2003, 9.) For example, safety equipment must *look* safe to gain possible customers' trust, not only be safe and functional.

2 THE GOAL AND METHODS

2.1 Purpose and goal

The purpose of this thesis is to develop a user-friendly roller conveyor system for transporting tires. The system should also include a safety cage for when inflating a tire, mounts for automatic inflation robots and a mechanical brake to stop a tire at a certain position, given that the conveyor is gravity powered. The system should also include tool holding add-ons like a tool wall or bead seater holder. The customer has also given prerequisites regarding technical solutions, mainly to achieve certain functionality of the final product. The roller conveyor is meant to be a part of a tire working line (Picture 1). As a tire goes through the process it can be ergonomically transported instead of carrying it or rolling it on the floor.



PICTURE 1. An example of a tire shop’s work line

This collaboration came to be due to the author’s working history and interest in the field, and the customer company’s continuous efforts for product and method development. The topic was selected amongst various possibilities by weighing personal interest and practical need the most. The customer of the thesis is a Finnish company that designs, imports and sells tires, rims and relevant equipment for private and company customers. Their main emphasis is on internet sales, but they also have various workshops, stores and partner locations for customer service. Their webstore reaches annually over 3 500 000 visitors, and their market share is about 10% of the Finnish markets.

Markets for tire working equipment are rather niche, and not too competed. Products similar to this idea exist but are different in several ways. They might be overly complicated, muscle powered, not as proficient or just blatantly expensive. Outsourcing manufacturing based on own schematics and solutions make it possible to bring a functioning and modularly variable product with a low price to the markets.

The goal of the thesis project is to produce blueprints for a modular conveyor system with its possible add-ons. The customer could then manufacture a prototype for their own use and testing, and later outsource manufacturing of the product for larger scale sales.

2.2 Project strategy

This thesis work is a product design project. Product development and design are often mixed with each other, but product design should be considered a part of product development process. Development process is a larger entirety covering everything from a customer need to the production start. Product design phase usually begins at the end of concept phase, and its usual goal is to develop documents with which the product can be manufactured. (Hietikko 2015a, 13.)

To create necessary manufacturing documents SolidWorks computer program is used. SolidWorks is a CAD (Computer Aided Design) program by a French company Dassault Systemes, and its utilized under Savonia University of Applied Sciences' student license. The customer company has access to AutoCAD program by Autodesk, and when the product design is ready, AutoCAD can be used to recreate blueprints, since modelling isn't necessary anymore.

The customer has manufactured two prototypes of their own roller conveyor with safety cage, inflation robot mount and a brake. These prototypes haven't been modular, and the design doesn't favor mass production since they have been manufactured from the materials available. The core idea of the concept is present, but the measures are a subject of change and most connections are made by welding. The CEO of the customer company has wished for an "IKEA -ideology", where parts could be joined together with simple tools to pre-existing attachment points.

The modular system can be divided into five main units: the roller conveyor, the safety cage, the brake, the inflation robot mount and tool walls. The roller conveyor acts as the main unit, on which other units can be attached. Preliminary plans suggest the inflation robot to be mounted on the safety cage, but the other units should be independent systems. The parts should be designed in a way that two systems with same parts could be assembled as mirror images of each other.

Manufacturer of the prototypes had to rely on materials at hand, but when planning for mass production all the parts can be designed from the beginning to match and fit each other, making it easier to make a modular and easy-to-install model. Material selection isn't as important on the early level of designing, since the parameters, like thickness and length, can be changed later when using a CAD program.

2.3 Customer's prerequisites

The customer company's CEO has set rules for the product. By fulfilling these wishes the product would be what the customer initially wanted. Compromising these initial guidelines would lead the project in an unplanned direction. The listing presented below is not in order of importance.

1. The conveyor should work based on gravity, utilizing no external power source. Human effort to move tires on the conveyor would take time away from other installation work, thus eating away efficiency. The conveyor needs a brake to stop wheels from rolling during inflation.

2. The conveyor should be made of modular units, so that it is customizable for different lengths and capacities of inflation. The length of one module should be between 800 mm and 1000 mm.

3. Parts can be flat-packed in delivery boxes.

4. Simple and easy fastening, if possible by a single tool. Preferably with hexagonal bolts and on-place welded nuts or threaded holes.

5. Simple technical solutions with as few moving parts as possible. This makes manufacturing and assembly easier, lasts longer without malfunctions and keeps manufacturing costs low.

6. Safe. Workers should be able to work around the product without the risk of getting injured. In addition to the safety cage, this means the product shouldn't have sharp edges or sticking objects on which to injure oneself.

7. Fast mounting solutions for following items: SteyrTek inflation robots, tool walls for balancing and installation equipment and a mount for a bead seater and its balancer.

8. The conveyor width should be at least 800 mm and the insides of the cage 900 mm to allow for a 35" tire. The cage height should be at least 400 mm.

2.4 Utilized material

The main sources of information in this project are observation and literature. Observation includes Author's own experience and insight on the matter gained through working in this field between 2007 and 2014. Also, continuous conversations and opinion exchanges with the personnel of the customer company are important sources of information. In addition, a list of prerequisites for the product was created to fulfill the wishes of the company's CEO. Talking with people isn't interviewing (Huotari et al. 2003, 10), and while this level of perception doesn't fulfill parameters for scientific research it was deemed adequate since the customer was already aware of what kind of product they wanted.

The literature for this project includes guidebooks on various subjects: research, work safety, writing, product design and CAD program designing. A mind map was created in order to help visualize connections and relations of concepts in the project (Picture 2).

PICTURE 2. A mind map for the thesis project

3 DESIGN THEORY

3.1 CE-marking

EU's directive 2001/95/EC (general product safety directive) is intended to ensure high level of safety of consumer products that are not covered under any sector-specific EU harmonization legislation. The key provision of GPSD is, that producers are obliged to place on the markets only products which are safe. (EU Commission notice 2016, 12.)

To this end, CE marking system ensures that certain products sold in European Economic Area (EEA) are manufactured in a way European harmonization legislation approves. CE mark is put on a product by the manufacturer who is then responsible of the claim that the product stands up for the legislation. However, the CE marking is required only for products under an adopted CE directive or legislation and using the CE mark unnecessarily is prohibited and sanctionable. (cemarking.net 2018; EU Commission 2016, 64.)

According to the EU Directive 2006/42/EC (2006, 27) about machinery, a gravity powered roller conveyor described in this project doesn't fulfill the definition for machinery, since it is not powered by external power source or human labor and is not ready to be fitted into a device that could power it. As the product type is not under any other directive or legislation, it is concluded that it doesn't need a CE mark for markets inside EEA (EU Commission 2016, 14).

3.2 Design for Manufacturing and Assembly

Acronym DFMA means, that product design strives for easy-to-manufacture and simple and flawless-to-assemble methods. Configuration is the central factor in DFMA ideology, for it dictates how successfully a product is designed, assembled and serviced later in the life cycle. The more complex a configuration is, the more risk factors are included in it. That is why it is important to always avoid unnecessary parts. (Hietikko 2015a, 16-17.)

There are ways to analyze configurations and help designers to simplify their products. These methods vary from programs integrated into CAD-programs into simple rules of thumb. In its simplest DFA-analysis can be performed by putting each part of the assembly under three questions:

1. Does the operation require the part to move in relation to other parts?
2. Has the part to be manufactured from different material than other parts?
3. Has the part to be separated from other parts for service and maintenance?

In principle, all the parts that can be answered "no" are potential targets of integrating together with other parts. (Hietikko 2015a, 17-18.)

3.3 3D-design

The purpose of 3d modeling is not to make three-dimensional models, but to make high quality documents for manufacturing (Tuhola & Viitanen 2008, 4). 3d modeling enables benefits that traditional 2d designing cannot offer. Its biggest benefit is easy part fitting and checking assembly comparability. A model can also be effectively used in strength analyses integrated in the program. (Tuhola & Viitanen 2008, 13.)

The properties of a 3d design program are superior when compared to 2d designing in this type of project. Modular units are designed separately, and to be able to verify their compatibility in assembly mode helps to assure of the suitability of the blueprints. A visible three-dimensional model also helps comprehension when presenting a work-in-progress product.

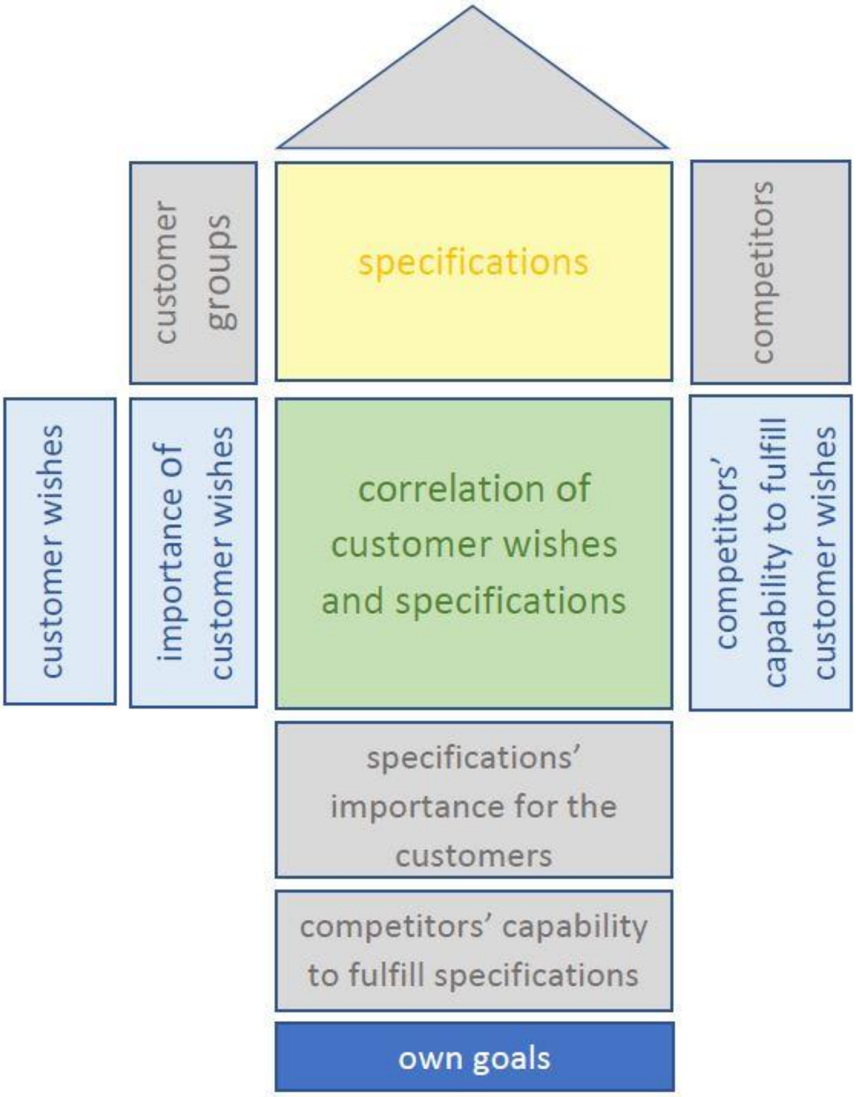
3.4 QFD method

Quality Function Deployment method was developed in Japan in the 1970's. It helps to transform customer needs into measurable goals. At the same time, one can compare their performance against the competition on the goals that stem from the customer needs. QFD system is efficient, because it is easier to achieve certain quality and functional goals if you know them well before reaching for them. (Hietikko 2015b, 79-81.)

In QFD, customer needs are transformed into objectives that are measured by universal parameters. For example, one cannot design a door that is "easy to open", if the exact definition of "easy" is unknown. It could mean the amount of force needed to open the door, which would be measured in Newtons (N). Once a measurable unit is found, a tolerance limit for design can be set. (Hietikko 2015b, 81.)

First step is to make specification out of customer wishes. These specifications are presented as quantities and their amounts. Each customer wish is given a quantity, and some might need more to clarify the need. For example, "easy to install" could be measured in seconds (s) as "installation time", or in steps as "required steps for installation". Both are right, although the meaning is very different. Sometimes fast installation might be difficult to perform and require specialized tools. Some wishes cannot be measured as quantities, for example "nice looking". In these cases, the customer wish is selected as the quantity, and value is marked as subjective (subj.). (Hietikko 2015b, 73.)

After specifications, a QFD matrix can be created. It has sections for customer wishes and their importance, specifications, correlations between specifications and customer wishes and competition analysis and capability. The QFD matrix system is often called "house of quality" (Picture 3).



PICTURE 3. QFD house of quality (Hietikko 2015b, 82. Translated)

The QFD matrix created for this project (Figure 1) can be studied by using the house of quality as a key to understand the meaning of different sections in the matrix. The scales for customer wishes and competitor capability were 1-5, and the scale for correlation between customer wishes and specifications was 0-1-3-5.

Each specification's correlation with customer wishes and the importance is multiplied by each other to get the total importance of the specification. This way it is easy to see which specifications matter more, and which can be possibly compromised.

FIGURE 1. The QFD matrix made for the thesis project

	importance	**Specifications**									**competition**	
Customer wishes		*inclination adjustment [m]*	*cost [€]*	*interchangeable positions [y/n]*	*tools needed [pcs]*	*time to connect parts [s]*	*moving parts [pcs]*	*hazardous sections [pcs]*	*at least 900mm per side [y/n]*	*operator actions [pcs]*	ahcon	no conveyor
Gravity powered, no power source	5	5	1	1						3	2	1
customizable configuration	5	3	1	5	3			1	3	1	3	1
easy, fast and simple fastening	4		1	3	5	5	1				4	5
as few moving parts as possible	3		5				5	1			3	5
safe	4			3				5	1		5	2
mounting solution for add-ons	5			3	3	5	1	1	1		5	1
big enough for a 35'' tire	4								5		5	5
affordable to manufacture and sell	4		5				3		1		2	5
detachable for flat delivery packages	3				1				5		2	5
saves workers' time	5	3		3				1		5	3	1
											sum	
Specification importance		55	49	84	53	45	36	38	63	45	468	
relative importance		12 %	10 %	18 %	11 %	10 %	8 %	8 %	13 %	10 %	100 %	
competition performance		0	N/A	n	2	N/A	2	1	y	7		
goal		0,4	N/A	y	1	N/A	1	0	y	5		

4 TIMETABLE AND RESOURCES

4.1 Preliminary schedule

This thesis is divided into three separate phases: planning, implementing and finalizing. Planning phase started by finding the topic. Creating the topic description, kick-off meeting with the assigned supervisor and writing the thesis plan were following steps. After the supervisor and customer had both accepted the thesis plan, implementation phase commenced. In this phase a 3D model of the whole system was created according to the plan. Blueprints were made from these 3D models, and a prototype was manufactured by the customer. Finalizing phase includes presenting the thesis project and publishing the thesis.

The project was initially planned to finish during the spring period of 2018. The first meeting with the customer and the agreement on the topic was held on Thursday 8th of February on week 6 of 2018. Ending the project during May 2018 would give 12-16 weeks for the project.

Initially, planning phase was thought to be over by the end of February, and Finalization was given two weeks at the end. This gave 7 to 11 full weeks for the design work starting 1st of March on week 9. Finalizing would then begin somewhere between late April and middle of May.

The initial project timetable was as follows:

Planning 8.2.2018 – 28.2.2018

8.2.2018 – Start meeting with the customer.
9.2.2018 – Topic description
15.2.2018 – Visit in the customer’s main location and studying the prototypes.
16.2. – 28.2.2018 – Thesis planning, material gathering and studying.

Implementing 1.3.2018 – 22.4.2018

1.3. – 18.3.2018 – The conveyor frame
19.3. – 1.4.2018 – The safety cage
2.4. – 15.4.2018 – The braking system and tool wall
16.4. – 22.4.2018 – The inflation robot mount

These dates were preliminary suggestions showing deadlines for different units in their needed order. If a design finished early, the next phase would have started right away, not on the planned date.

Finalization 23.4.2018 – 31.5.2018

30.4. – 31.5.2018 – Handing the thesis in, end seminar, maturity test and publishing the thesis.

4.2 The actual schedule of the project

As originally planned, the planning phase was finished on time by the end of February 2018. The kick-off meeting with the supervisor was held on 22nd of February, and the thesis plan was finalized based on the supervisor's feedback on the following week.

Differing from the initial plan, the implementation phase got divided into different versions of the product. This was because it was deemed easier to start some parts completely over than to adjust the parts. The first version of the product was already started on 22nd of February and finished by the end of the month, so the implementation phase overlapped the planning phase by a few days. Different parts of the conveyor were developed together with other parts, not in a way that was originally planned in the initial timetable. This was due to the modular nature of the product. Changes in one part often affected other parts too.

Implementation phase continued until early May. The schedule got stretched by a couple of weeks, partly because some schematics were modified multiple times. This dragged the project a bit but resulted in better functioning results.

The finalization lasted through May 2018 with finishing the report. The presenation seminar and maturity test were scheduled on June 6th, after which the publishing was the final step.

4.3 Resources

The resources in this project included computer programs and supervisors provided by Savonia UAS. The customer's own prototypes and workshop were located far from the project location, and as such were not considered as direct resources. However, customer's workers were making a new prototype based on this project during the implementation phase and could test mechanics and solutions in action and see if they work properly. Naturally, the know-how and experience of everyone included in on the project was also a great resource in the design process.

The design process itself didn't cause expenses, and most of the costs came from transportation, for example when visiting the customer's different locations. Prototype costs and worker salaries weren't affected by the thesis project, for the personnel were serving the customer company already before the project.

4.4 Strengths and risks

A Strengths, Weaknesses, Opportunities and threats -analysis gives a fast and simplified look at the project and its possible outcomes. This analysis was made in the beginning of the project, and it held true quite well throughout the project (Figure 2).

FIGURE 2. SWOT analysis of the project

Strengths	**Weaknesses**
- knowhow - 3D design proficiency - customer's experience and passion	- Author's inexperience - a long distance to try out prototypes
Opportunities	**Threats**
- gaining professional experience - getting a good product as an outcome - prepare for future possibilities on modular design	- time limits (schoolwork at the same time) - not finding suitable solutions - blueprints too hard to manufacture properly

Strengths on this project are easy to analyze. The customer is a professional on the topic, and that combined with the author's background and first-hand knowledge combined with CAD-program skills are a strong combination.

Weaknesses are the author's inexperience in engineer level working and providing usable data for a company. This obstacle is not too hard to come over, but it might cause some fluctuations on efficiency early in the process. Long distances require different type of communication, but it shouldn't be too hard to try out new ideas in practice, as long as the worker gets proper schematics to work with.

Opportunities are the most promising part of this project. If everything goes well, the author will gain good experience on product designing and the customer gets a good product to their sales catalogue with quite reasonable price. This also leaves the door open for future implementations of the same type of systems that could utilize modularity.

The biggest threat is the time limit. Because the project isn't worked on full time, the time limit might prove narrow. Another threat is not finding suitable solutions for the product. This would mean that the prerequisites given early on couldn't be met, like fitting all the add-ons modularly. These kinds of difficulties may be overcome by group effort with other people sharing the matter. Another threat is that the blueprints must not be too complex, and the tolerances can't be too strict, so that the manufacturer is able to make a working product. Still, tolerances must be high enough to guarantee the quality of the product.

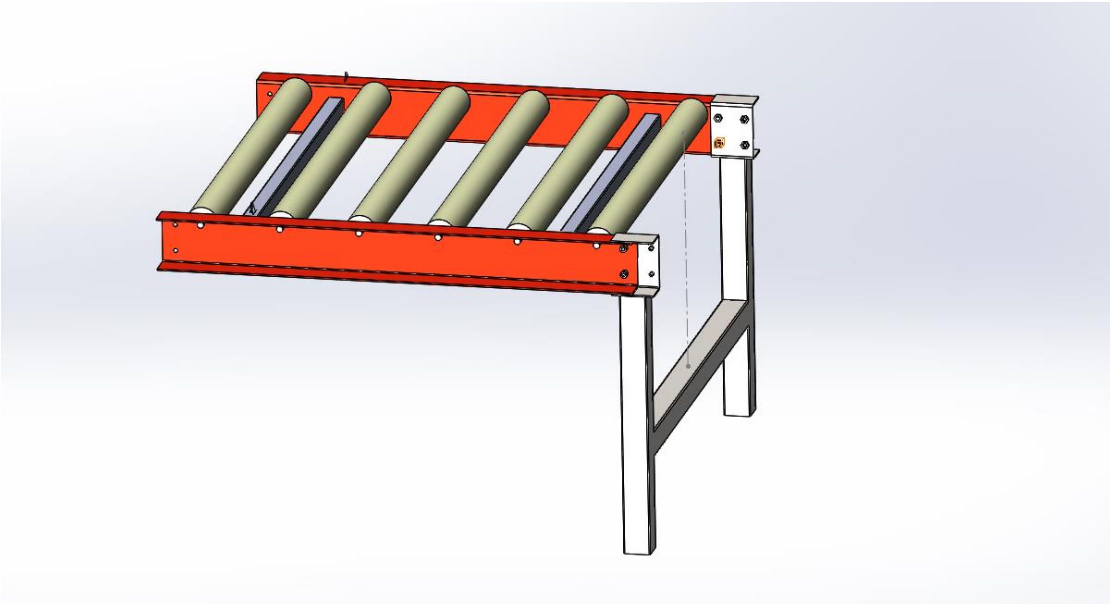
5 IMPLEMENTATION

Implementation is the practical phase in which the actual product is developed. Three different versions of the roller conveyor system were developed in this phase. This was different from the original plan, but it was deemed better to start a completely new draft of the product when major changes took place after negotiations with the customer.

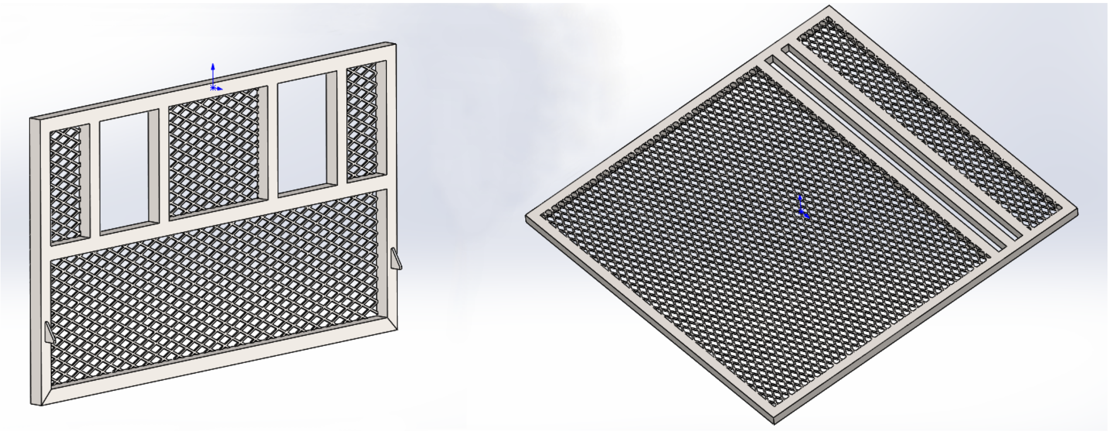
5.1 Version 1

The first version (Picture 4) was made for the purposes of getting a model body of the system, so that it is easier to plan and develop other parts. The measures of the parts were not precise or made according to any pre-existing raw material sizes since this was just concept work. Not all the parts of the system were made in this version, and it only had the conveyor itself and the protective inflation cage (Picture 5). It was decided not to develop any of the other add-ons further for this version, since the connections and technical solutions would be different in the final product.

The same rolls were later used in other models. They were simple models, and didn’t have any details, since they would be outsourced, and different types of rolls could be used in the same frame. Only things that matter for them are the length and the diameter for the axle and the cylinder.



PICTURE 4. Version 1 of the conveyor being developed

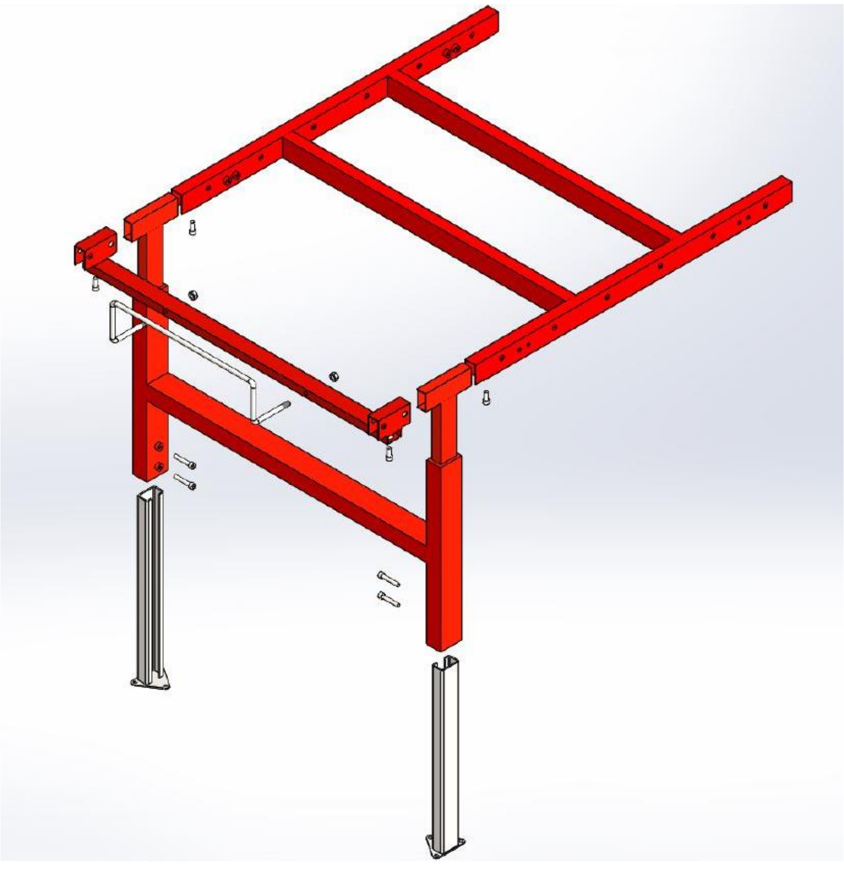


PICTURE 5. Parts of the cage developed for version 1 were modified and re-used in later versions

The version 1 was switched into developing version 2 by the end of February 2018.

5.2 Version 2

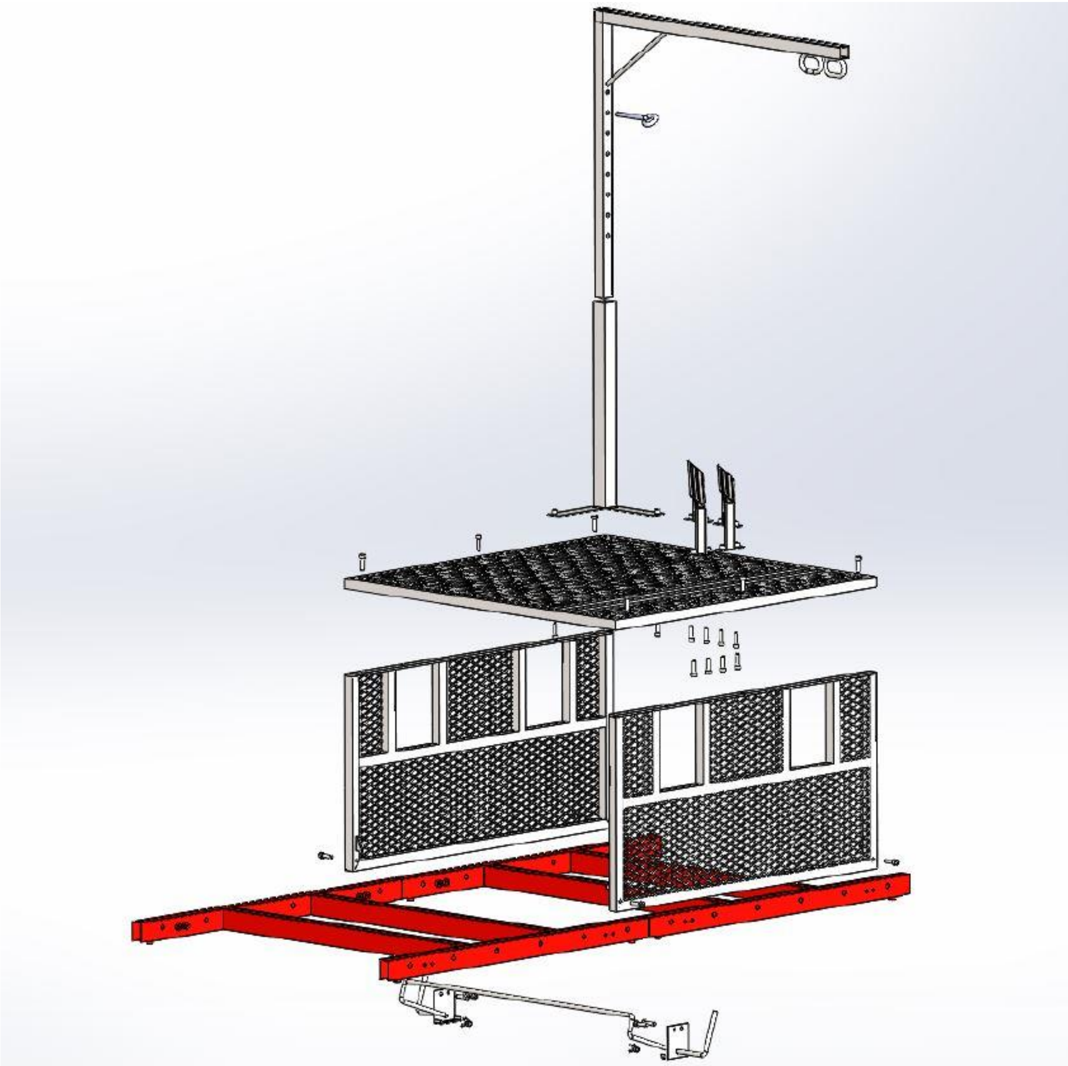
The design of version 2 was thought more thoroughly than its predecessor. DFMA was implemented in this version, and the parts were made of stock-sized steel profiles (Picture 6). Also, almost all the connections were re-designed since the initial solutions were nowhere near satisfactory according to the QFD chart. In this version the legs' end would fit inside the frame, and then be tightend to position by a bolt. The conveyor frame was totally re-done, but some parts of the legs and the safety cage could be re-fitted with some changes.



PICTURE 6. The second version utilized stock-sized structural steel and simple connection solutions

Other add-ons were also included to the assembly in this version, namely the brake, inflation robot mounts, tool wall and air hose holder (Picture 7). The stand for a bead mounter and its balancer was not included in this version, for it was thought better to be a separate entity rather than a fixed part of the conveyor.

The biggest difference this version has compared to other manufacturers' products or previous prototypes is the hose return system. Other variants usually have a regular hose that doesn't automatically return, or a hose inside a spring that would pull it back after use. These solutions weren't working properly for this product, so a hanging spiral hose was tried out (Picture 8). When a spiral hose is connected to a tire that starts rolling down the conveyor, it stretches along. When the hose is released the spiral shape and gravity return it back to the front.



PICTURE 7. The connections were designed in a way that hex-nut bolts could be directly screwed onto threaded holes without separate nuts

Additional parts were created to simulate the finished product to gain a better visual feel of the product. A tire, air hoses and inflation robots were added into the assembly, although they are not a part of the actual project (picture 8). This version was also sent to the customer for a review unlike the first version. Developing this version further by QFD, DFMA and customer's feedback lead into the final version of the system.

PICTURE 8. Complete assembly of a finished product with its add-ons

The last pictures of version 2 were sent to the customer on 12th of March 2018, and after that the models were not developed further. Possible developments were decided to be implemented on the third version together with the customer's development ideas after a meeting, since it was very possible that big changes could be made into the product and developing features further for this second version might have ended up being a waste of time.

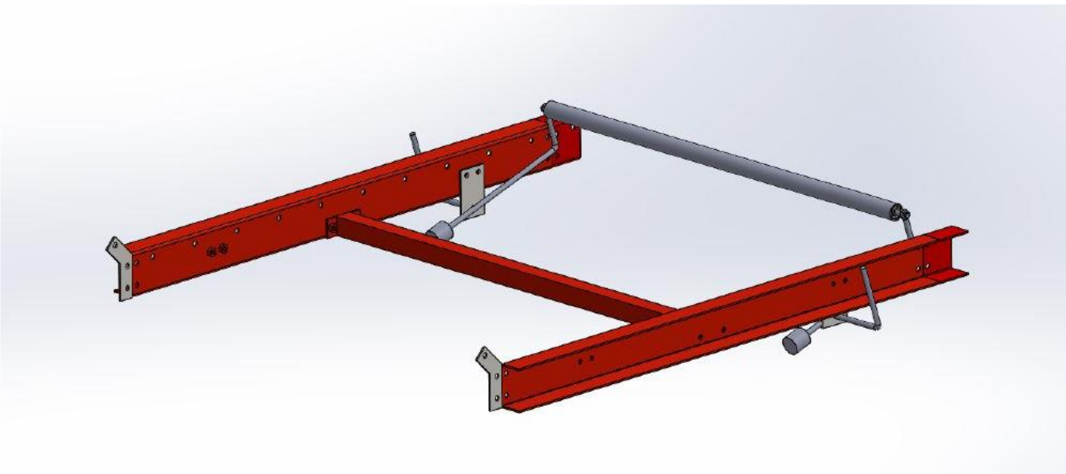
5.3 Version 3

The third version of the roller conveyor is the last version designed from scratch. Only some old parts from the inflation cage and the hose stand were utilized in this version, and they were also modified. Logic on this version remained the same; to utilize stock-sized steel parts to ensure availability and cheap manufacturing. In this version, the emphasis was put on making the parts simple and separable for efficient packing and manufacturing (Picture 9), although functionality remained the highest criteria.

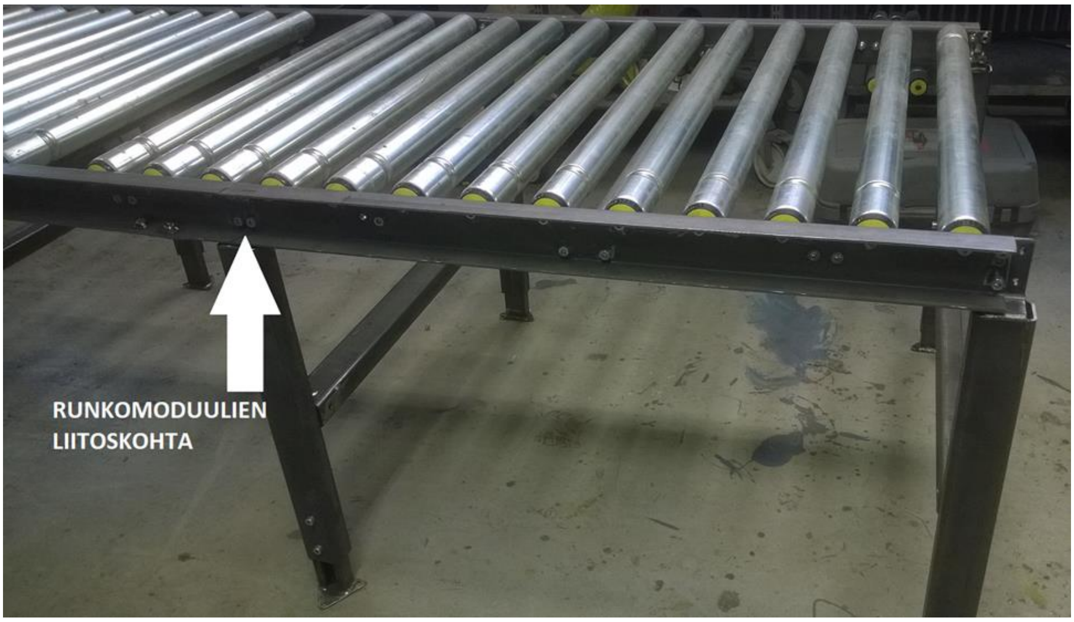
PICTURE 9. Parts ready to get painted. The picture shows how all the parts could be tightly packed in small packages. (Härkönen 2018)

A functioning prototype was manufactured from this version in the customer's workshop. The schematics were sent by e-mail. Design flaws, missing measures or betterment ideas were negotiated through phone or e-mail.

The frame was reworked to be manufactured from a C-profile steel as per customer's wish (pictures 10 & 11). The reason for changing the frame profile was that it's easier to install any kind of rolls on an open frame profile. The frame also got its separate end parts, one higher than the other to stop a rolling tire. The customer also wanted the middle support beam to be separable, so that everything can be packed into a smaller space in IKEA-style. The stopper in the end of the frame was changed into the last roll to be raised. This makes it easier to take a tire from the conveyor, and it also takes away the risk of scratching rims. The rolls used for the prototype were the same that the customer had previously built their automatic warehouse with, since they were available. Any other rolls would also have sufficed, as long as they would fit inside the frame and have less than 8.5 mm axle diameter.

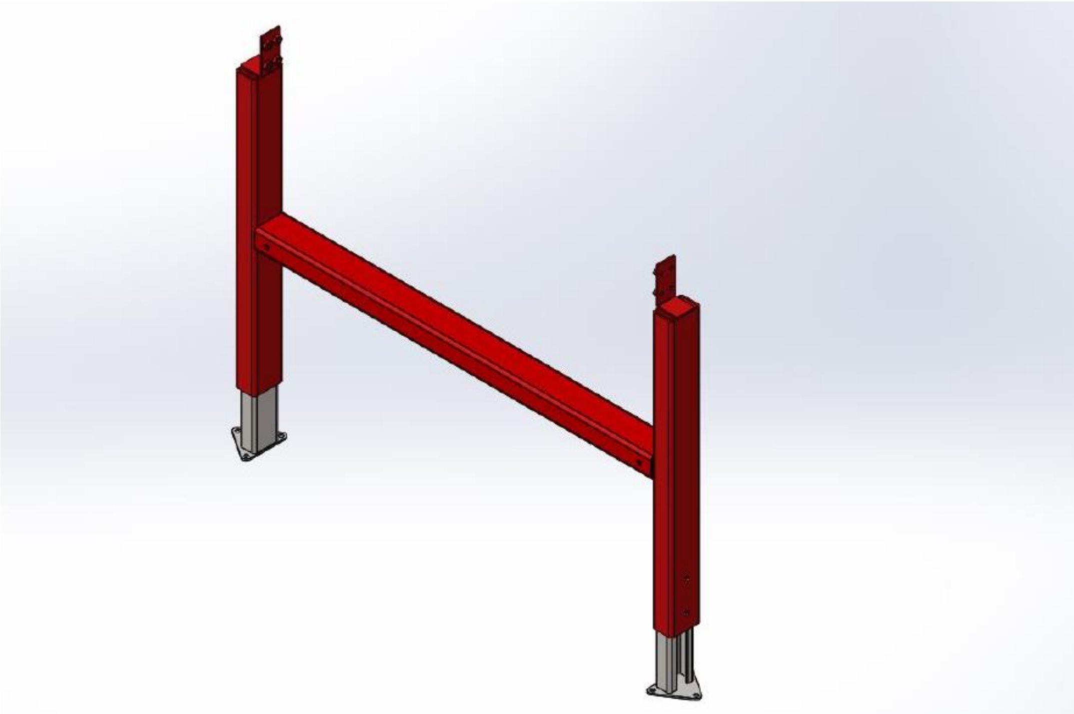


PICTURE 10. The frame with an old brake model

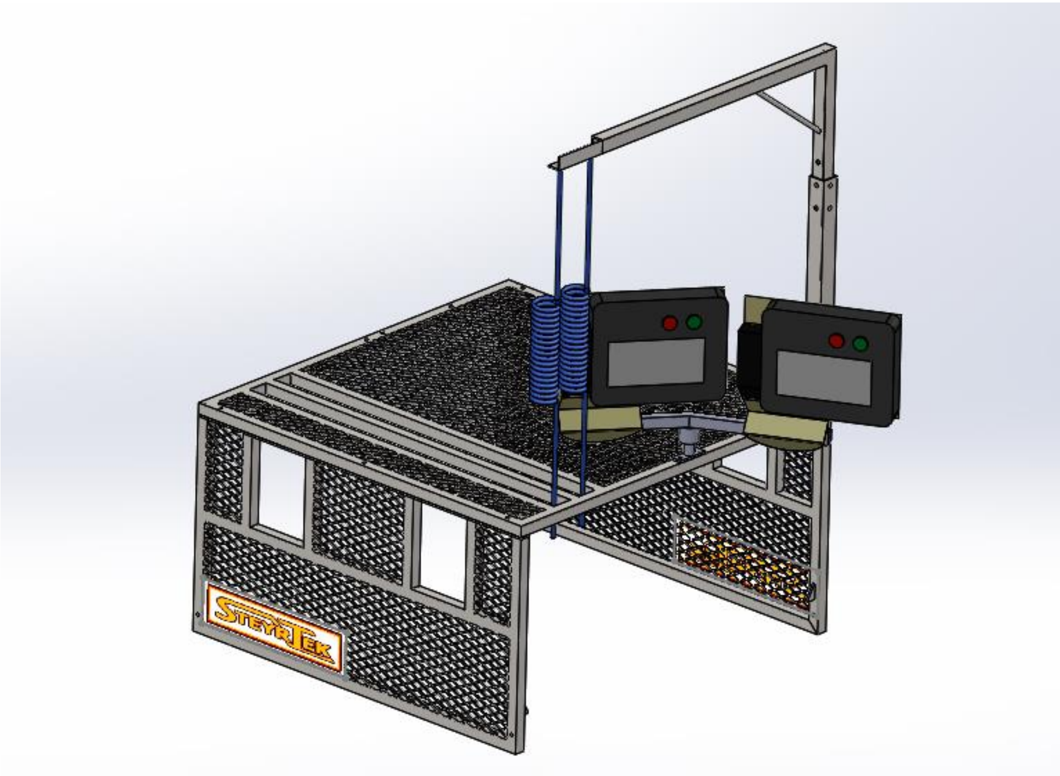


PICTURE 11. An unpainted frame with legs attached (Härkönen 2018)

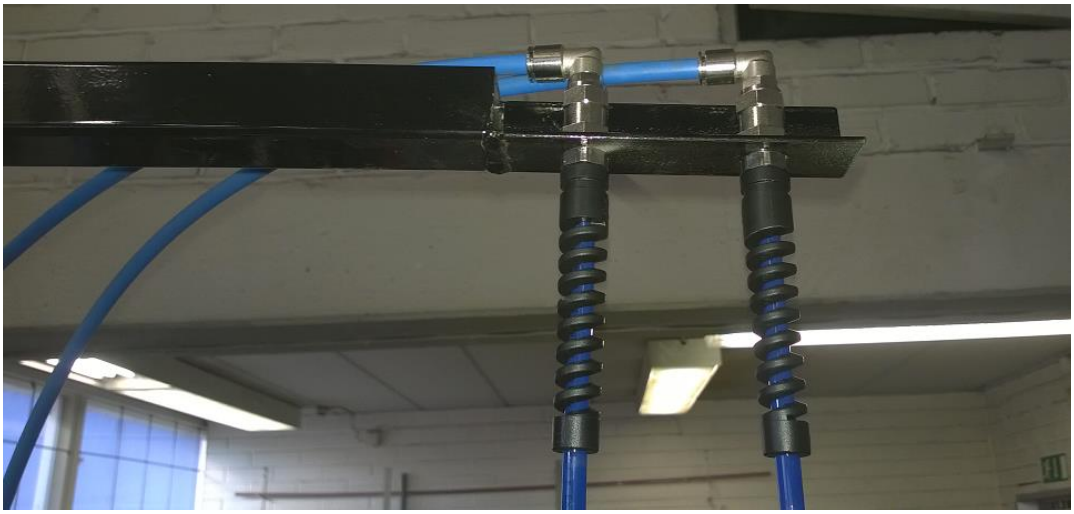
The legs were designed to fit the new frame, and to be taken apart as well (Picture 12). This was a compromise against DFMA, since the parts now have more work phases in manufacturing, and more bolts to attach during an assembly. The customer stated that the legs wouldn't be assembled and dismantled so often that it would become a problem. Separable parts can also be packed in smaller crates, so it fulfills QFD demands better. The height controlling system remained the same in principle, but the measures were changed to fit new parts.


PICTURE 12. The new leg model is made from separable parts, so it can be transported in smaller packages

The same source parts were used in the cage, but measures and hole positions were changed to fit the new version. The add-ons on the cage were modified and re-designed multiple times to find the best possible solutions together with the prototype manufacturers. This meant that also the cage had to be regularly worked on to change hole positions and groove widths. The inflation robot mount was redesigned multiple times to find a good solution. The final design has fixed attachment position but can be rotated to a desired position (Pictures 13 & 15). The air hose stand was similar to the second version's stand, but the adjustment connection was decided to be made with two bolts rather than a pin for a tighter connection and feel. Also, the hose connection point was changed. Spiral hoses are secured on the stand with nuts, and hoses coming from inflation robots are connected to them with 90-degree connectors (Picture 14).



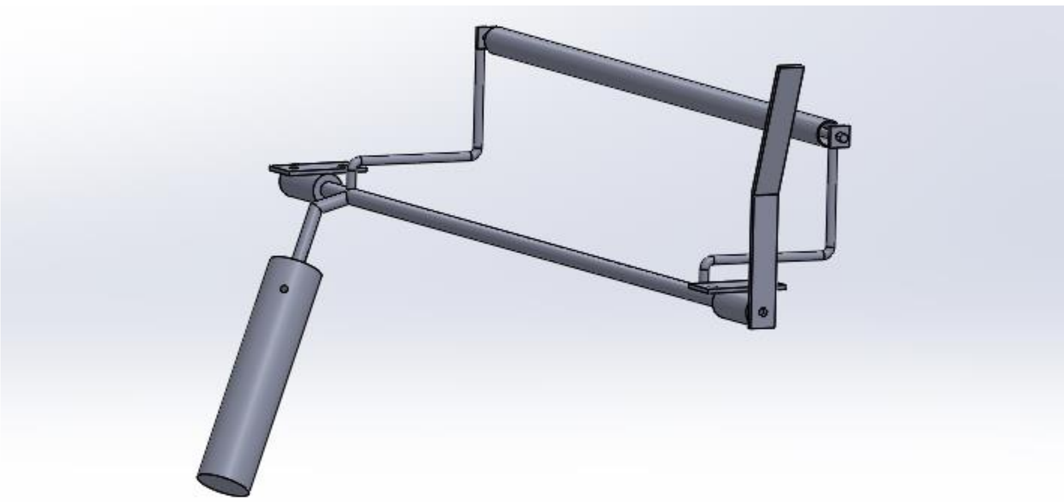
PICTURE 13. The cage got brand logos on it, and the add-ons were modified for better functionality.



PICTURE 14. The hose connections (Härkönen 2018)

PICTURE 15. The inflation robot mount rotates and is fixed in place by a bolt. The prototype is assembled as a mirror image of the 3D model, which is possible due to the modular nature of the product. (Härkönen 2018)

The braking system was totally re-designed. The first big change was to make it operate by gravity and getting rid of the springs that pulled it back up in the old version. A couple of different versions were planned and tried out. The brake was made in trial-and-error way since it was faster to try out working measures and weights, and then draw the schematics based on them. The development started with a simple kind of brake to keep part count as low as possible and to avoid many moving parts. In the end, the final version had ball bearings and many separate parts, which was undesirable from the DFMA point of view, but resulted in superior functionality (Picture 16). Also, new attachment points with pre-fixed hexagon nuts had to be made into frame parts for the final version of the brake (Picture 17).



PICTURE 16. The final version of the brake functioned with a counter weight to pull the roll up to stop a tire. The handle can be mounted on both sides.

PICTURE 17. The brake installed on the prototype. The counterweight has a separate stopper to absorb impact. (Härkönen 2018)

A tool wall was also added into this version as per customer's wishes. It was modelled after an actual piece that the company had in their inventory. Connection is made with the same bolts that keep the legs together. The holes are 9 x 9 mm with 38 mm spacing, so common tool hooks and other equipment are compliant with it (Picture 18).

PICTURE 18. The tool wall at the end of the conveyor can be used to hold tools for the next work phase, like balancing (Härkönen 2018)

6 CONCLUSION

The thesis project is a great example of a product design process in a larger product development process. The development process has started with the customer noticing an opportunity in the market, starting to research on it and later making prototypes of their own. The start of this project had a great timing, for the concept phase with the prototypes was at an end, and the next natural step was to make detailed manufacturing documents.

The project is very close to actual professional work. It was engaging and helped to develop the author's professional skills and readiness to enter working life as an engineer. The project was useful for the customer also, for the ultimate goal is to outsource products for sale based on the prototype.

Topics handled in the thesis project are present in many companies in technological field. Product design, outsourcing, international manufacturing and internet sales are all part of today's business- and industrial life.

The implementation of the project held the schedule fairly well and resulted a functioning prototype for the customer's use (Picture 19). The prototype increases safety and effectiveness, is easy to assemble and take apart, utilizes simple and cheap technology and requires minimal number of different tools. Without one exception on the brake, every attachment in the product is done with a 6 mm hexagon socket head bolts. As such it fulfills the prerequisites set by the customer in the beginning of the project.

In implementation the voice of the customer became the most important guiding factor of the process. Although QFD and DFMA were useful tools, giving them the priority over the customer wouldn't have sufficed. New approaches had to be negotiated with the customer, but no big issues ever rose during the process.

The development process could be continued through practical testing to see what practical issues would rise in the prototype based on user experience. After testing, the blueprints should be refined based on the user feedback, and these new solutions should be tried out as well. Finding a suitable manufacturer for mass production could also prove challenging, and the customer's own connections and experience is most useful on this matter.

PICTURE 19. The prototype in its final color (Härkönen 2018)

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