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Development, design and construction of a flexible tablet mount

Master's thesis in Product Development

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This master thesis is the final project for me, Viktor Bennersten, in my postgraduate studies at the Department of Product and Production Development at Chalmers University of Technology. It has been a development project at i3tex AB for Volvo Cars Corporation and the project was run in collaboration with two other students: Andreas Andersson and Emil Söderquist.

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Abstract

Volvo Cars Corporation is a large, global car manufacturer. They have seen a need for a tablet mount in their cars and in order to not have to develop a new mount for every popular tablet. They want it to be flexible so that it can hold any existing or future tablet between 7” – 10.1 “. Due to legal requirements, it must also cover the edges of the tablets while still allowing the user to reach any sockets and buttons.

This task was adopted by three Chalmers students at the master programme Product Development through the consultancy company i3tex AB. The project was split between the three students who did individual master theses within the product development project. This master thesis focuses on the design and construction during the development of the flexible tablet mount.

The project was decomposed into one minor and then three major phases: planning, prestudy, concept development and detailed design. A thorough work was done in order to cover any possible solution during the course of the project and several promising ideas were generated. 77 concepts were created which were then evaluated and refined until only one final and one back-up concept remained.

The final concept was then designed in higher detail. A computer aided design model was created which was then used for tolerance sensitivity analyses, strength and safety analyses and for prototyping. The model was further developed by applying suitable material and by investigating applicable production methods. The back-up concept was also designed with a higher level of detail, modelled with computer aided design and analysed for tolerance sensitivity. Both products have a large potential to fulfil the needs of the customer.

Publications and documents

The project this thesis report covers was divided between three different theses. All three thesis reports should be read to gain a complete view of the entire project. Throughout this thesis report, there are therefore references to the other reports. They will be referred to as:

Report A Söderquist, E. *Development of a flexible tablet mount focusing on market and user studies.* Gothenburg: Chalmers University of Technology, 2014

Report B Bennersten, V. *Development, design and construction of a flexible tablet mount*. Gothenburg: Chalmers University of Technology, 2014 (this report)

Report C Andersson, A. *Development and finite element analysis of a flexible tablet mount*. Gothenburg: Chalmers University of Technology, 2014

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1 Introduction

1.1 Background

Volvo Cars Corporation, VCC, is a global automotive company that develops and produces premium cars. Their first car was produced the 14th of April 1927 and they are now producing and delivering cars globally. VCC has four core values that are their main focus in all their entire products: quality, design, safety and environment (1) (2).

Since the introduction of the first iPad in 2010 (3), the tablet market has exploded in sales and popularity. The technology and the performance of tablets are continuously improving and the competition on the market is growing rapidly. The biggest actor on the market, Apple, sold over 70 million tablets in 2013 which was an increase in sales compared to 2012 when they sold about 61.5 million units. Interestingly though, at the same time Apple's iPads lost market shares: from 52.8% in 2012 to 36.0% in 2013. Android-based tablets made an impressive lift and went from 45.8% to 61.9% of the market shares. The most popular Android-based tablet manufacturer was Samsung, who sold over 37 million tablets in 2013 (4).

The popularity of tablets has opened up completely new ways of entertaining people both at home and on the move. Many use their tablet for entertainment while travelling in their cars. The market department at VCC has seen this as an opportunity to introduce a new product as an accessory for their cars. To develop a new mount for each new popular tablet would be a never-ending process in trying to keep up with the tablet market. Due to the rapidly changing tablet market with new models being launched at a high frequency the result would be that VCC would always be one step behind, forcing them to be reactive. That would be an unfavourable situation and thus it was deemed highly desirable to develop a flexible tablet mount that would be able to hold all existing and future tablets.

The task fell to the accessories department at VCC which develops both various gadgets and tailor-made solutions for certain customers. An example of a product they have is the entertainment system which allows passengers in the back seat to watch videos when travelling. The accessories department have already developed the interface to the back of the seat and the headrest where the tablet mount will be installed.

The mount is supposed to be an optional feature for the customer and it will be mounted in the finished car before reaching the customer. It could also be installed as an aftermarket product but it would have to be done at a Volvo workshop.

There are several existing tablet mounts on the market today, many of them supposed to be fastened at the back of the headrest. However, none of those products are both flexible and fulfil VCC's high demands regarding quality and safety. They want their tablet mount to be a premium product in line with their core values and with higher functionality and quality than the competitors, which also meant that it was allowed to cost more than the competitor products.

The development of the mount was taken over by i3tex, a consultancy company, which in turn presented it as a thesis project. VCC is one of i3tex major customers.

1.2 Project description

As stated in Publications and documents, this project was divided into three separate master theses. Parts of the work in the project was carried out together and thus some parts of the reports are also very similar but the project group members always had their own areas of responsibilities. For example the concept development phase, which can be read about in section 4, was almost entirely done together. Thus, that section of the reports will be almost identical.

The prestudy and the detailed design phases were conducted individually. These parts in the reports are thus very different. More information about the project approach can be seen in section 2.1.

1.3 Purpose

The purpose of the project was to satisfy the need for a way to better facilitate the use of tablets in cars, both for entertainment and work. The product will expand the assortment of accessories for VCC and it should be viable for every potential Volvo-buyer, no matter what tablet the customer has.

1.4 Objective

The objective of the project was to develop a tablet mount for VCC during 20 weeks from January to June 2014. The mount should work for any tablet between 7" - 10.1". Due to legal requirements on components in vehicles, the mount must also cover the tablet's edges which are generally too sharp. It must at the same time not cover any buttons or sockets for the tablet.

The tablet mount must be designed so that it fulfils all legal requirements. It should be user friendly and the functionality and design must be impeccable in order to fit in a Volvo car. The mount must also be producible.

1.5 Scope

As previously described, this project was divided between three separate master theses. At the same time, all group members work towards a mutual goal and the work areas will be entwined. Findings and progress for one project group member will naturally affect the entire project. The work in the areas of the other thesis reports will not be extensively covered in this report even though it will affect the outcome. Potentially short summaries of their findings will be presented with a reference to that report.

The focus in this project was to develop a tablet mount that would work for any tablet within the specified sizes. One exception was made though: The mount will not be designed for tablets of varying thickness or with otherwise uncommon shapes. The purpose was also to launch the tablet mount on the market as quickly as possible and thus the project group will not focus on futuristic concepts and features. The scope was also to develop a single tablet mount that would fit all sizes of tablets, not to make a series of tablet mounts with each covering a certain category of tablets.

Due to the complexity and legal restrictions, VCC clarified that the tablet mount will not be able to connect to the car's safety system. Nor will it be able to use electricity.

Lastly, the project group will not develop a new tablet, nor will it redesign the seat or the interface already developed by VCC. It will thus adapt to the existing interfaces and develop a tablet mount based on those preconditions.

2 Methodology and approach

2.1 Project Approach

The overall approach for the project process is inspired by the experience gathered throughout the courses in the master programme Product Development at Chalmers University of Technology. The process is closely linked to Ulrich's and Eppinger's approach in Product Design and Development (5) although it has also been adapted to fit with VCC's stage-gate method, which they call GTDS. Meetings with VCC were also planned in accordance with the GTDS gates. The value model was used as an additional inspiration for the development process (6). Based on the chosen process, four major stages of the project were defined:

1. Planning – a shorter stage to set the planning of the project.
2. Prestudy – the purpose of the prestudy is to create a knowledge base large enough to be able to make good design decisions later in the project. It also serves to gather inspiration for the concept phase.
3. Concept development phase – the phase in which concepts are created and evaluated.
4. Detailed design – the final phase in which the chosen concept(s) are developed with greater detail and more extensively tested.

Of the 20 weeks available for the project, one week was set for planning and project initiation, five weeks for the prestudy, eight weeks for the concept development and five weeks for the detailed design phase. The last weeks were planned for finalising the report and preparing the project presentation.

The majority of the work in the prestudy and in the detailed design phase was conducted individually and those parts are thus covered in Report A and Report C. The concept development was made almost completely in collaboration with all project group members. This is visualised in Figure 1.

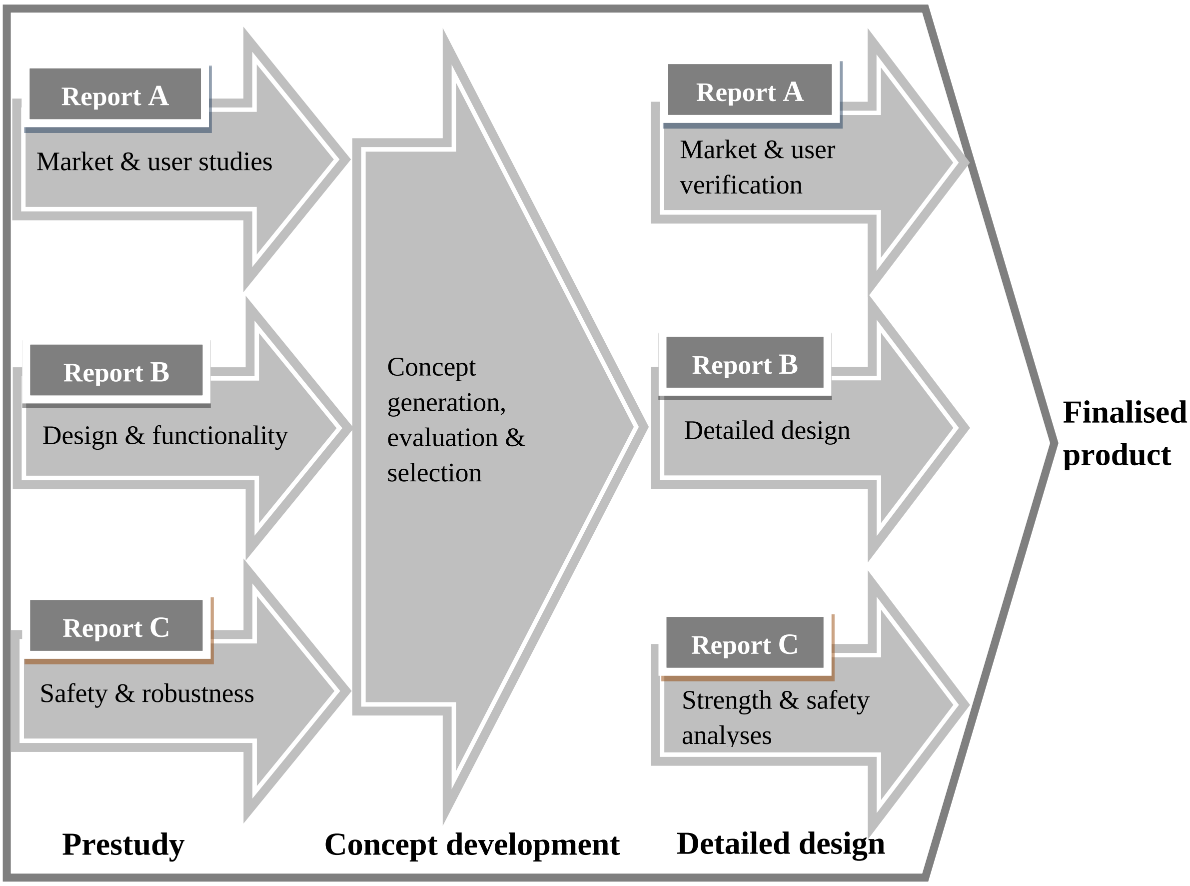


Figure 1 - Project process description

VCC's GTDS is based on three major stages:

- TKO - Technology Kick-Off. During this stage a time plan is established, stating the expected outcome of each phase in the project. The relation with the customer, which in this case is VCC, is also established. This stage ended with the planning report.
- TS - Technology Strategy. In this stage, the most important customer requirements are established and all required research is conducted. This stage also includes the concept generation and some screening of concepts. The stage ends when there are a few promising concepts left.
- CR - Concept Ready. One or a few concepts are developed which fulfil the customer requirements. Primary functions are optimised and verified.

These gates were used as milestones in the project, and made to fit with into the project approach. Since the second stage seemed to cover the majority of the project, an additional milestone was added to split this stage in two. The milestone was the finished target specifications, defining the end of the prestudy.

2.2 Prestudy

A major prestudy was conducted for the project, to ensure that the concepts would be evaluated based on the proper knowledge but also to inspire the concept generation process. The methods used during that prestudy are explained in this section, together with their purpose and the approaches used.

VCC had already conducted a prestudy which was available to the project group right from the start of the project. This came in the form of a prerequisites document together with some additional documents such as a minor benchmarking, a document of tablet sizes and a model of the interface between the mount and the arm. The prerequisites document worked as a basis for the prestudy, although almost none of the background material, on which that document was based, was available and therefore this project's prestudy was to a great extent independent of VCC's.

2.2.1 Product decomposition

The purpose of the product decomposition is to give a good overview of the product's functions. This makes it easier to brainstorm solutions for specific functions one at a time later in the concept development phase.

The approach used was to first note the main purpose of the entire tablet mount, then break down that function into sub functions, which in turn can be further decomposed.

2.2.2 Volvo Cars Corporation's prestudy

One major part of the prestudy was to review VCC's prestudy. This seemed like a natural place to start and it was important that the final product could live up to VCC's demands.

The review was done by first dividing the content of the prerequisites document between the project group members based on their areas of responsibility, i.e. market and user studies, design and construction and safety and strength analysis. The contents relevant for this thesis were the parts involving user, material, design, durability and solidity requirements. The information deemed relevant was then compiled to make it more accessible. Lastly the references used by VCC were gone through, for example standards and documents of legal requirements. VCC's standards were obtained through VCC while legal documents could be downloaded from different web sites.

2.2.3 Volvo Cars Corporation's design

It is very important that the final product looks and feels like a Volvo product. It must be coherent with their core values and live up to the same standards as other Volvo products.

To achieve this, VCC's style and design has been studied in order to be able to adapt to it and make good design decisions later. In order to familiarize with VCC's design language some aspects have been investigated:

- VCC's core values and view of design
- Colour schemes used in the interior of Volvo cars.
- Shapes and looks of components in the interior of a Volvo car.

The core values and what they stand could be found at VCC's web page (1). This combined with the impression and guidelines given by VCC works to define this.

The colour schemes and shapes have been studied both by studying the interior of new Volvo cars available to the project. For the colour, VCC's car configurator was also used (7).

2.2.4 Customer value

In order to gather external information, interviews with potential users were conducted as a part of the prestudy. These are covered in detail in Report A.

Sometimes there are aspects that affect how customers and users perceive a product that won’t emerge during normal interviews. These are so called unspoken needs and they exist because the users considering them too obvious, they forgot about them or they don’t really know about them even though they will later on impact their impression of the final product. The results from interviews are also very dependent on the situation and the characteristics of the questions, which also might cause some needs to not become apparent.

In order to therefore reduce the risk of missing user needs, a brainstorming session was conducted in order to find as many aspects as possible which can affect the users’ impression of the product. This was then consolidated within the group and the aspects were divided into suitable categories. It was then compiled into an Ishikawa diagram (8), which is a great tool for visualising results of this type.

2.2.5 Producibility

It is very important that the final product will be producible. It is important to keep that in mind, both when selecting between different concepts and during the detailed design. Several aspects affect the manufacturability and, just as for the customer value, a brainstorming session was conducted to cover these aspects. They were also divided into categories and presented in an Ishikawa diagram (8).

2.2.6 Observations

There were mainly two purposes for the observations. The primary purpose was to investigate the need for additional functionality for the tablet mount. Additional functionality could be if it should be able to adjust its position or if it should be designed so that the tablet is positioned better for the user, e.g. with a different angle than the arm. The secondary purpose was to evaluate VCC’s design choices. Later in the project, it became evident that the design of the fastening for the mount was already set and that it would not be changed. Thus, the results from the observations will only work as a basis for future recommendations.

Still, in order to gather this knowledge, information about how users would like to position the tablet if they would use it in the back seat of a car was needed. Both horizontal and vertical distances were interesting, as well as the angle of the tablet. Additionally, information about their position in the front seat while driving was important since the tablet will be mounted in the back of the front seat, which means that the position of the front seat will directly affect the position of the tablet.

These observations were not made to gather statistical data but simply to analyse how much the tablet positioning and angle could vary between different people. Therefore the sample of participants is not made to represent the future users but rather to cover different kinds of people and especially to find extremes.

A walk through of how the observations were conducted and the measurements calculated can be seen in Appendix A. For a list of equipment and software used for the observations, see Table 1 in 2.7 Materials.

2.2.7 Benchmarking - tablets

When developing a mount for tablets, it is of course very important to study the different tablets on the market today. The purpose of this benchmarking was mainly to gather knowledge about:

- What different sizes can tablets of 7” – 10.1” have?
- What dimensions exist among tablets?
- Where are the buttons and sockets located on the tablets?

This data will then be used for the detailed design of the tablet mount in order to ensure that it will work and fit properly for any tablet. The benchmarking was mainly conducted by looking up tablets on the internet.

2.2.8 Benchmarking - tablet mounts

A natural part of the prestudy was to learn what type of products and technical solutions already exists on the market. Tablets are very popular products with a lot of accessories available to them, and thus there are also a wide variety of tablet mounts. This benchmarking was done to gather knowledge of these existing solutions on the market and the focus was studying functionality and possible solutions for holding the tablet. It was mainly done to work as an inspiration for the concept development phase.

The benchmarking has been conducted in two ways. The first step was an internet search for devices able to hold a tablet, and for other, similar products. The second step was a field study to be able to see many of the solutions in reality as well as getting to touch and operate them. Since the project didn’t have a budget to purchase several different tablet mounts, they were instead studied and photographed in shops and at retailers.

The results were then split into three categories where the first was tablet mounts from other car companies, the second was other tablet mount solutions and the last was patents.

The purpose of the patent search was primarily the same as for the general benchmarking, to work as an inspiration for the concept development phase. The idea of looking into patents was to find more innovative and outside-the-box ideas. It was never the purpose of this project to verify the product with regards to patent claims since this would be something VCC would do anyway if they would want to implement the final concept.

2.3 Concept development approach

The concept generation was mainly done quantitatively to generate a high amount of different concepts in order to cover an as large area of the solution space as possible. This was done using different brainstorming-methods and the concept generation started already in parallel with the prestudy because it seemed beneficial to generate ideas before the project group members had dug too deep into the prestudy.

The concept generation, refinement and evaluation were done iteratively and to some extent in parallel but of course the concept generation was the main focus early so that there would be concepts to refine and evaluate. To further facilitate the creativity, the project team worked in different environments during the concept generation, both by switching between different rooms, but also moving to other locations. Ideas were also gathered from people outside of the project group.

The concept refinement also included combining and splitting up concepts. Refinements were made after the concept generation and also after each iteration of the evaluation.

The concepts were evaluated several times with different methods. In addition, the project groups own subjective thoughts were also allowed to weigh in heavily and the methods were only used as tools to aid in the evaluation, not as definite truths. A visual representation of the concept evaluation phase can be seen in Figure 2.

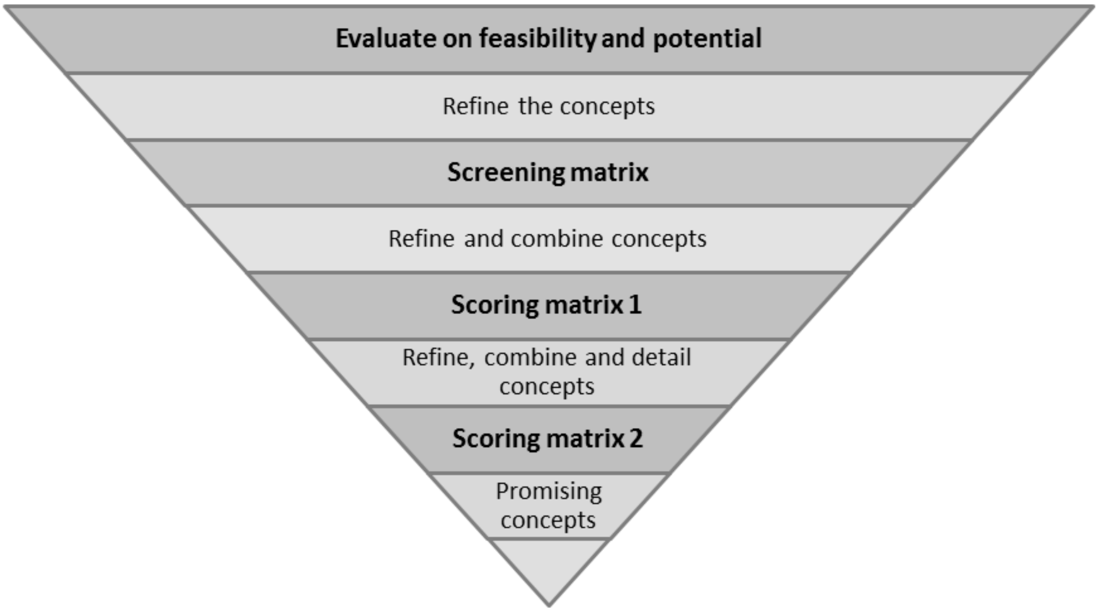


Figure 2 - Visual representation of concept evaluation phase

2.4 Concept Generation

2.4.1 Functional brainstorming and morphological matrix

Brainstorming with focus on finding solutions for the specific product functions that had already been identified in the product decomposition in the prestudy. The reason for doing this was both to create a morphological matrix, from which many concepts could then be generated, but also because many ideas might not surface when looking at entire concepts. During this brainstorming, the purpose was to cover all possible solutions and it was thus a quantitative method.

The solutions presented in the morphological matrix were combined in several different ways in order to produce many concepts. This was sometimes conducted with quality in mind, trying to make solid, promising concepts and sometimes done quantitatively to produce many different solutions for later evaluation.

2.4.2 6-3-5 brainwriting

The purpose of this method is quantity, when done properly it can generate 108 concepts in just above 30 minutes. It is supposed to be done by six people, where everyone has five minutes to write down three concepts on a piece of paper. After the five minutes, each person then sends his or her papers to the next person and receives the papers from another participant. Using the previous person's concepts as a source of inspiration, three new solutions are to be made on new papers, again in five minutes. The old inspiration papers are then set aside and the newly produced concepts are sent on. This is then done for a total of six times, so that when it is over each participant has produced 18 solutions (9) (10).

Since there were only three people in the project group, the internal session became a 3-3-5 brainwriting, but otherwise following the procedure described above. Breaks was also allowed between each of the six sessions so that the participants were given time to clear their minds.

Another session was also conducted with external participants. The group for the other 6-3-5 brainwriting session consisted of four people, friends to the members of the project group. The participants were allowed to overlook some of the main requirements in order to not feel too limited in their innovativeness.

2.4.3 Brainstorming with stimuli

The purpose of brainstorming with stimuli is using some type of stimuli to trigger the brain into coming up with new ideas for concepts. This can be done both with related stimuli and unrelated. The session conducted for the concept generation included a mix of both related and unrelated stimuli.

Images containing objects related to the subject are considered related stimuli. In this case, the related stimuli mainly consisted of benchmarked solutions for tablet mounts. When reflecting upon the solutions of other developers, new concepts can emerge (5).

Unrelated stimuli could consist of images of anything from a boat to a dishwasher. The project team iteratively picked three random images, presented them and then discussed if the stimuli could in any way be connected to the problem at hand (5).

2.4.4 Classification

To be able to keep all concept sketches organised and in order to make it easier to find a certain concept sketch, they were classified into one of six different categories. It was also established to make it easier to recognise if a certain category of concepts were thrown away too early in the evaluation process. Which category a concept belonged to depended on its physical characteristics.

2.5 Concept Evaluation

The purpose of the concept evaluation phase was to move from the large amount of concepts created in the concept generation and iteratively funnel down the amount until only a final concept was left. Between each evaluation, all concepts were refined based on the evaluated weaknesses, as can be seen in Figure 2.

2.5.1 Initial screening

The purpose of the initial screening was to reduce the number of concepts that would be evaluated in the upcoming matrix methods. If the amount of concepts would have been too many when using the screening matrix, it could easily be overwhelming which would make it difficult to evaluate all concepts equally.

At the initial screening, the concepts were tested towards the major requirements, their improvement capabilities and their feasibility. Concepts not deemed to be suitable for further development were removed.

2.5.2 Screening matrix

The Pugh matrix was considered a good tool for concept screening in order to get rid of concepts that are inferior to other. It can also show patterns in what type of solutions are considered strongest for each specific requirement.

The Pugh matrix compares concepts with a chosen reference. It lists the most important criteria, and each concept either gets a +, - or 0, depending on how well it fulfils that criterion compared to the reference (5).

The criteria for the screening matrix were chosen so that they would cover all the relevant aspects of the target specifications. It was also highly desired to keep the amount of criteria to as few as possible. The reference concept was then chosen to be considered about average for all criteria.

2.5.3 Concept scoring

A concept scoring matrix is a good tool for a more detailed evaluation of concepts, compared to the screening matrix. It further reveals the strengths and weaknesses of the concepts and also adds a rating so that not a much worse and a slightly worse concept get the same score. This way it also highlights aspects of the concepts that need to be refined or that could be beneficial to apply to other concepts. Thus it gives a good basis for refinement and suggestions for combining concepts (5).

The scoring matrix was used similarly as the screening matrix. The differences were that the criteria were weighed compared to each other and that no reference was used. Additionally the concepts were rated on a scale of one to five, instead of the ±, based on the following:

1. Much worse than average concept
2. Worse than the average concept
3. Average compared to the other concepts
4. Better than the average concept
5. Much better than the average concept

The concepts were spread out over the scale so that for almost each criterion, there would be a one and a five. The purpose of this was to highlight the differences.

First concept scoring
For the first scoring matrix, there would still be quite many concepts left. Therefore the matrix should not include all requirements from the target specifications but rather a few criteria, as in the screening matrix.

Second concept scoring
The second scoring matrix was to be more extensive than the first. At this stage, only a few concepts would be left and those were to be thoroughly evaluated since this would be one of the final steps of the concept evaluation.

Before the second scoring matrix, a virtual model was to be created for each concept using CAD, Computer Aided Design. The purpose was to create the concept with further detail as a part of the refinement. Additionally this would enable to concepts to be more objectively evaluated than they would have been from just sketches.

2.5.4 Final evaluation

At this stage, the project group would have to make the decision of which would be the final concept to continue working with in the detailed design phase.

The final evaluation consisted of the project group's own evaluation combined with the input from two external sources. Feedback from both VCC and potential users were to be taken into consideration at this final step, see Figure 3.

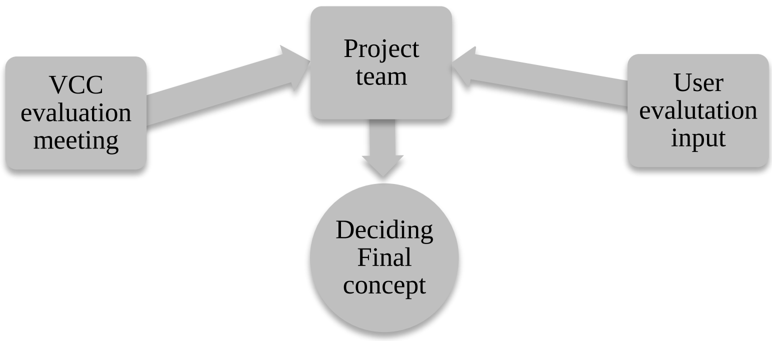


Figure 3 - The input for the final concept selection

As an additional refinement, the CAD models of the concepts were to be further improved. This was done mainly due to the fact that they were going to be presented to VCC and potential users but also as a natural part of further refinement.

2.6 Detailed design

The purpose of the detailed design phase was to finalise the chosen concept. Technical solutions were to be solved and designed with higher detailed, choice of material should be made, the aspect of manufacturing should be covered and designed for and so forth. Additionally, the model should be built as a physical prototype.

2.6.1 Design

Models were designed using Catia V5. The purposes of creating a virtual model of the final concept were many:

- To visualise the final product.
- To test the functionality of the final concept, identifying problem areas and facilitate the solving of such.
- To allow for safety and FE analysis.

To use virtual models at this stage was never questioned since they are in many ways superior to the other alternatives. A 3D model gives much better visual explanation of the final product than sketches and drawings do plus the fact that it can be simulated. To only use physical prototypes during the detailed design phase was never considered a good idea either, because even though they are even better visualisations of the product and can be tested directly, it is very difficult and time consuming to make changes to them compared to a virtual model.

However, physical prototypes were also used to further verify and get a feel of the product but not until the later stages of the detailed design phase.

There were several important aspects to keep in mind in order to make good CAD models. Since time was limited, there was not a lot of time for major adjustments which made it important to cover all aspects from the beginning. The primary aspects important for the CAD modelling were:

- Functionality
- Looks
- User-friendliness
- Safety
- Producibility

Functionality

The functionality of the final product must be impeccable. This means that gears and joints must be designed to work smoothly together. This also includes tolerances and design for robustness. Joints should work smoothly without too much unintended friction but are not allowed to have large gaps. The product must not have joints with much play since it would cause the structure to be rickety and not feel very qualitative. This means that the design decisions should always be made in order to make the structure as robust and insensitive to variations as possible.

In accordance with VCC’s prestudy, the product must not lose any of its functionality due to damage caused by everyday use. It is very important that the structure is strong enough to not be damaged at normal handling. The product will be tested with finite element analyses, FEA, for certain load cases and then potentially be redesigned in order to be able to withstand them. The choice of material is also very important for the mount’s strength and durability. More information about the load cases and FEA can be seen in Report C.

An extensive failure mode and effects analysis, FMEA, was conducted during the prestudy. This also worked as a basis for the decisions made regarding the design. Information about the FMEA can be found in Report C.

Looks
It is important that the tablet looks good and even more important that it is coherent with VCC's interior design. This has to be kept in mind during the detailed design and it means that all screws and such must be well hidden and no parts are to stand out or extend from the mount in strange ways. It should also give the impression of being robust, qualitative and safe.

Lastly, the product should be presented in colours similar to those used in the interior of a Volvo car.

User-friendliness
It is highly desirable that the product requires as few operations as possible to operate. These operations should also be intuitive, easy to use and require optimal force. Another important aspect of the user-friendliness is the fact that the same mount must be usable both in the right and left back seat. This means that an object that is located on the right side of the mount would be easily reachable for the passenger in the left back seat, but it might be more difficult to reach for the passenger in the right back seat, since it comes close to the door and the b-pillar.

Safety
When the virtual models have reached a high enough level of detail they will be tested for safety and more of this can be seen in Report C. Since this will be done late in the detailed design phase, it is however important that the product is designed with safety issues kept in mind right from the start of the detailed design. The primary important issues that have to be considered for the design are:

- No parts that the head might collide with are allowed to have a radius of less than 5 mm, which then naturally also include the tablet's edges.
- The tablet must remain mounted in the event of a crash which means that the components holding the tablet must be strong enough.

Producibility
The Producibility of the product comes down to two important aspects: what manufacturing processes are required and how easy it is to assemble.

In order to make it cheap to produce, it should be designed with the manufacturing process in mind. For each part, there should be a clear idea of what process is required to manufacture it, which of course also depending on choice of material.

The product should be made in such way that it is easy to assemble. It should not require the product to be held in certain ways and many parts fitted together at the same time. The procedure for assembly should be straight forward and only require common tools.

2.6.2 Tolerance analysis

Tolerance simulations will have to be run for the product in order to analyse areas and components sensitive for variation. It also guides in choosing the correct materials and manufacturing processes for the product. The tolerance simulations were made using RD&T.

The analyses were made on the areas and parts considered most sensitive for variation and the components were connected in the most realistic yet still possible way. Tolerances were set based on common processes and materials.

The structure was analysed using Monte Carlo simulations, which generates random values for each connection and measurement within their tolerances. The model is then updated for these values, the value for each measurement is saved and the process is repeated for a set number of iterations. The structure was also analysed for which connection points had the largest contribution to the variations (11).

2.6.3 Choice of material

The final product has to be produced with a suitable material. It is very important to choose a material that fulfils the requirements as good as possible, it must also be strong enough and have a proper stiffness.

The choice of material was based primarily on the strength and safety analyses, which can be read about in Report C. The material must not fracture or otherwise be harmful to the user in the event of a crash. It is also very important that the mount does not break or lose its functionality due to normal use. Other aspects taken into account were the material requirements presented in section 3.4 and 3.5 in the prestudy.

The choice of material was conducted using the software CES Edupack (12).

2.7 Materials

The equipment and software used during the project are listed, together with their function, in Table 1.

Table 1 - Equipment and software used in the project

Equipment and software	Function
Adobe Photoshop	Observations
Bubble lever	Observations
Catia V5	Virtual models
CES Edupack	Material choice and information
Digital goniometer with built-in bubble lever	Observations
Espacenet	Patent search
Folding ruler	Observations and thinking-aid
iPad 2 & iPad3	Observations and thinking-aid
Matlab	Presentation of observations
Microsoft Excel	Data processing
Microsoft Word	Compilation of report
RD&T	Tolerance analysis
Red, electrical tape	Observations
SLR camera	Observations
Volvo V70	Observations and VCC brand studies

3 Prestudy

The results from the prestudy are presented in this section.

3.1 Product decomposition

The product was analysed based on its functionality. The identified functions were noted and broken down into semi-functions. The product's identified functions can be seen in Figure 4. The connection to VCC's interface was not further decomposed since it had already been developed.

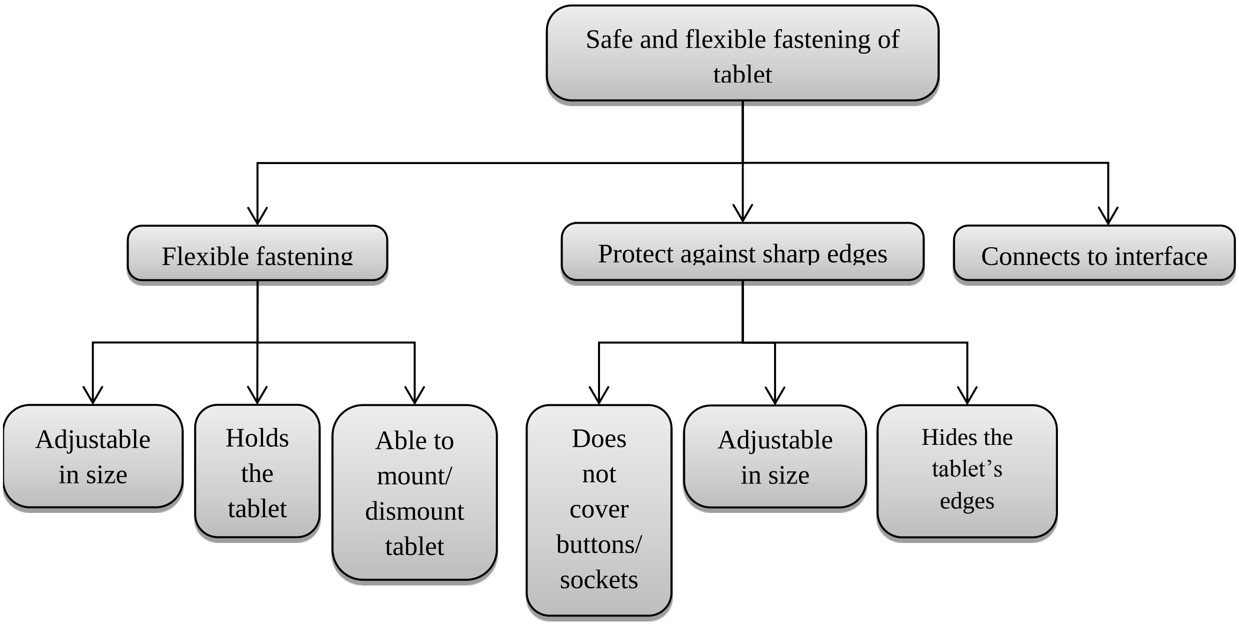


Figure 4 - Product decomposition

3.2 Volvo Cars Corporation design

The design is one of VCC's four core values and VCC's main design philosophy is that:

"Good design is not only about an appealing look. It is just as important that the product is user friendly and intuitive. If the product is not functional, it can never be beautiful." (13)

VCC also states that their products should be characterised by elegant simplicity and function. They should both look appealing and be genuinely safe. Each product should also be designed with the user in focus, ensuring comfort safety and control to users (13).

The products VCC offers are supposed to be premium products. It is therefore important that also the accessories, such as the tablet mount, maintain a level of quality that is at least as high as for any other detail in the interior of the car. It is very important that it does not impair how the car is perceived. The product also must not differ too much from the rest of the interior in its visual appearance.

Because of this, the product must be robust and give a qualitative impression. Any split lines must be cleverly designed and tolerances kept at a sufficient level. It must not feel clumsy or be fragile and it must be logical and intuitive to use in accordance with VCC's design philosophy. The shape of the mount should also be smooth, simplistic and stylistically pure to match the rest of the car's interior. The surfaces and colours must also fit with VCC's design, and the interior of new Volvo cars are often off-white, dark grey, blond, soft beige or espresso brown with styling details of crossed aluminium, dark aluminium or surfaces depicting wood or charcoal (7).

3.3 Volvo Cars Corporation's customer requirements

VCC wanted the tablet mount's design to look and feel like a Volvo product and thus the design has to show that it is Volvo designed and branded. This also includes a premium handling and appearance. Additionally, it was desirable to minimize the risk for mirroring and sun reflection in the tablet screen.

When it comes to functionality, the mount should hold the tablet securely locked. It is also important that the mount works in both portrait and landscape mode. In order to make it easy and pleasant to use for the customer, it should be simple to insert and remove a tablet from the mount and all buttons and sockets should be reachable when the tablet is mounted.

The mount should give a robust impression and it must not be dented, distorted, scratched nor have pieces broken off at normal handling

Additionally, models and drawings must be produced with Catia V5.

3.4 Volvo Cars Corporation's design prerequisites

For confidentiality reasons, most of the material in VCC's design prerequisites cannot be shown in this report. Only summaries of the content will therefore be presented in this section.

The requirements on solidity are valid for new parts and up to a certain time or distance for the car. It also only applies to use in what is considered normal operating temperatures. Problems at other temperatures are considered less severe.

Under these conditions, no noises, squeaking or creaking are allowed during normal operation. The characteristics of the opening and closing motions should be linear, soft, muffled damped and without chafe. Forces should be consistent and not vary over the operation and no loose play is ever allowed in any direction.

All surfaces must be resistant to common stain removing agents and areas susceptible to spill should also sustain substances such as common food and drinks. It is also important that the product is made out of materials that do not corrode.

Additionally, the product must be tested in several ways before it can start being produced. The product is for example tested for impacts, different climates, UV radiation, ageing etc. After each test, the product must fulfil certain requirements such as:

- No change in grey scale
- No colour variations
- Surfaces must not become blotchy
- No gloss defects
- No visible deformations and no cracks
- No release of adhesives
- No odour

3.5 Material requirements

Materials regulated by laws are compiled and presented in Appendix B. There are also requirements on plastic components, which are listed in Appendix C.

There are some additions to the previously mentioned lists. In accordance with VCC's policies, materials from endangered species must not be used nor should any rare or noble metals with a high environmental load unit, ELU, be used. Also, none of the materials classified under VCC's Restricted Substance Management Standard, RSMS, should be used, neither should any materials listed in the EU REACH annex XIV (14) in concentrations greater than 0.1%.

VCC also have requirements preventing the use of materials that burn or propagate flames across the surface over a certain limit.

3.6 Interfaces

In the front, the mount will have to hold on to a tablet and more information about the dimensions and shapes of different tablets is presented in section 3.10.

On the back side, it has to be able to connect to VCC's interface. Since this has already been developed, the mount will have to fit to it. The interface is also supposed to be able to rotate, allowing it to be positioned in either portrait or landscape mode. The mount is attached to the interface with a screw through a hole in the centre of the interface.

A virtual model of the interface was obtained from VCC, however it was read-only and it was therefore redesigned as a part of the prestudy, so that the new model could later be applied to the tablet mount in the detailed design phase.

3.7 Customer value

The interviews resulted in a lot of input for the design of the tablet mount. The major points were that the mount should

- be robust and stable when used
- not feel clumpsy at all
- be discrete and coherent with VCC's interior design
- not cover the buttons or sockets nor prevent internet or bluetooth usage
- allow for easy attachment and detachment of the tablet
- be easy to adjust for different tablets
- prevent sun reflections in the tablet screen
- be tiltable
- not cost more than 4000 SEK

Additionally, for the vast majority of interviewees, the tablet would mostly be used by children. More content from the interviews can be found in Report A.

The internal brainstorming session resulted in several aspects for the tablet mount design. These aspects were analysed, decomposed and grouped into an Ishikawa diagram, see Figure 5. As mentioned in section 0, these are not results of the interviews or requirements from VCC but general aspects considered important for the impression of the final product.

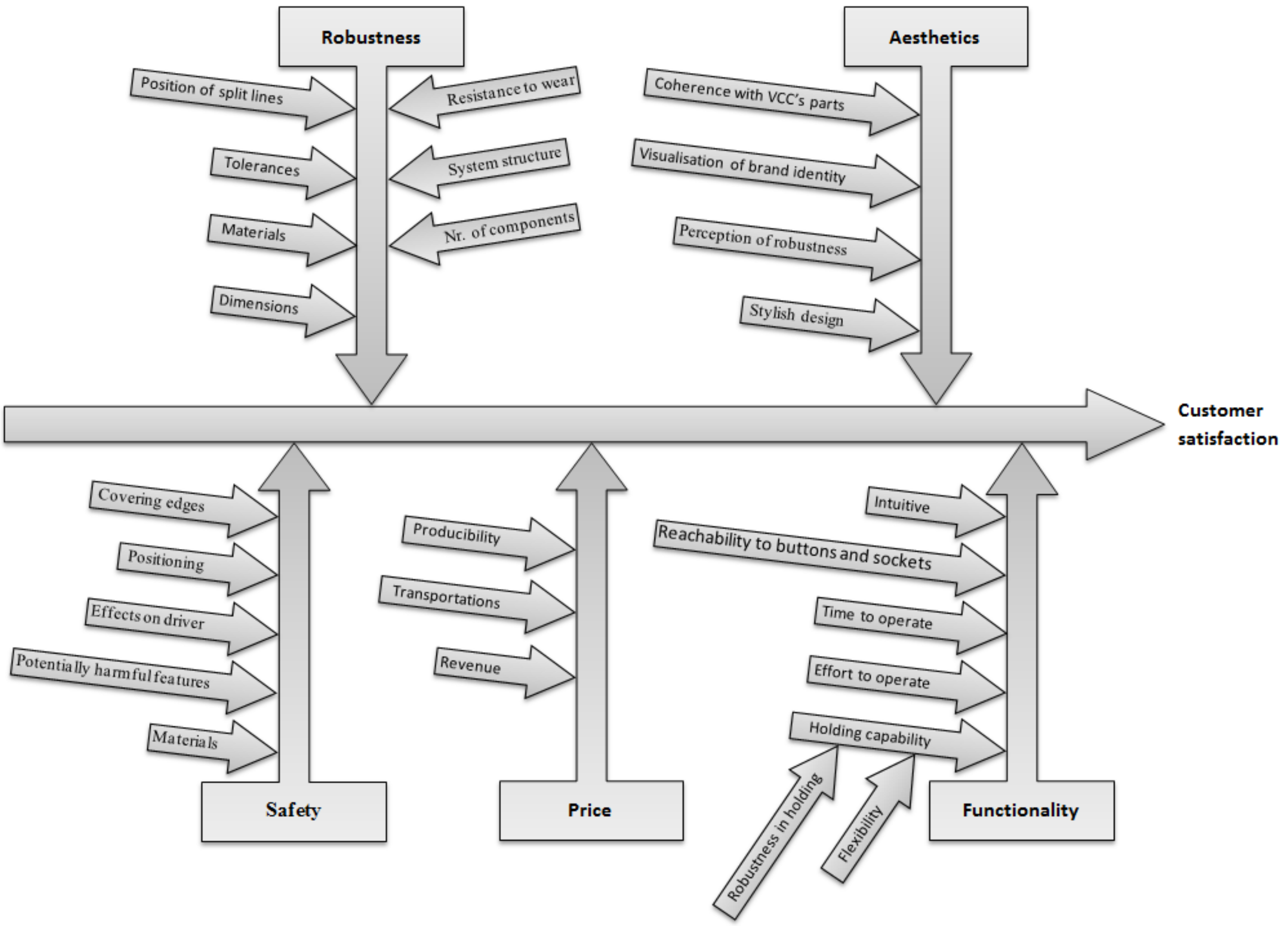


Figure 5 - Aspects affecting customer satisfaction

3.8 Producibility

The aspects affecting the producibility of the product has been broken down in an Ishikawa diagram, see Figure 6.

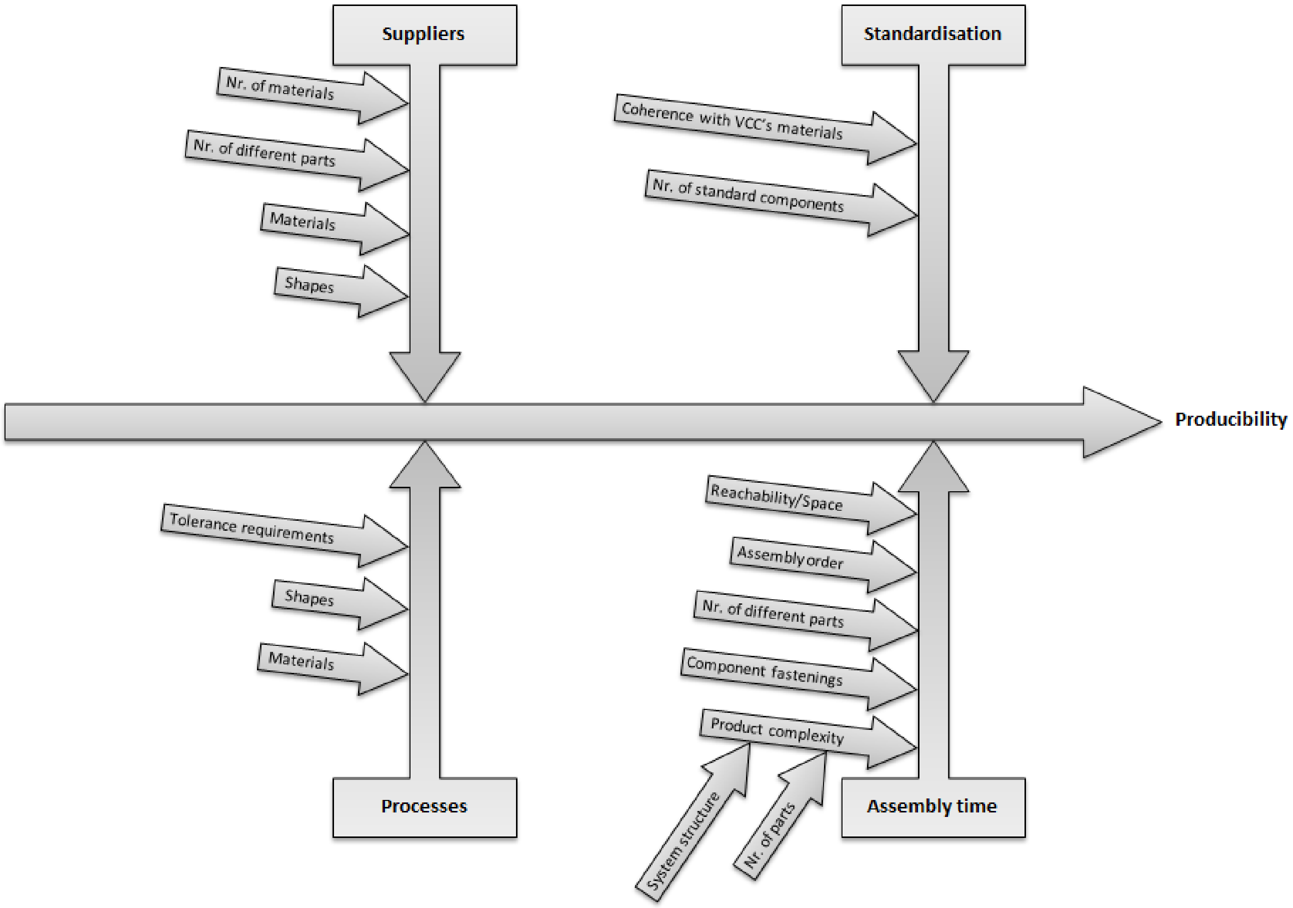


Figure 6 - Aspects affecting producibility

3.9 Observations

22 persons participated in the observations for the positioning of the tablet in the back seat and 15 persons also adjusted the driver's seat. The participants were all Swedish but of different age, gender and size.

Values from the observations are listed in Table 2. The precision of the observations as well as a list of all the measurements can be seen in Appendix D. The appendix also includes potential sources of errors for the observations.

Table 2 - The results from the observations

	Measurement	Mean value	Max. dif. +	Max dif. -	Highest-Lowest
Tablet	Distance to back headrest	729.0	70.9	-149.5	220.4
	Distance to roof	422.7	111.2	-104.8	215.9
	Angle	52.6	17.7	-19.7	37.4
Front seat	Distance to back headrest	904.9	108.1	-111.9	220.0
	Angle	100.6	8.2	-10.3	18.5

Figure 7 shows the mean positions for the tablet and front seat in red, and all observations in blue. The red cross at the top left of the plot represents the spot in the roof, straight above the back headrest and all values are in mm.

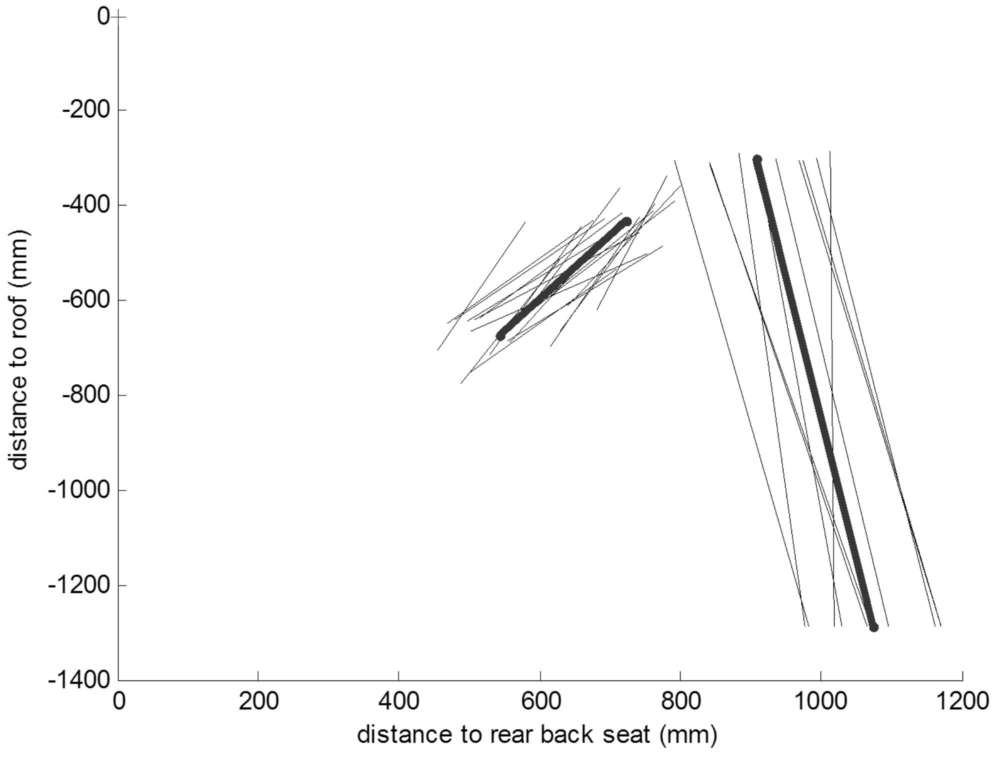


Figure 7 - Position for tablet and front seat, thick lines are mean values

When further analysing the results, see Figure 8, it becomes obvious that there is no correlation between the horizontal distance and the angle of the tablet. There seems to be a pattern regarding the height of the tablet and its angle though, suggesting that a person holding the tablet high would also hold it more vertical. The reason for this is most likely that the person watching the tablet faces it towards his or her eyes, so that the tablet isn't watched from an angle.

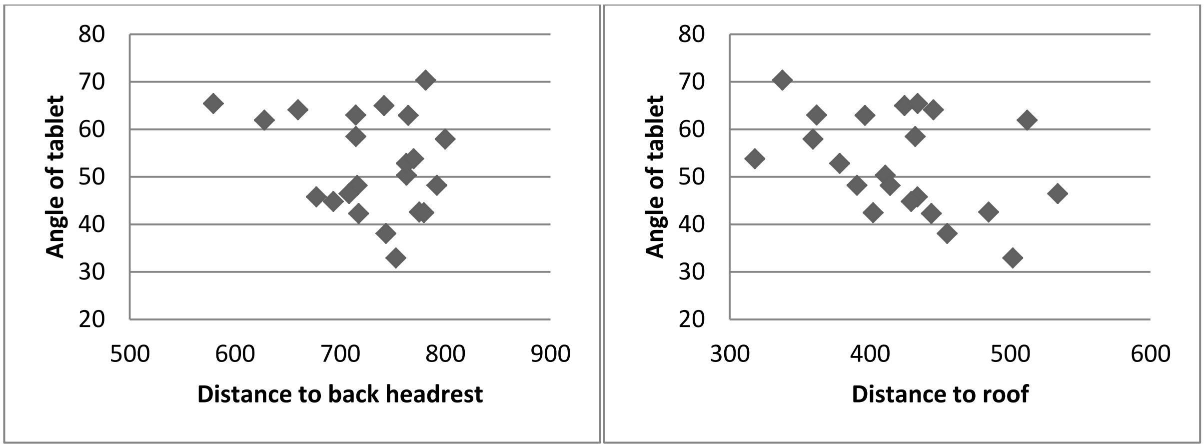


Figure 8 - Position for tablet relative to the angle of the tablet

Regarding correlations between horizontal and vertical positioning, ignoring the extreme values, there is a minor pattern that a person holding the tablet close to him or her would also hold it lower. This can be seen in Figure 9. The pattern is very weak though and more observations are needed in order to confirm this.

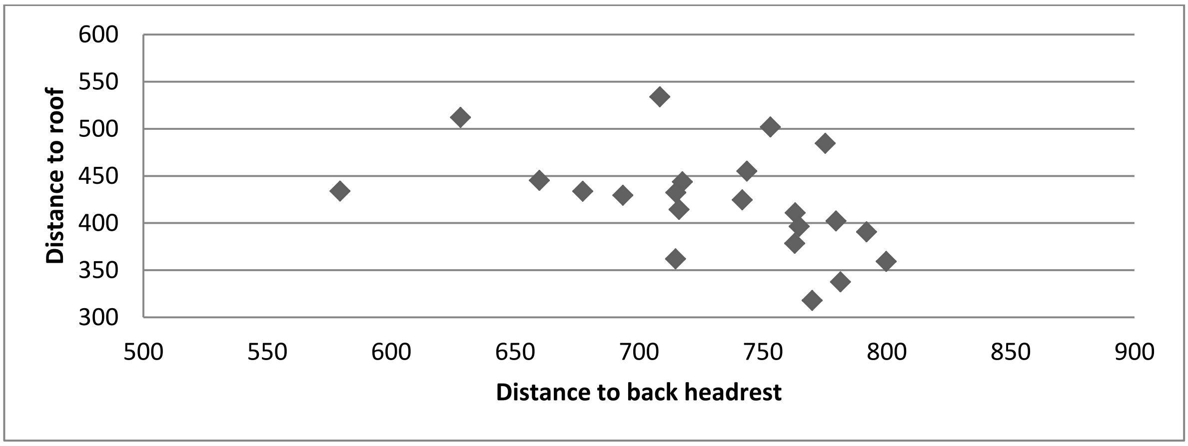


Figure 9 - Distance to roof compared to distance to back headrest

Using the mean values, the tablet should be positioned 186.32 mm from the back of the front seat and position the tablet with an angle of 55.64°. As a result of this, the distance from the centre of the tablet to the front headrest would be 318.77 mm. Regarding the extremes, with a short person in the back seat and a short person in the driver's seat that distance would be more than 600 mm. In the opposing scenario, with two tall persons, it would be difficult to use the tablet mount at all. However, the tall person would most likely not even fit in the back seat behind the other tall person. In this case, short person referred to the one who held the tablet closest to him or her, or sat furthest forward in the driver's seat. The tallest persons are defined as the opposite.

The interviewees' tablet angle varied much, from about 32.90° to about 70.30°. Considering both the angle of the seat and the angle of the tablet, the angle between the tablet and the front seat was calculated to be in the range of 29.20° – 79.70°, which is a large span. Concluding the results of the observations, it seems desirable to be able to adjust the position and the angle of the tablet mount.

3.10 Benchmarking – tablets

One of the documents obtained from VCC was a summary of different tablet dimensions. It covered both large and small tablets and was a great basis for the future design requirements. The document can be seen in Appendix E. Additional benchmarking on tablet sizes was also conducted, with the result that VCC's document was deemed sufficient. The values from that document gave the following size ranges:

- Length: 189 – 271 mm
- Height: 120 – 180.8 mm

In order to have some extra margin and allow for future tablets of slightly different sizes, the following ranges were chosen as requirements for the tablet mount:

- Length: 180 – 280 mm
- Height: 110 – 190 mm

Unfortunately for this project, all tablets do not have the same dimension ratios either. During the benchmarking it became obvious that tablets exist both as 16:9, 16:10 and 4:3. No other dimension ratios were found, even though there is a chance that tablets with different ratios might be developed in the future. Even so, the requirement for the tablet mount was set based on these values so that for each size, the mount should be able to handle every tablet with ratios from 16:9 to 4:3.

The thickness of tablets would also be valuable information for the detailed design, and it was generally between 7-10 mm.

The last step of the tablet benchmarking was to identify where the buttons and sockets are located on tablets. This was of course important in order to be able to design a mount that will not cover these on any tablet.

It quickly became apparent that there could be buttons and sockets on all edges of the tablet. Even within a single brand, there were several different placements for the same button. Since there did not seem to be any standards for placements, future tablets could easily have their buttons and sockets in new locations as well, potentially making the tablet mount unusable for those products. One pattern was clear from the study though, that the charging socket seemed to always be placed on the centre of a side. Even though it could be both on the long and short sides it was always centred. The areas right next to the charging sockets were also always clean of buttons and sockets, at least on all tablets covered in the benchmarking. Therefore that area could be used to hold the tablet. Additionally, no tablet had any buttons and sockets on the corners, even though some models had buttons and sockets very close to the corners. Thus the corners were considered less ideal for holding the tablet.

Due to the fact that tablets are thin, it was considered unfeasible to hold on to the upper and lower parts of the tablet's side while still allowing enough space in between for buttons and sockets to be reached.

3.11 Benchmarking – Tablet mounts

3.11.1 VCC's competitor's solutions

Some competitors have, or are developing, their own tablet mounts. Information was gathered from the car companies' web sites. Most large car companies were studied, and the ones who offered a tablet mount are presented below.

Audi

Audi has taken the development of adapting cars to tablet usage one step further by developing their own 10.2" Android tablet called the Mobile Audi Smart Display. It appears the aim is to hit the market in a few years and it is supposed to be compatible with the car via a Wifi interface so that it can control functions such as window controls, doors, sun roof controls, temperature etc. (15) (16).

BMW

BMW is the only other car producer found that has a tablet mount which is capable of being positioned in two different modes, writing and watching. The tablet mount is rotated down from the upper position to the lower. It is also rotatable around its centre point and to a certain degree tiltable however the tilt function is mostly for the writing mode. It is however only compatible with iPad 2, 3 and 4. The tablet mount has a matte, black colour with silvery details such as buttons and inner edges, which can be seen in Figure 10.

The tablet holder is a module in their travel and comfort system which is built around a base unit which is fastened in the headrest. This base unit can then be used for other things such as a coat hanger, a universal hook or a foldable table.

The price for BMW's tablet mount is 1425 SEK (17).

Figure 10 - BWM's iPad mount

Mercedes Benz

Mercedes offers iPad docking stations at the back of the headrest. They have a built-in ability to charge the tablet and the package can also be combined with their in-vehicle hotspot to provide a Wifi connection. The mounts can be rotated and tilted and the iPad is inserted by opening the frame along one of the short edges. Regarding the design they are clean and quite simplistic, they have a black shiny frame in the front and a glossy silvery colour behind that. The arm holding the mount seems to be dark and matte to match the surface and colour of the seat.

According to their web page, one docking station costs 400 USD. However, according a retailer in Gothenburg, the price there was about 10 000 SEK for two docking stations, one for each side (18).

Nissan

Nissan seems to have a tablet holder for their cars, however it was difficult to find any information about it.

Peugeot

Peugeot does not have a tablet mount for their cars at the moment even though one of their concept cars from a few years back included a tablet mount for the front passenger seat. It does however not seem to have been included in any of their commercial vehicles (19).

Toyota

For Toyota's rear seat entertainment system, the buyer can choose two iPad mounts in exchange of the two standard 7" displays. These seem to be rotatable, include a built-in charging for the tablets and have a simplistic design. The entire mount seems to be in the same matte, dark colour.

The option with iPad mounts could only be found on Toyota's Swedish we site, not on their international, which seemed quite odd. It was also quite difficult to find since they are not promoting the product at all.

The price for the base package of the rear entertainment system with the two iPad mounts is 11 200 SEK (20).

3.11.2 Other solutions

There are a lot of different tablet holders on the market, both made for cars or for usage elsewhere. The tablet mounts have been categorized into 14 different categories which will be explained one by one.

- Bags
- Cushions
- Flexible arms
- Holding four corners
- Holding two corners
- Holding one edge
- Holding two edges
- Holding three or four edges
- Magnets
- Modular

- Plate with flexible fasteners
- Rubber bands and elastic tapes
- Socket solutions
- Suction cups

Bags
Bags are similar to socket solutions only that they are made out of fabric or leather. The user generally inserts the tablet from the top and the solutions are designed for specific tablets, i.e. they are not flexible for different dimensions. They naturally cover the edges but are often soft and might yield or turn when pushed. An example of a bag solution can be seen in Figure 11.

Figure 11 - Example of a bag solution

Cushions
These tablet holders are cushions with a slot in which the tablet can be inserted from the front. The will not hold the tablet rigidly, yielding if the user is pushing the tablet, and they will easily let go of the tablet in a crash, sharp turn or quick acceleration. Cushions generally cover the buttons and sockets, although since they are soft and will easily yield the user should still be able to reach them by pushing away a part of the cushion.

Flexible arms
The function is to hold the tablet in place by bending the flexible arms around the edges of the tablet, just like a hand bending its fingers around the edges. The arms could either be made out of a bendable material or they could be made out of links. The flexible arms can easily be adjusted for different tablets and they would make it easy to mount and dismount the tablet. However, they would be deficient when it comes to holding on to the tablet in the event of a crash, or maybe even in a sharp turn. They also don’t naturally cover the edges, except for the areas covered by the actual arms.

Holding four corners
This means that the product is holding the tablets four corners. This is generally done by some X-shaped structure that is either adjustable in size or static, where the tablet is forced or simply put into the structure. When holding all four corners, the fastening becomes quite rigid and the tablet would most likely stay in place even during an accident. Most solutions for holding all four corners seem easy to operate however they do not naturally cover all edges.

Holding two corners

This is similar to the previous solution except that it holds on to the tablet on two opposing corners instead of all four. It makes the holder easier to adjust to different sizes but loses some of its ability to hold the tablet robustly in place.

Hold one edge

The tablet is only held in the lower edge. This method is most likely only able to keep the tablet standing on a flat surface. The mount will most likely let go of the tablet in a sharp turn, on a bump or in a crash. The holder could potentially be tightened enough to hold the tablet but it would then require a high force, potentially damaging the tablet. It also does not naturally cover the tablet's edges.

Hold two edges

The tablet is held in two edges, either from the sides or more commonly at the top and bottom edges, see Figure 12 for an example. The fastening becomes quite rigid and most solutions are simple to operate however they do not naturally cover all edges.

Figure 12 - Example of a tablet mount that holds two edges

Hold three or four edges

The tablet is held in three or all four edges. This makes for a stable fastening but can sometimes require more actions to operate. It also does not naturally cover all edges. An example of such a tablet mount can be seen in Figure 13.

Figure 13 - Example of a tablet mount that holds all four edges

Magnets

Magnets attach to the back of the tablet. This only works if the tablet is made out of a magnetic material. It would be easy to mount and dismount the tablet but to keep the tablet steadily in place the magnets would have to be quite strong and it is unknown how much this affects the tablet itself. It also does not naturally cover the edges.

Modular

A modular tablet mount is one where some parts are exchangeable to make it fit for tablets of different size. They might for example hold the tablet along the upper and lower edges with frames that can be switched depending on tablet. It could also be a solution where the mount is a tablet case which can then be fastened to a structure on the back of the headrest. An example of the latter can be seen in Figure 14.

Figure 14 - An example of a modular case solution

Plate with flexible fasteners

The holder consists of a plate, onto which the tablet is put, and then locked in place by movable fasteners along the plate's edges or in slots through the plate's surface. The fastening should most likely be rigid and on some solution the plate extends outside the tablet, offering some protection from the edges, although not from the front. The plates with flexible fasteners are generally quite laborious to operate.

Rubber bands and elastic tapes
The tablet is held in place by elastic tapes, or rubber bands, that are pulled up around its corners, either on two corners or on all four. Behind the tablet there is generally some kind of plate holding the elastic bands. This solution makes it easy to mount and dismount tablets of different sizes but there could be problems keeping the tablet in place in the event of a crash. The plate holding the elastic bands could be larger than the tablet, thus in some way protecting the edges from the sides, however it provides no protection from the front.

Socket solutions
The tablet is inserted into a socket, generally from the top. The sockets are often not very flexible and only work for tablets with similar size and dimensions. They do however cover the edges in most cases.

Suction cups
A suction cup is holding the back of the tablet. They make it very easy to mount the tablet and should be quite easy to detach it as well. There are suction cups that can hold quite rough surfaces, so the fact that not all tablets have a smooth back side does not have to be an issue. With suction cups, it is however problematic to keep the tablet in place in the event of a crash and it does not naturally cover the edges of the tablet.

3.11.3 Patents
Patent searches were made at Espacenet (21) using search words related to the subject. Examples of patent solutions found were:

- A rigid back piece from which telescopic arms reach out to hold two edges.
- A rail system, hanging in strings supported by suction cups.
- A telescopic tube-system allowing flexibility in the structure holding the tablet.
- Modular solutions.
- Solutions similar to cassette tape insertions.

3.12 List of target specifications

One of the major purposes for the prestudy was to work as a base for the target specifications. The different aspects and criteria found during the prestudy were compiled into Table 3. They were sorted depending on where the requirements came from and classified as *must* or *should* to enlighten their importance.

Since these are only the criteria from areas regarding the design and construction there were target specifications from the other areas as well. These are covered in Report A and Report C.

The requirements and target specifications from all areas were combined into one document which would be used as a base for future concept evaluations and design decisions, see Figure 15. The complete list of all combined target specifications can be seen in Appendix F. Future references to the target specifications will refer to that complete document.

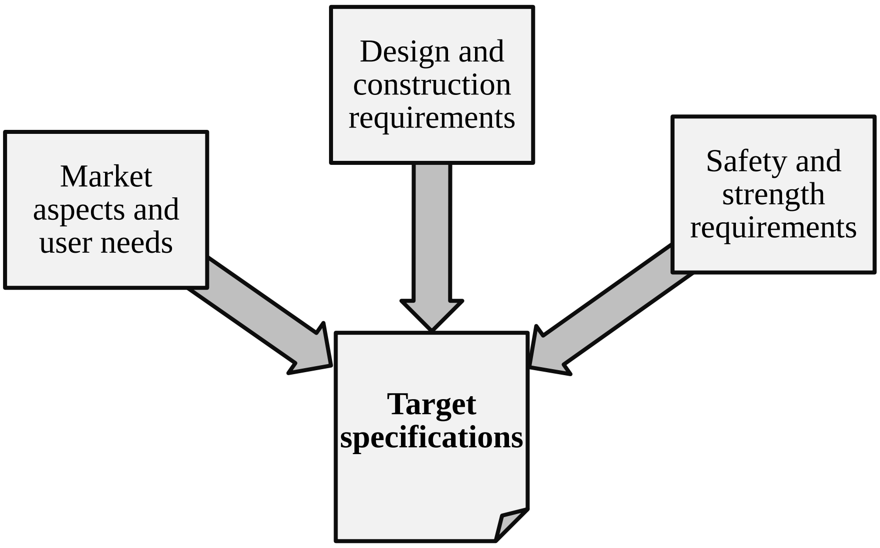


Figure 15 - The combination of requirements for the target specifications

Table 3 - The target specifications for the design and construction

Importance	Requirement	Origin
Must	be usable for a wide variety of commercial tablets	VCC, project goal
	feel and look like a Volvo product	VCC's design requirements
	have premium handling	
	have premium appearance	
Should	prevent reflection and mirroring in the tablet screen	VCC's functional requirements
Must	hold the tablet securely locked in the mount	
	be easy to use for mounting and dismounting the tablet	
	allow the user to reach all buttons and sockets	
	not be deformed or fractured by normal handling	
Should	appear safe	VCC brand identity study
	be coherent with the interior design of Volvo cars	
Must	hold as high quality as the rest of the car's interior	
Should	be intuitive to use	
Must	Not make unwanted sounds during normal operation	VCC
Should	have linear, soft and non-chafing motions	VCC solidity requirements
	have consistent forces over the operation	
Must	be able to fit VCC's interface	VCC
	not conflict with any material restrictions or regulations	Laws
	be able to withstand VCC's temperature and ageing tests	VCC
	be resistant to chemicals regularly used in cars	
	not corrode	
Should	have an optimal angle for the average user (circa 57°)	Observations
	have an optimal position for the average user (circa 300 mm from the front seat)	
	allow for tilting the tablet (range: 60°)	
	allow for adjusting the tablet’s vertical position (range: 200 mm)	
	allow for adjusting the tablet’s horizontal position (within a range of 300 mm)	
	support usage with people of different height and size in the front seat	
	support usage at different angles	
	give an impression of robustness	Identified customer value
	be functionally robust	
	be aesthetically robust	
	Be designed to allow for variation in production	
	be cheap	
	require minimum effort to operate	
	require minimum time to operate	
	not have negative effects on the driver	
	not be potentially dangerous to the user	
	have as few components as possible	Producibility
	have as simple shapes as possible	
	have a simple product architecture	
	Contain as few different materials as possible	
	as much as possible use standard components	
	be easy to assemble	

4 Concept development

This section presents concept development from the generation of the first rough concepts to the selection of the final concept. As mentioned in section 2.1, the concept development phase was conducted together by the project group members and thus this section will be almost identical as the same section in Report A and Report C.

4.1 Concept Generation

The concept generation was supported by all the knowledge and inspiration from the pre-study. A lot of time and effort was invested in this phase since an extensive solution space had to be covered due to the complexity of the product.

The functional brainstorming resulted in a morphological matrix, which can be seen in Appendix G. It was based on the functions identified in the product decomposition. Each function was brainstormed separately and efforts were made to cover all potential technical solutions.

Many of the generated solutions were dependent on other solutions, for example a suction cup attachment was not deemed feasible with a deformable structure. In order to enlighten these relations, additional columns were added to the morphological matrix. These columns were made to show which technical solutions fit with each other, which can be seen in Table 4. In the table, the suction cup is chosen for attachment solution, and the possible solutions for flexibility are marked with green.

Table 4 - An example of the feasibility-check in the morphological matrix

Attachment		Flexibility	
Band		Elastic	Not feasible
Flexible arms		Springs in structure	Not feasible
Non-permanent glue		Deformable	Not feasible
Clamping supports		Threaded rods	Feasible
Clamps		Separate, built-in solutions for different sizes	Not feasible
Cushion		Nothing	Feasible
Magnets		Module-based	Feasible
Glue + solvent		Different attachment locations	Feasible
Case		Adjustable band	Not feasible
Slot		Automatic roll	Not feasible
Suction cup	1	Manual roll	Not feasible
Resting supports		Rail system	Feasible
Clamping frame		Slidable in track	Feasible
		Track with springs	Not feasible
		Telescopic inwards	Feasible
		Telescopic in tablet's plane with springs	Not feasible
		Telescopic in tablet's plane with gears	Feasible
		Telescopic in tablet's plane with, manual	Feasible
		Telescopic along rigid structure	Feasible
		Rotatable parts in tablet's plane	Feasible
		Attached to frame	Feasible

The morphological matrix was used for both qualitative and quantitative concept generation. The qualitative approach meant carefully choosing technical solutions that seemed promising and would fit well together. These were then combined into complete concepts.

The quantitative approach meant choosing technical solutions with less thought for the intent of creating many concepts. This was also done by randomly selecting solutions and combining them into concepts to find more out-of-the-box solutions. Some examples of concepts generated from the morphological matrix can be seen in Figure 16- Figure 18. The combination of solutions into complete concepts continued until all feasible ideas in the matrix had been used at least once.

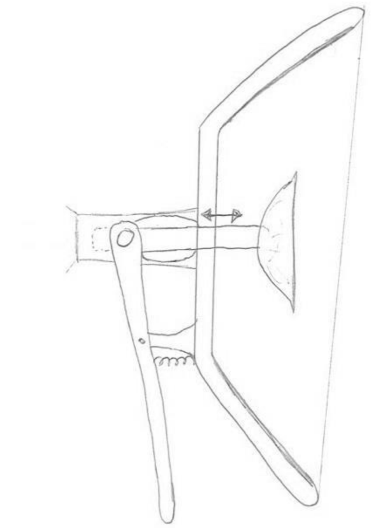


Figure 16 - Suction cup with rigid frame

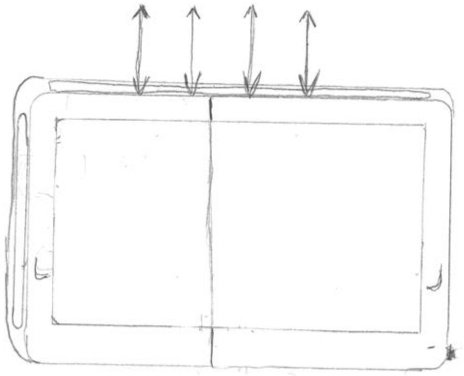


Figure 17 - Semi-flexible structure with VHS-insertion

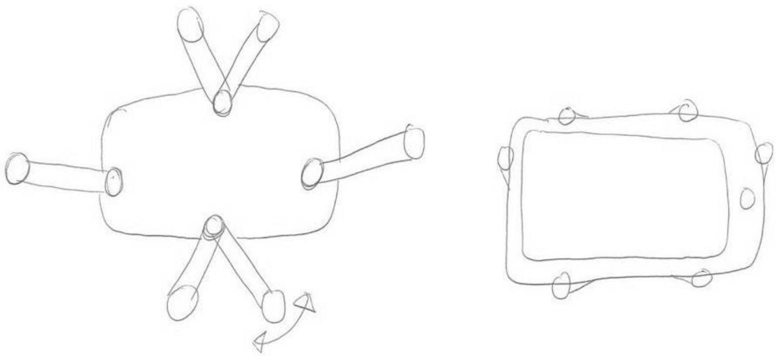


Figure 18 - Point attachment concept with rotatable arms

The internal 6-3-5 brainwriting was used with great success and resulted in 54 new concepts of varying quality. Due to the short time limits and the fact that entire concepts were generated instead of just technical solutions, the concepts generated generally differed quite much from those of the morphological matrix. One example of a brainwriting concept can be seen in Figure 19.

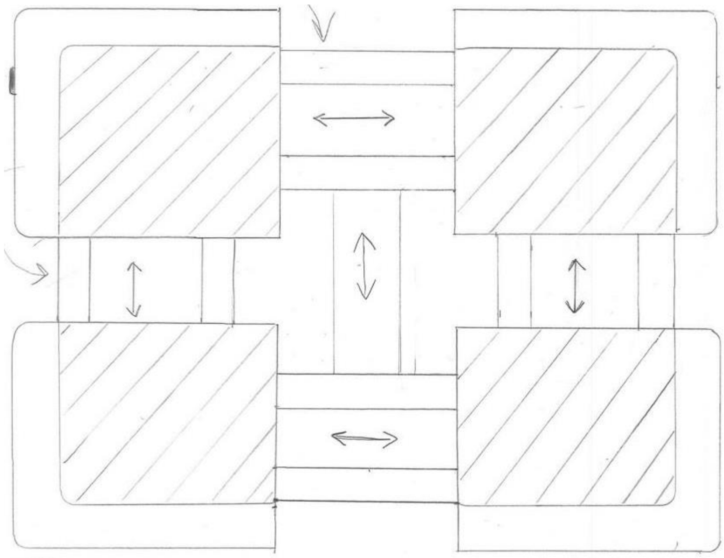


Figure 19 - A flexible frame-concept which was generated from the 6-3-5 brainwriting

The brainstorming with stimuli was used quite late in the concept generation process but still lead to some new ideas and concepts. For example the concept in Figure 20 was created with the stimuli from a dishwasher and a rollercoaster, with the foldable frame in the concept resembling the retaining structure of a common rollercoaster.

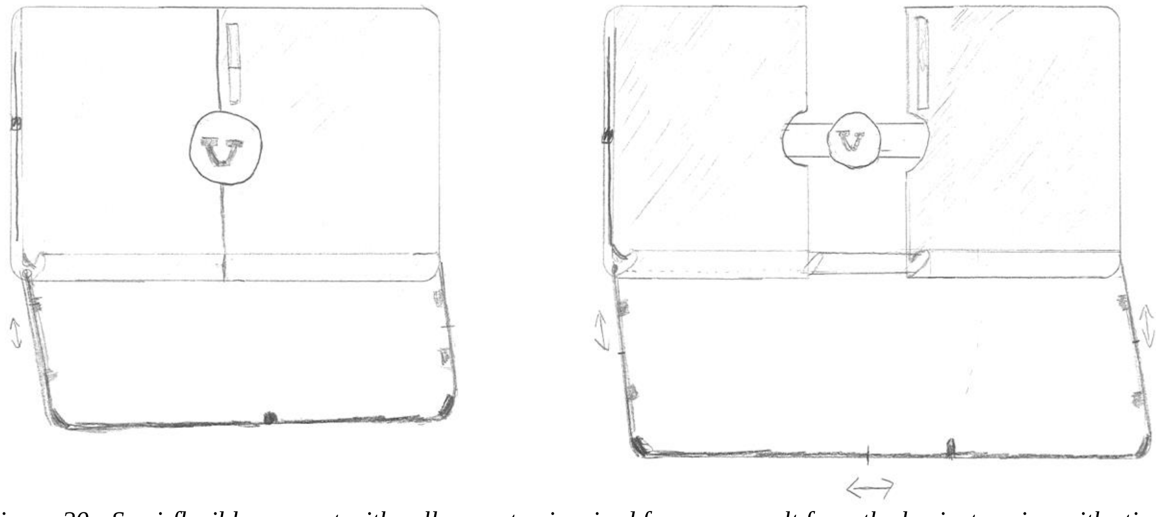


Figure 20 - Semi-flexible concept with rollercoaster-inspired frame, a result from the brainstorming with stimuli

The external concept generation sessions were conducted both as a 6-3-5 brainwriting session and by discussing ideas with other students at Chalmers University of Technology. They were both conducted rather late in the concept generation phase and neither of the two gave any new concepts. They could therefore instead be used as a confirmation that a majority of the solution space had been covered. When it comes to the 6-3-5 brainwriting session, the participants found it hard to embrace all the information that was needed for generating complete concepts and this could be an additional reason why not so many new ideas emerged.

The final step of the concept generation consisted of going through all concepts. Many concepts were only rough sketches and sometimes only the sketcher could understand them and many were also identical or at least very similar to other concepts and could be merged. Some concepts were removed too, due to their lack of completeness. These were generally concepts from the later stages of the 6-3-5 brainwriting.

All concept sketches that were not removed this way were refined with better detail and then categorised. The categories were based on the concepts' physical characteristics and the concepts were divided between them as:

- **Back-attachment mount** – the tablet is only held at its back – 3
- **Deformable mount** – flexibly deformable mounts, such as a rubber frame – 8
- **Flexible mount** – the mount is flexible in both directions – 38
- **Point-attachment mount** – the mount is held at several points around the edges – 2
- **Rigid frame mount** – the mounts is not flexible at all – 20
- **Semi-flexible mount** – the mount is flexible in one dimension – 6

Thus, a total of 77 concepts entered the concept evaluation.

4.2 Concept evaluation

This section describes the funnelling down from the initial 77 concepts down to the final one. A visual representation of the phase, together with the number of concepts for each level can be seen in Figure 21.

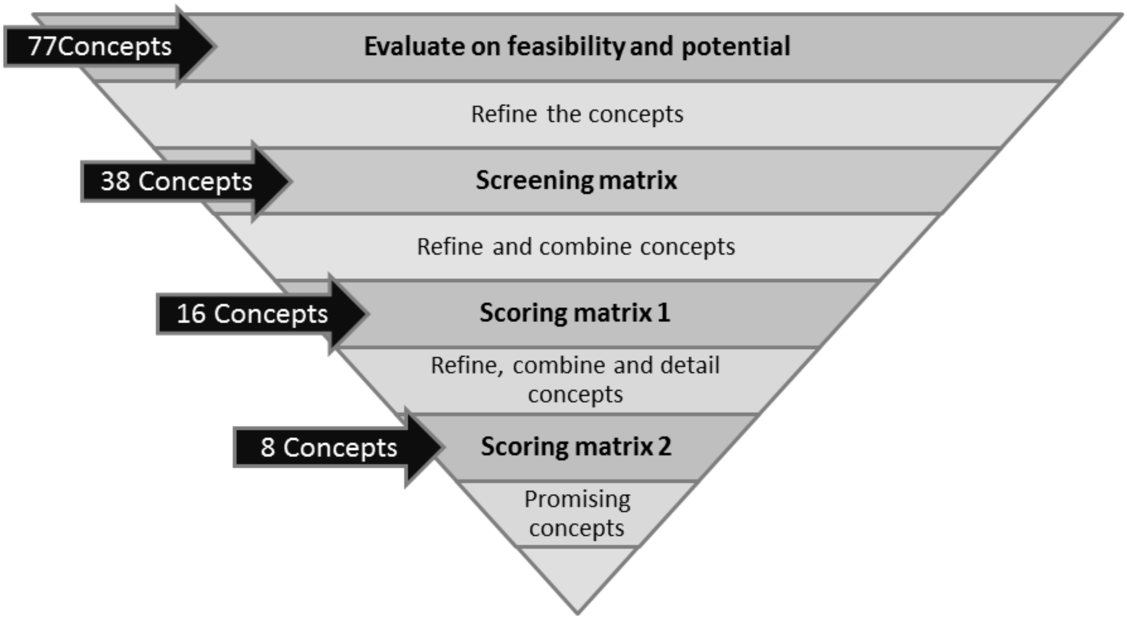


Figure 21 - Visual representation of the concept evaluation, with the number of concepts entering each step

4.2.1 Initial concept screening

Each concept was evaluated based on if it had potential to live up to the following aspects:

- Ability to fulfil vital requirements such as minimum radii of components and holding the tablet securely in a crash.
- Feasibility to construct
- Potential for a premium handling and appearance

Each concept was evaluated based on the three previously stated criteria in order to decide if the they should be further developed or not. Similar concepts were also combined in order to reduce the number of concepts. The first criterion covered the concepts' potential to fulfil the vital requirements, which in this case mostly involved being safe in a car crash. If a concept did not fulfil all vital requirements at this point, but was still found to have potential, it was kept to refine or combine with other concepts.

A number of the solutions failed on the second criterion, which was feasibility. If the concept was based on advanced technology or technical solutions with a high cost it was generally removed.

A large portion of the concepts considered too lack potential when it came to the handling and appearance. The question asked for the third criterion was: would VCC ever put a product like this in one of their cars? If the answer was no and no way of refining the concept so that it would be good enough was identified, it was removed.

After the refining, combining and funnelling down there were 38 concepts left to make it to the next step of the concept evaluation phase. These concepts were given a name based on an abbreviation for their category plus a number. The abbreviations for the categories were:

- Flexible mounts - FL
- Semi-flexible mounts - SE
- Deformable mounts - D
- Rigid frame mounts - FA
- Point-attachment mounts - P

A collage of the concepts that were discarded in the initial screening phase can be seen in Appendix H.

4.2.2 Concept screening

One of the remaining concepts, named FL13, was chosen as the reference. It was a simple, telescopic frame structure with one arm going from one corner to the opposite, connecting the frame to the back piece with the tablet being held at the corners. A sketch of the reference concept can be seen in Figure 22.

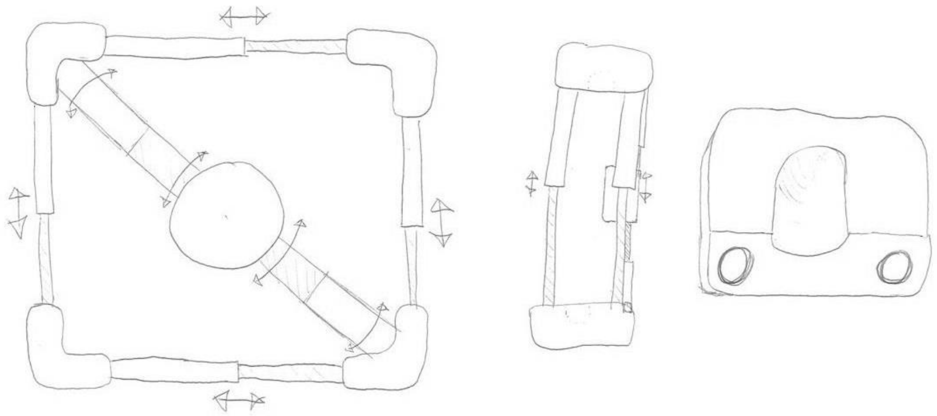


Figure 22 - Concept FL13, which was used as reference in the screening matrix

Seven criteria were chosen covering all relevant requirements and these can be seen in Table 5. The first column shows the different criteria, the second column explains the judgement aspects on which the concepts were evaluated and the covered requirements from the target specifications are listed in the third column. A list of the target specifications can be seen in Appendix F.

Table 5 - The criteria for the screening matrix

Requirement	Judgement criteria	Covered requirements
Crash safety	Coverage of edges, secure holding, unsafe deformations, protrusion	1.2-1.9, 3.29
Aesthetically appealing	Coherent with Volvo's design, instils quality/safety, good looking	2.2-2.4, 3.12, 3.17-3.19, 4.1, 4.4
Ease of use and flexibility	Intuitiveness, time, simplicity in use, range of flexibility	2.1, 3.18, 3.20, 3.21, 4.2, 4.3
Physical robustness	Strength, fastening strength, structural stability, stability in usage	2.5-2.7, 2.12, 3.16, 4.3, 5.1-5.3
Simplicity	Number of parts, complexity of connections	3.14, 4.5, 4.8, 4.9, 4.10, 4.11, 4.12
Accessibility to buttons and sockets	Charging, audio, volume buttons, on/off, home button, speakers	3.1-3.8

All 38 concepts were evaluated for each criterion in the matrix. The complete screening matrix can be seen in Appendix I. A short presentation of the results:

- 7 concepts got a score of +2
- 9 concepts got a score of +1
- 12 concepts got a score of 0
- 4 concepts got a score of -1
- 3 concepts got a score of -2
- 1 concept got a score of -3
- 1 concept got a score of -5

The project group now revisited each concept, investigated why they got their score and decided if they should be continued with. This was not directly based on the result of the screening matrix but rather used it as a guide for the evaluation. One important aspects from the matrix was if a concept had gotten a lot of + and - or if it had gotten mostly 0's. For example, a concept with a score of 0 that had +3 and -3 could have some really good features although it is being pulled down by other negative features. In such a case, the positive features could potentially be combined with the positive features of another concept and thus it is generally more interesting than a concept which have gotten all 0's. For example, concept P2, which can be seen in Figure 18 or Appendix K, was kept with the ambition of combining it with a telescopic frame.

All five concepts which ended up with a negative score were removed as well as a lot of concepts that scored a zero. The concept FA5 got the result +1 in the matrix but was still removed due to the fastening being considered too weak. Additionally, the concept FA9 was also removed even though it scored a +2 in the matrix. The reason was that it just did not seem possible to make a cushion feel premium enough. The concepts chosen not to continue with can be seen in Appendix J.

15 concepts were chosen for further refinement and evaluation. Additionally three pairs of concepts were chosen for combination. One concept, the reference FL13, was chosen to both be continued with on its own and combined with another concept, FL4. The concepts chosen to continue with can be seen in Appendix K.

During the refinement and combination of concepts, they were described in higher detail and minor calculations and analyses were made. During this stage, problems occurred with a few concepts.

The combination of FL4 and FL 13 was rejected, as was FL8. Additionally, the new version of P2 with a telescopic frame, Figure 23, encountered difficulties when it became obvious that it would not be able to hold the smaller tablets. The rotatable arms would simply move one side's centre piece too far for the telescopic function to work. Since this was required to continue with the concept, it was therefore removed.

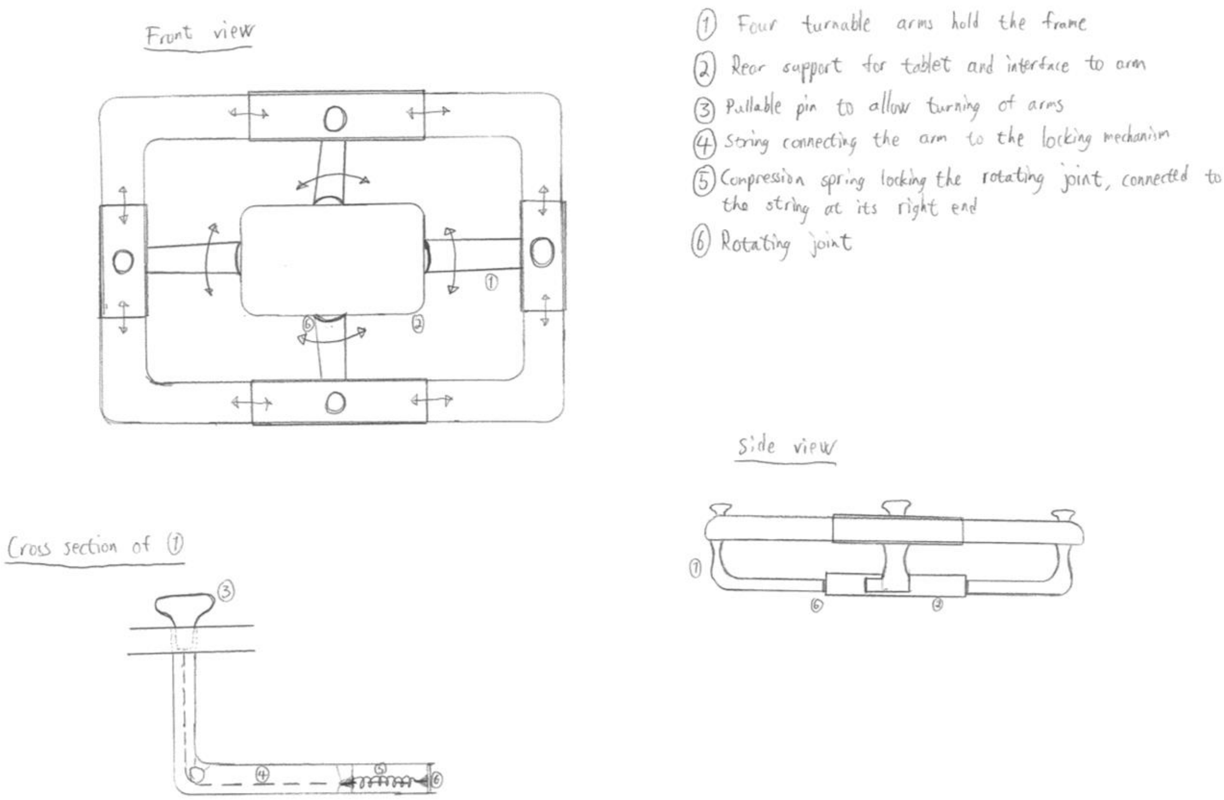


Figure 23 - New version of P2 with telescopic arms

What remained after the screening, refinement and combination was 16 concepts. These had been sketched with higher detail and they were also given new names based on their function and appearance rather than their old categorisations. This was done to make it easier to remember their names. The final 16 concepts can be seen in Appendix L.

4.2.3 Evaluation of technical function

Since there was some uncertainty during the screening regarding how well springs could hold the tablet, some tests were conducted before the first scoring matrix. A test rig was built out of chipboard and wooden strips. The test rig was built to resemble a tablet mount holding the tablet with the force from the springs and a thick metal plate was used as a tablet, see Figure 24. The springs were for shock absorbers for RC cars and these were chosen because they had a dampening effect and a good stiffness. The springs could quite easily be compressed by just the push of a hand, but still had a chance of holding the tablet in place. The rig was tested both with one spring, as in Figure 24, and with two springs.

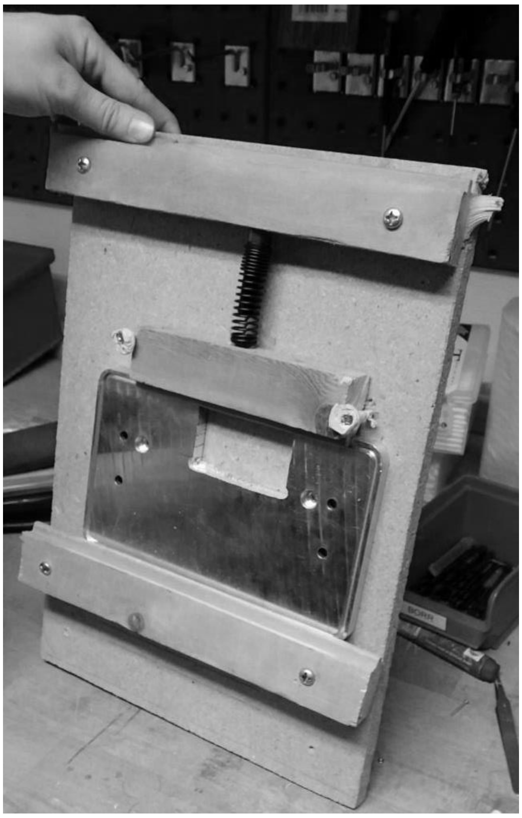


Figure 24 – Test rig for evaluating the holding strength of springs

The test was conducted by dropping the test rig from a height so that it landed on its upper edge, which is the top edge in Figure 24. This way the force from the tablet would press directly at the springs. When dropped from a few meters into asphalt, the test rig was able to hold on to the tablet and based on the results, springs were considered good enough for fastening even though a locking mechanism would most likely be preferred in the event of a crash.

4.2.4 First concept scoring

The first scoring matrix used the same criteria as the screening matrix, see Table 6, except that it did not include the criterion for safety. The reasons for not including the safety aspect, which can seem quite important, were that all concepts at this stage were considered about equally safe. At least the differences were so small that the project group was unable to distinguish between which concepts were safer than others.

The criteria were then weighted compared to each other and this is shown in Table 6.

Table 6 - The criteria for the first scoring matrix

Criteria	Judgement aspects	Weight
Aesthetically appealing	Coherent with Volvo's design, instils quality/safety, good looking	22.00%
Ease of use and flexibility	Intuitiveness, time, simplicity in use, range of flexibility	18.00%
Physical robustness	Strength, fastening strength, structural stability, stability in usage	26.00%
Simplicity	Number of parts, complexity of connections	13.00%
Accessibility to buttons and sockets	Charging, audio, volume buttons, on/off, home button, speakers	21.00%

Robustness was considered most important, due to VCC's high demand on quality. They would simply not put a rickety product in a Volvo car. It is also very important that the product is functional and does not lose that functionality over time. The looks of the tablet mount comes next, again because VCC would not sell a product that is not aesthetically appealing and coherent with their interior design. The third most important aspect was the accessibility. The reason for this is because a customer would be really upset if they bought a flexible tablet mount, that is said to work for all tablets, and then it prevents some of the tablets main functions, potentially making it unusable. The ease of use is still important, but was considered less relevant than the previous three. The least important criterion was the complexity. The reason for this is that as long as the cost of the concept falls within VCC's target cost, it was considered okay. Even if it would be more expensive, that might be justifiable provided the mount is functional, robust and good looking.

The 16 remaining concepts were evaluated and rated in the scoring matrix and this can be seen in Appendix M. As for the screening matrix, each concept was revisited after the scoring to evaluate if they were worth continuing with or not, using the scoring matrix as guidance. Eight concepts were considered too deficient for continuous progress and it was also these eight concepts that got the lowest rating in the scoring matrix.

The eight concepts chosen for further development and evaluation, in order of rating, were:

1. Swatch
2. Ref
3. Cog
4. Modular
5. Lever
6. Flag
7. PBR
8. Side Slot

4.2.5 Presentation of the eight final concepts

The remaining eight concepts were refined with regards to in what areas they scored poor ratings in previous evaluations. All concepts were modelled in Catia V5 which also helped in enlightening more problems with each concept. These flaws and opportunities lead to the concepts being refined even further.

Tablets of different sizes were also modelled and the concept models were tested with the tablets. This lead to one of the major problems that was found at this stage because the tablet mounts would need a larger size range than earlier believed. The reason was that tablet size variations affected the solutions more than expected.

There were still eight concepts after the refinement process and these eight concepts are described in this section.

Concept 1 - Ref
Ref was the concept used as the reference in the screening matrix, it was then refined with some slight changes. The initial Ref had only one diagonal arm, which was then replaced by two arms in an X-shape as can be seen in Figure 25. To only use one arm was not considered robust enough. The supports along the sides are slidable along the frame, so that they can be moved in order to not cover any buttons or sockets. These also connect the front and rear sections of the frame, making it more stable.

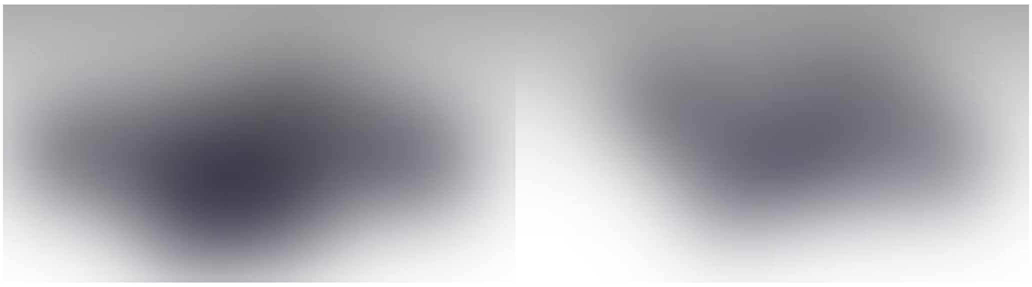


Figure 25 - Ref

To operate the mount, the user pulls two opposing corners to expand the frame so that the tablet can be mounted. The next step is to push the two corners together until the mount stops at the tablet. The concept uses no locking mechanisms, no gears and no springs and was thus considered a very simple concept. At the same time this means that the mount requires two hands to operate.

Key features and drawbacks:

- \+ Simple
- \+ One and the same procedure to mount any tablet
- – Requires two hands to mount and dismount the tablet
- – The arms have to be in two separate planes which makes the mount thicker
- – The mount relies only on friction to lock the tablet in place

Concept 2 - Cog

Cog has similarities in the design with Ref but it is more complex due to additional components, mainly for a gear system. It was decided to evaluate both and see which of the two concepts seemed most promising. The major difference was the gear system in the middle of Cog. The gear system makes all telescopic arms elongate at the same rate, directly dependent of each other. Additional gears also make the dimension ratio changes of one arm affect all other arms such that when for example the top left corner is pulled downwards, the lower right corner moves upwards, retaining the symmetry and making the operation easier for the user. A picture of Cog is shown in Figure 26.

Cog has triangular back plates to strengthen the structure and make the design look solid when the mount is in its minimum state. Just as for Ref, Cog has moveable support on the sides to not cover any buttons and sockets. The concept has no buttons or springs, making it depend on the friction of the joints to hold the tablet in place. On the other hand, this makes the mount simple and intuitive to use.

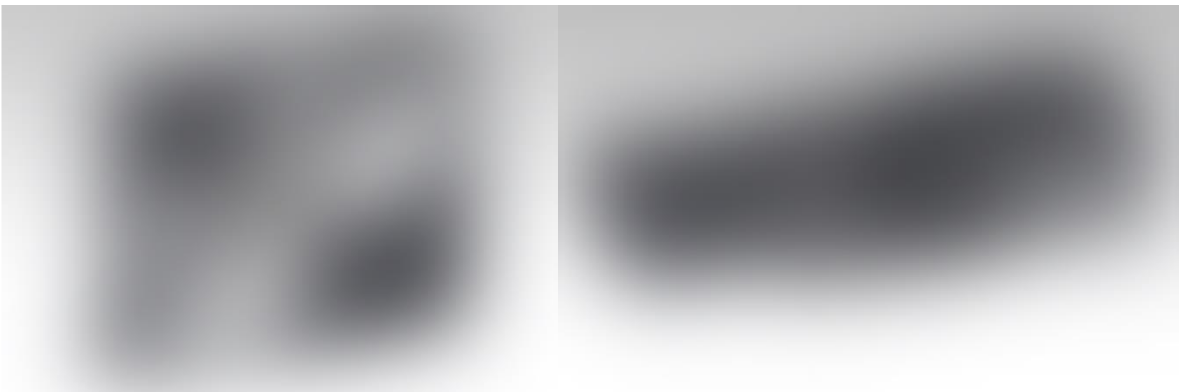


Figure 26 - Cog

To mount a new tablet, the user can simply pull in one corner, thus expanding the entire mount. Pulling that corner upwards or downwards will also change the dimension ratios. The user can the put the tablet in place and push a corner to constrict the mount until it stops at the tablet.

Key features and drawback:

- \+ Intuitive for the user
- \+ Usable with only one hand
- \+ One and the same procedure to mount any tablet
- – Very complex
- – No button that locks the mount
- – Requires fine tolerances, especially the gear-system
- – The arms have to be in two separate planes which makes the mount thicker

Concept 3 - Side Slot
Side Slot, which is shown in Figure 27, was initially inspired by the operation of putting in a VHS cassette into a VHS-player. The simple motion of just pushing the tablet into place without having to adjust the mount every time seemed desirable. The idea of a hatch, as on a VHS-player was quickly deemed as unfeasible though, because it would require a large gap underneath the hatch so that it could spring back to its initial position. Such a gap would make the tablet able to move around in the mount, which would be really bad. So instead of a hatch, a small pin was used, see Figure 28.

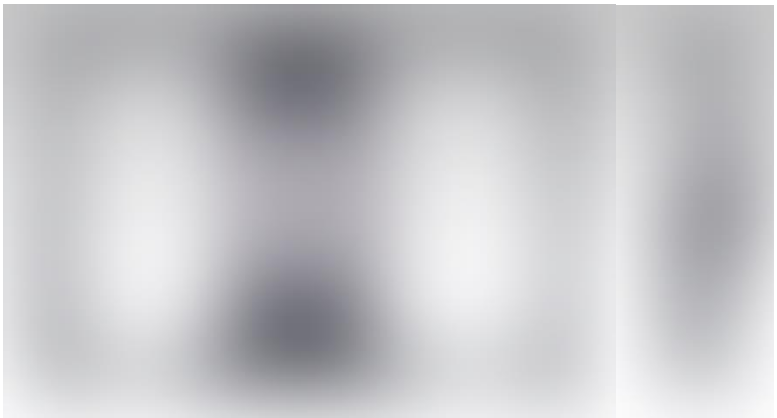


Figure 27 - Side Slot front and side view

The pin has a special triangular shape so the user can just slide the tablet into the mount from the side, pushing down the pin. This is of course provided that the mount is adjusted for the right size. When the tablet should be released, the user pulls down the pin and pulls out the tablet through the side of the mount.

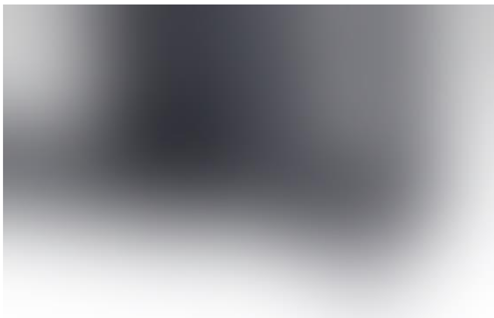


Figure 28 - Side Slot's pin

The previous version of this concept was only attached to the arm from the lower section of the frame. This was considered too weak and thus the concept was instead made so that the frame was connected to the back piece on both long sides. It is still fewer connection points than most of the other concepts though, which gives it a reduced robustness and allows the mount to be asymmetric around its centre point.

The user has to adjust the mount's size only when a new tablet is to be mounted and this is done by pressing the two locking buttons on the frame and then manually pulling the frame to the desired size.

Key features and drawbacks:

+ Easy to mount and dismount the same tablet
+ Mounting the same tablet only requires one hand
+ Only one motion to mount tablet
– Not as easy and intuitive to adjust for new tablets
– Asymmetric
– The structure can be weak when the mount is its largest size

Concept 4 - PBR
PBR is the only semi-flexible solution that made it to the final eight concepts. As can be seen in Figure 29 the concept cannot be adjusted in height. The width is adjustable with the red buttons behind the mount on both sides to maintain symmetry. Having buttons on the back could make the concept less intuitive to use, but is beneficial for its appearance.

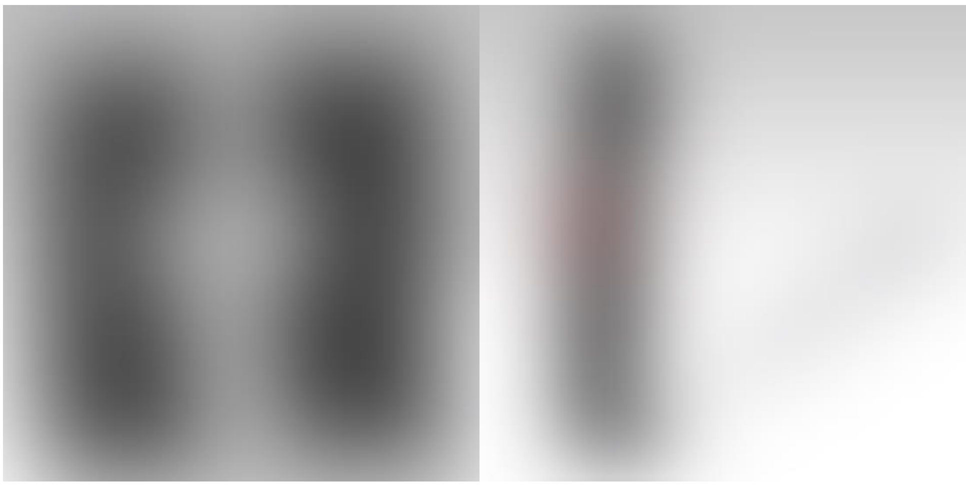


Figure 29 - PBR front and side view

The foldable bracket keeps the tablet in place and was designed as a telescopic frame, making it adjustable so that it can be made to fit any tablet. The bracket is locked in a slot on the back plates. No buttons on the short sides or the upper long side of the tablet are covered since the tablet is kept in place by the bracket's corners. On the lower long side, some buttons or sockets could be covered, yet there are holes through the lower part of the mount which are made to allow access for most common tablets.

One drawback with the concept was the design when holding a small tablet. As can be seen in Figure 30, a large part of the mount is left over the bracket when it is adjusted for a small tablet. Another negative aspect of the design is when a tablet is mounted and used in portrait mode. The concept would then look asymmetric and the vertical support for the tablet might be insufficient.

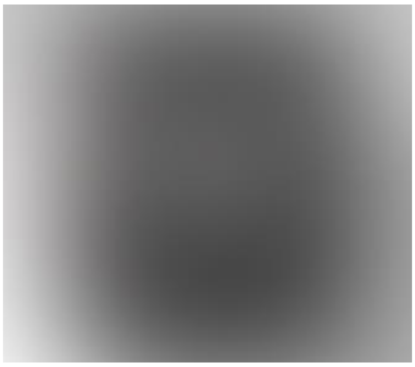


Figure 30 - PBR for small tablets

Key features and drawbacks:

+ Simple
+ Easy to mount and dismount the same tablet
+ Robust back plates
– Primarily designed for large tablets
– Asymmetric
– Not good for portrait mode

Concept 5 - Flag
Flag is based on four back plates that are connected with rods, as can be seen in Figure 31. Each back plate is connected to the next with two rods and the back piece is connected to two of the horizontal rods. The rods are attached to one back plate and slide in slots on the connecting back plate.

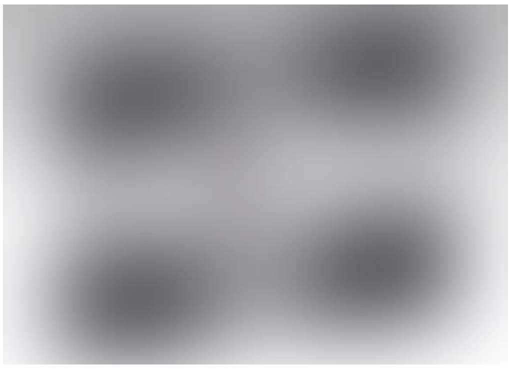


Figure 31 - Flag

To be able to lock the structure, there are buttons on the back of Flag which locks the rods. The buttons can be seen in Figure 32 and pressing them allows the mount to be expanded. Just as for PBR, buttons on the back make the product a little less intuitive but benefits the appearance.

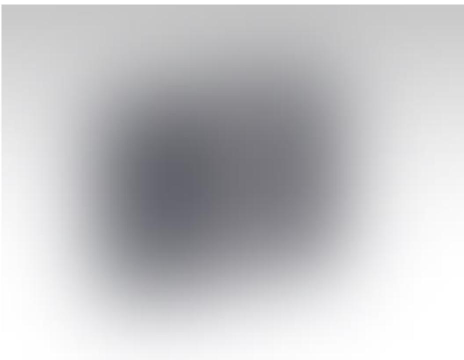


Figure 32 - The back view of Flag

The blocks have holes on the side to not cover the buttons or sockets and the concept is simple with few unique parts. The major negative aspect is the asymmetry which would occur if the user does not pull all sides equally much.

In order to mount a tablet, the user would grab the opposing corners with the buttons, press them and pull the structure apart. The user can then put the tablet in place and push together the structure. Since all joints are either horizontal or vertical, it is also easy to adjust one direction without affecting the other.

Key features and drawbacks**:**

- \+ Simple
- \+ Robust impression
- – Asymmetric
- – Potentially complex locking mechanism
- – Mounting and dismounting requires two hands

Concept 6 - Lever

Lever is a telescopic frame which is connected to the back piece by four arms, forming a cross, and the concept can be seen in Figure 33. Two levers are also connected to the back piece in one end and to a part of the frame in the other. The levers are telescopic and are slidable along a slot in the frame. In the back piece the levers are connected to two separate cog wheels which in turn are connected to gear racks on the arms. When a lever is moved, the mount either constricts or expands, with one lever controlling each direction, height and width. Due to the gears, both sides always move equally much so the structure is always symmetric. The sliding buttons on outer end of the levers lock to the frame structure when they are not being pushed, so that the structure retains its size.

Due to the fact that the arms, levers and gears have to be in two different planes, the structure becomes quite thick, which is of course a negative aspect. Another problem might be that the gear ratio needs to be high so that the levers are able to move the arms from minimum to maximum position with only a small motion. This could be problematic since quite a lot of force would probably be required to move the levers.

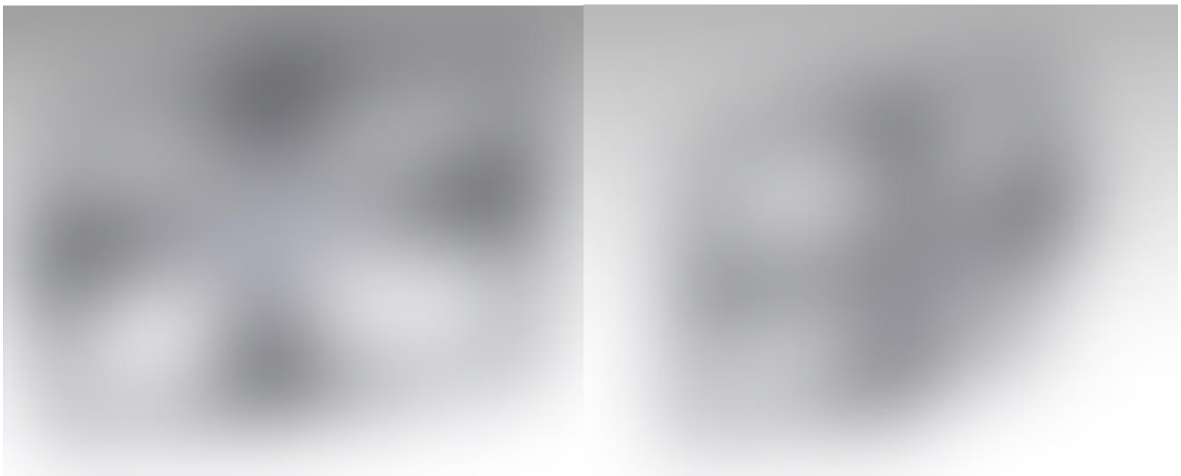


Figure 33 - Lever, front and rear view

Key features and drawbacks:

- \+ Symmetric
- \+ Usable with only one hand
- – Complex gear system
- – Requires high gear ration, will make the movement require quire a lot of force
- – Requires several motions for mounting and dismounting with only one hand
- – Thick back piece

Concept 7 - Modular

Modular handles the flexibility in a different way. According to the user interviews, this can be read about in Report A, many tablet-owners use only one tablet in the car. This concept focuses on those users.

When a small tablet would be mounted, the mount will be used as in Figure 34. From the upper frame, a spring support pushes down towards the middle. This is what holds the tablet in place when it is mounted and no further adjustment is required as long as the user does not switch to a large tablet. To mount the tablet, the user simply pushes one of the tablet's long edges against the spring support so that the other edge passes by the lower part of the frame. The tablet is then mounted.

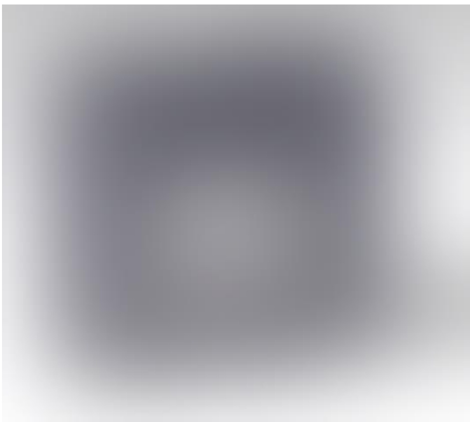


Figure 34 - Modular for small tablets

When adjusting the mount to hold a large tablet instead, the user disconnects it from the rear interface, which is connected to the hole in the middle of the mount, see Figure 34. The user then disconnects the spring support. When the support is disconnected the user can push the small frame towards the back plate until it stops. The large frame has then been pushed out on the other side of the mount. The user then turns the mount around, attaches the spring support and connects the mount to the interface again. The mount would then look as in Figure 35. The action of disconnecting and preparing the mount for a different tablet size will take some time and the concept is thus highly directed towards people only using one size of tablets.

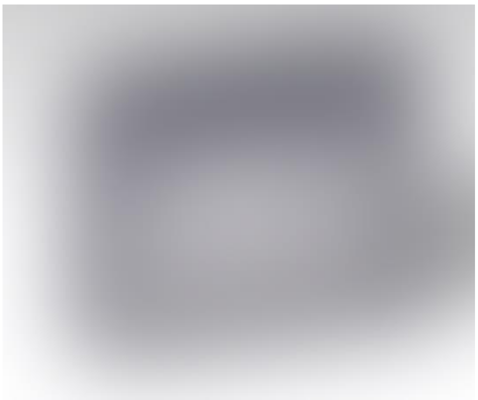


Figure 35 - Modular for large tablets

Key features and drawbacks:

- \+ No adjustments needed to mount and dismount the same tablet
- \+ Very simple
- \+ Usable with only one hand
- – Very difficult to adjust for different tablet sizes
- – The mount is always big, even when using a small tablet
- – There will have to be gaps between the sides of the tablet and the frame
- – Will look very asymmetric in portrait mode
- – Can be difficult to reach buttons and sockets

Concept 8 - Swatch
The frame and arms for Swatch design is similar to that of Lever, with the telescopic frame connected with a cross to the back plate, as can be seen in Figure 36. However, this concept has a completely different functionality.

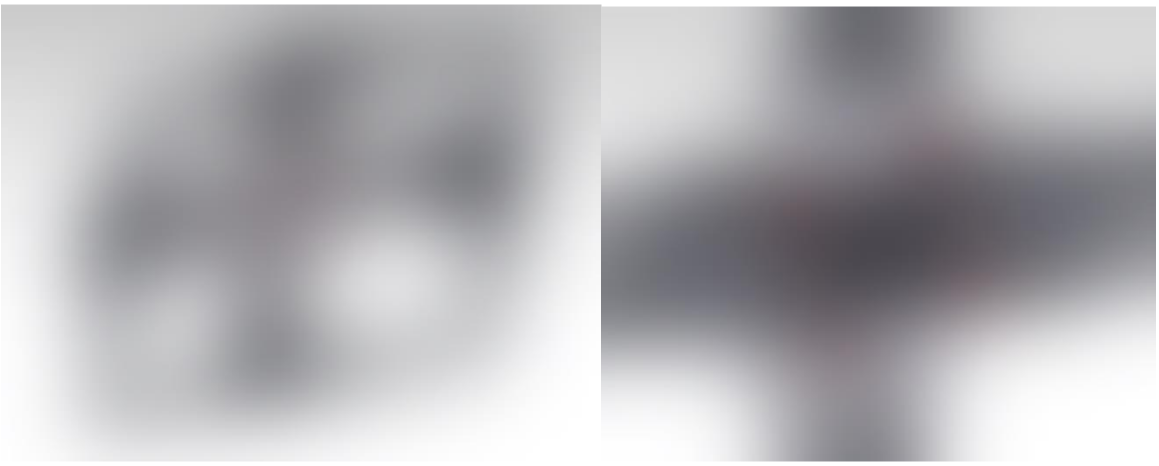


Figure 36 - Swatch front and a detailed view of the buttons

To mount the tablet the user pulls out the sides to a maximum locked size. The red buttons lock the arms in this place until the user puts the tablet there and the buttons are pushed in, see Figure 36. There are springs in the frame and this makes the mount automatically constrict when the user puts the tablet in the mount so that it presses the red buttons.

In order to dismount the tablet, the user pulls out the frame, and when it reaches its outer position the buttons pop up, thus once again locking the frame.

Key features and drawbacks*:*

+ Automatic and innovative mounting
+ One and the same procedure to mount any tablet
+ Usable with only one hand
– Many actions required to pull out the arms
– The mount does not have any locking mechanism, it relies solely on the springs

4.2.6 Second concept scoring

The criteria for the second concept scoring matrix were chosen from the target specifications. These were sorted into groups based on the criteria from the first scoring matrix. The weights for the groups were also kept as they were for the criteria in the first scoring matrix. These weights were then spread out among the sub-criteria as shown in Table 7..

The weights of the sub-criteria were based on the results of the prestudy, especially from the interviews and the benchmarking. Additionally the project group member’s personal opinions played an important role in setting the weights.

Table 7 - The criteria for the second scoring matrix

Criteria	Weight
Aesthetically appealing	**22.00%**
Instils quality	7.00%
Instils safety	4.00%
Design with tablet	5.50%
Design without tablet	5.50%
Ease of use and flexibility	**18.00%**
Time and simplicity to mount / dismount tablet	6.30%
Intuitiveness	1.80%
Range of flexibility	6.30%
Time and simplicity to adjust size between tablets	3.60%
Physical robustness	**26.00%**
Strength	5.20%
Fastening strength	6.50%
Structural stability	7.80%
Stability in usage	6.50%
Simplicity	**13.00%**
Number of parts	3.77%
Number of unique parts	4.42%
Complexity of connections	2.86%
Has as simple shapes as possible	1.95%
Accessibility for buttons and sockets	**21.00%**
Charging	2.94%
Audio jack	3.36%
Volume buttons	2.31%
On/off	4.20%
Home button	5.04%
Speakers	0.42%
Mic	1.68%
Front camera	1.05%

The eight concepts were rated for all criteria in the second scoring matrix, as can be seen in Appendix N. The result with the scores was:

1. Modular - 3.473
2. Swatch - 3.401
3. Flag - 3.345
4. Cog - 3.300
5. PBR - 3.218
6. Lever - 3.129
7. Ref - 3.123
8. Side Slot - 3.092

Based on the results, the group discussed each of the concepts thoroughly, weighing positive and negative aspects as well as potential areas for improvement.

The first decision made stood between Ref and Cog. These two concepts were considered to be too similar to continue with both. The major difference is that Cog, if working as intended, is significantly easier to use while Ref has a much lower level of complexity. Since the gear system also makes all Cog’s corners move dependently, it also has a lower risk of mechanical failure for the frame. On the other hand, the risk for mechanical failures in the gears and the gear racks are instead an issue. Since simplicity in design was considered less important than ease of use, the decision fell in Cog’s favour, thus eliminating Ref.

Modular got the highest rating in the scoring matrix due to its high level of simplicity and robustness. The same also applies to PBR, although to a lesser extent. Modular’s major drawback was when changing from a large tablet to a small, or vice versa. To have to disconnect, readjust, turn and then connect the mount in order to switch to another tablet was seen as a major drawback. The visual aspect was also a drawback, as were the fact that there is nothing holding the tablet from moving from side to side in the mount.

PBR’s drawbacks were similar to those for Modular. The major drawback here though, was when a small tablet was mounted, in which case PBR would look as in Figure 30. There were ideas of how to solve this issue, such as using modular parts for the back plates. This got rejected however since the user would need many operations to switch between sizes and also because loose parts can easily be misplaced and lost.

The problem for Modular and PBR was that no solution seemed possible to improve their weaknesses. It would be too difficult to make them feel like premium products suited for a Volvo car. Therefore it was decided not to continue with any of the two, even though they, especially Modular, got good ratings in the scoring matrix.

The five remaining concepts had drawbacks as well, but the drawbacks seemed fixable and more analysis and technical calculations were required to verify them.

Side Slot had a unique mounting which seemed interesting and was considered to need further evaluation. Much of its poor ratings came from the robustness which mainly depended on its connection between the frame and the back piece, which was easy to solve.

Swatch had its innovative mounting as a major strength and got overall high scores in the scoring matrix. Springs had already been tested for holding the tablet in place, but the tests were not thorough enough and further evaluation was needed.

Cog had an even larger problem when it came to holding the tablet in place, since it relied only on the friction of its joints. Some kind of locking mechanism was very likely to be required and this should be further analysed.

The issue with Lever was the high gear ratio that would be required. This could make the lever really tough to move, which seemed problematic and were to be investigated.

Flag was considered the simplest concept to make it into the final five, since it had no gears or springs. The issue with Flag was the fact that it can be made asymmetrical in relation to the back piece. The structure could, to a small extent, move freely in its own plane, which was what causes the problems.

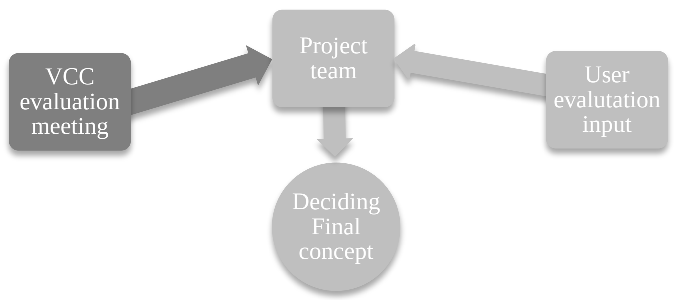
As a summary, all remaining concepts had some great features, but also some drawbacks. All issues did not have a solution at this stage but the important part was that they had potential to fulfil the target specifications. The final five concepts were thus:

- Cog
- Flag
- Lever
- Side Slot
- Swatch

4.2.7 Final evaluation

The final evaluation of the remaining concepts consisted of three parts:

- The VCC evaluation meeting
- The user feedback
- The project group's final evaluation



VCC evaluation meeting

VCC's overall impression of the concepts seemed good and the project's coverage of the solution space was considered impressive. Some feedback was given for each concept, as well as some final recommendations:

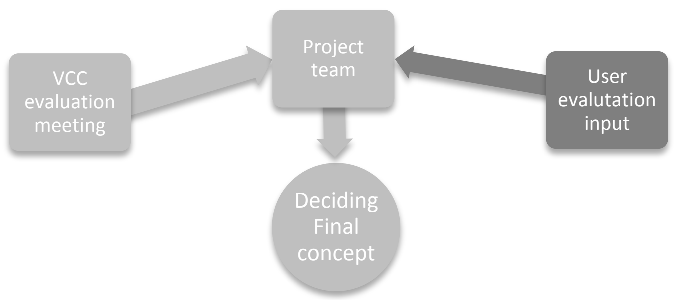
- Cog – Great concept, also similar to concepts VCC had already been researching, even though their idea only had one diagonal arm instead of an X-shape. However the concept would need very fine tolerances for the gear system and for all the movable parts to work, which will be costly. It would also require some kind of locking mechanism to be able to hold the tablet in the event of a crash. Great concept when it comes to mounting and dismounting the tablet. It was also considered to look good in it smallest position without a tablet and the mount should always be in this state when no tablet is mounted.
- Flag – Looks robust and it was the only concept they could directly say that it was feasible to produce. It was also considered less costly than the other concepts. Could be a little awkward for the user to mount and dismount the tablet.
- Lever – The lever function could be a great locking mechanism with the sliding buttons, rather than a mean to change the size of the mount. The gear ratio will most likely be very high, which will make it difficult to adjust the mount.

- Side Slot – Really liked the idea of the mounting and dismounting of the same tablet. It was also great that the user will not need to adjust the frame every time when using the same tablet. The frame looked a little weak in its outer position however and the adjustment for different tablets would need to be more intuitive.
- Swatch – they liked the innovative, automatic mounting. However, the mount would need some kind of locking mechanism because springs will most likely not be enough to hold the tablet in the event of a crash. They would also prefer if the buttons were moved to the frame instead of their current position on the back plate. Additionally it would be great if the springs could be used to constrict the mount to its smallest position when no tablet is mounted.

VCC also had some general points that should be considered:

- The tablet mount should constrict itself to its smallest state when no tablet is mounted. A mount in its outer state, with no tablet mounted, will most likely break in a head collision which could be dangerous to the passenger.
- It is great if the user does not have to readjust the tablet mount every time when using the same tablet.
- The tablet mount must be intuitive to use. It is important to minimize any chances the user has to make mistakes when operating the tablet mount.

When asked for a recommendation on which concept or concepts to choose, VCC suggested a combination of Swatch and Lever. They wanted Swatch's mounting feature together with its striving to always be in its inner position. At the same time they wanted it to lock in the outer position and when it holds the tablet. For this purpose they suggested Lever's lever as a mean of locking the tablet mount.



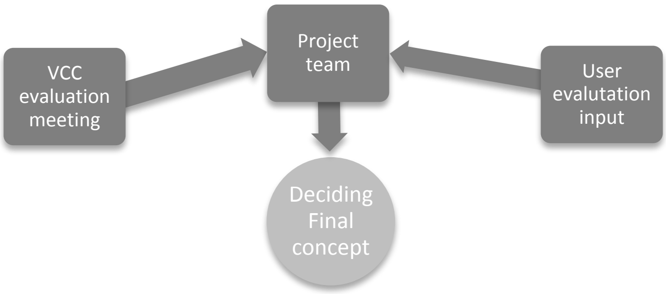
User feedback

A video was created explaining the final five concepts. This was shown to potential users and they were asked to answer the following questions based on their impression of the concepts:

- Rate the concepts based on exclusiveness.
- Which concept seems easiest to use?
- Which concept seems safest?
- Which concept would best fit in a Volvo?

There was no clear winner for the overall feedback. Cog was considered the most exclusive, closely followed by Swatch. Side Slot scored a close victory over Swatch and Cog when it came to ease of use. When it came to safety, a vast majority chose Flag and in when it came to which mount would best fit into a Volvo car, Cog won with Flag as a close second. The only concept that really stood out from the rest was Lever which had consistently low scores.

More information about the user feedback can be seen in Report A.



Final selection
Based on the feedback from VCC and the potential users the project group would now make a final decision. All concepts and all possible combinations were thoroughly evaluated and discussed. VCC's desire for the tablet mount to constrict to its minimal size when no tablet is mounted weighed in heavily in the evaluation. In addition to keeping some concepts as they were, seven alternatives were up for discussion as potential final concepts:

- Cog with tensional springs, as in Swatch, and a button in one corner, locking the structure. The springs' purpose would be to always constrict the mount to its inner position when no tablet is mounted.
- Cog with a button in one corner, locking the structure.
- Swatch combined with Lever. Using the lever to lock the structure, not to change dimensions. This was VCC's recommendation.
- Flag combined with Swatch. The Flag, but with tensional springs constricting the structure, making it go to its inner position when no tablet is mounted.
- Side Slot but with a cross of arms, making it more robust.
- Side slot with Swatch. To use the tensional springs from Swatch, but only in the horizontal direction when the mount is set in landscape mode. This constricts two sides to their inner position when no tablet is mounted, but still does not need readjusting each time when using the same tablet.
- Flag but with cross-shaped rear arms, which always cover the gaps between the four plates. It would still be a simple concept, and the user would not be able to see through it.

The positive aspects and drawbacks of each alternative concept were considered. The project group finally decided to choose Cog with tensional springs and a button for the final concept. If that concept would work as intended, it would be the simplest to use at the same time as it would be very intuitive. Additionally the looks of the design was highly appreciated in the user feedback. One issue though is that the concept is very complex and there are still some uncertainties. Due to this, a second concept was also chosen as a back-up, if too many problems would occur with the chosen concept.

The back-up concept was the new version of Side Slot, using tensional springs for the horizontal constriction. This was still not a very simple concept, but still considered feasible and it did not have as many uncertainties as Cog. The really simple concepts generally had too many drawbacks and were therefore rejected.

After this phase, the project moves on to the detailed design phase. The concept will then be further developed in higher detail and Cog will be the main priority.

5 Detailed design

In the detailed design, the final concept, and potentially the back-up concept, was to be designed with higher detail and the majority of this phase was spent working in Catia V5. The design of the final concept is described in section 5.1 and the design of the back-up concept is presented in section 5.2. The next step was to analyse the structure for variation robustness and tolerances, which is presented in section 5.3. The last step of the detailed design was the choice of material, which is covered in section 0. The process did however not consist of these three steps in sequence, but was instead an iterative process. The strength and safety analyses were also very important aspects for the detailed design and those are covered in Report C.

To facilitate the explanation of the models and analyses made in this section, a coordinate system as in Figure 37 was used. This also means that unless otherwise stated, the tablet will be in landscape mode and directions such as left or right, top or bottom and front or rear will be based on this default position.

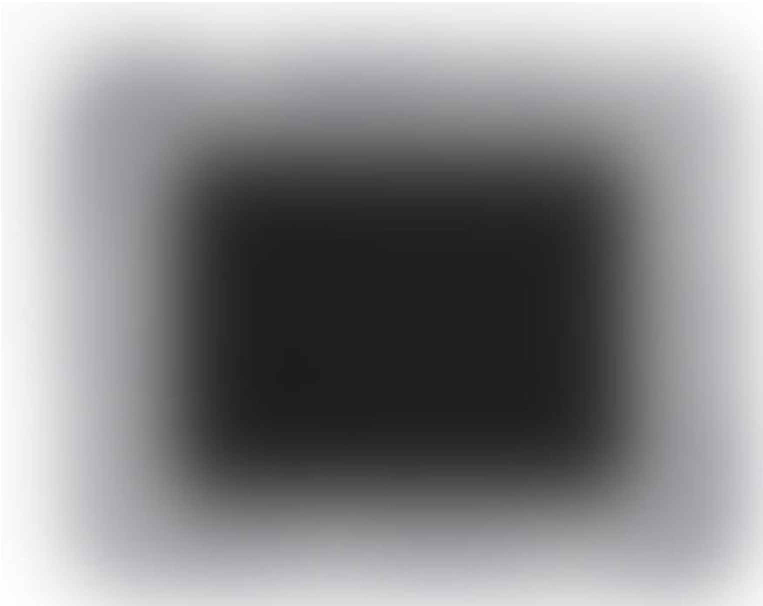


Figure 37 - Explanation of the coordinate system

5.1 Design of Cog

One objective of the detailed design phase was to produce a physical prototype. All parts for the prototype were to be 3D-printed, even the gears, and thus had to be designed accordingly. The 3D-printer was said to require gaps of 0.2 mm between adjacent components in order for the joints to function. The model was then designed so that the gaps between each component, such as the telescopic joints, had this value. The only exception was the gear system which was designed with a larger gap in order work with less friction.

5.1.1 Functionality for the user

User friendliness is very important in the final concept, while still covering all safety requirements. Thus, the final concept will be operable with only one hand. The user grabs one corner and pulls it out which makes the entire structure expand. By pulling that corner up or down, the user can also easily change the dimension ratios for the mount, for example to switch between a 16:9 and a 4:3 tablet.

Springs in the frame automatically constricts the mount, so that when no tablet is mounted it returns to its minimum state. There is also a button, strategically placed at one of the corners, which when not pressed, prevents the mount from expanding. The mount would still be able to constrict even when the button is not pressed.

5.1.2 The design

Cog was first designed as in Figure 38, with the four arms connecting to the arm, forming an X.

Figure 38 - The first detailed design of Cog

The frame consisted of four major parts, where the opposing corner parts were identical. The frame parts have a front frame, which had the purpose of covering the tablet’s edges from the user in the event of a crash. The rear frame is there to add further stability to the mount. Two of the frame parts are smaller than the other two, fitting into them and thus creating telescopic joints. They are thus called outer and inner frame parts.

The outer frame parts have triangular plates spanning from the corner and along the rear frame. Its purpose is to add additional stability, but also to make the product look more robust and to give a solid impression when the mount is in its minimum state, as can be seen in Figure 39. The rear frame section also contains the springs which constrict the mount, see Figure 40.

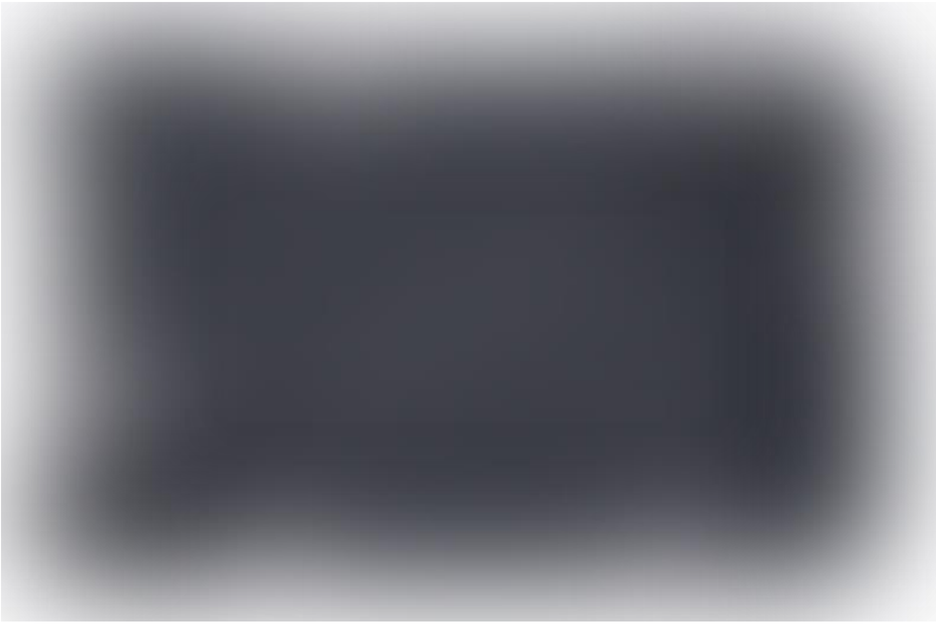


Figure 39 - Cog in its minimum state

Figure 40 - The springs located in the rear frame parts on Cog

Six supports are located along the frame of Cog and they are slidable so that they will not cover any buttons or sockets. There are two supports on the long sides and one on the short sides and they also help in stabilising the frame. The supports are limited to movement along the frame of the larger frame parts. There is a small block at the end of the large frame parts which prevent them from going off onto the smaller frame parts. The supports can be more clearly seen in Figure 41.

Both the supports and the corners are slightly curved inwards. This is due to the fact that tablets vary in thickness. With this shape the tablet will always be in contact with both the supports, keeping the tablet from falling out, and with the triangular back plates. This is visualised in Figure 42.

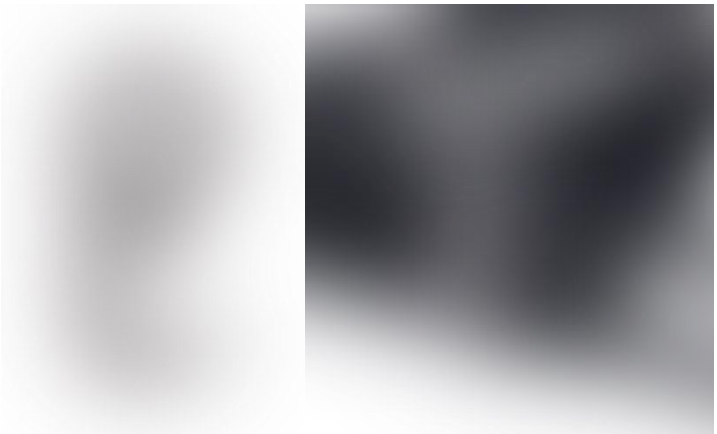


Figure 41 - The supports along the frame on Cog

Figure 42 - The curve on the supports and corners

The centre parts holding the frame can be seen in Figure 43. They contain the gear system which makes all arms extend and retract directly dependant of each other. At the back of the rear back piece is the connection to VCC’s interface. A screw connects the mount to the interface, and the shaft of that screw is used as the axis for the cog wheel. The screw head is hidden under a small cap at the front back piece.

Figure 43 - The arms and the back piece of Cog

The naming of some of the parts can be seen in Figure 44. Additionally, the large cap covering the entire rear back piece is called the front back piece. The rack arms are connected to the frame corners with bolts through the holes at the end of the rack arms.

At the end of the middle arms there are small blocks which fit into the slots on the rack arms. These blocks prevent the rack arms from being pulled too far in any direction, thus limiting the maximum size of the mount. The protruding tabs on the sides of the middle arms were initially intended only to make the physical prototype easier to assemble but were then kept in the model to facilitate assembly.

Figure 44 - 1: Rack arm, 2: Middle arm, 3: Rear back piece, 4: Gear rack, 5: Cog wheel

The cog wheel in the middle of the back piece was made as an involute gear and it also had to fit together with the gear rack. The gears were designed as spur gears instead of helical, both because it would be simpler to model but also to avoid the axial forces from helical gears.

The gear would have to be small to fit in the back piece. Thus a gear module of one was chosen and the number of cogs was set to 18. The gear system can be seen in Figure 44.

An additional gear system with a cog wheel and two curved gear racks were used to control the change of dimension ratios for the mount. This would work so that when one arm was pulled down, the other arm on that side would be pulled up equally much so that the mount always keeps its symmetry. It would also make the dimension ratio changeable with the use of only one hand. These gears were never implemented in the model but the sketches of the idea can be seen in Figure 45.

Figure 45 - A sketch of the gear system for Cog

For Cog to fulfil the legal requirements it must retain the tablet in the event of a crash. In order to do this, it was deemed necessary to have some kind of locking mechanism. A button was to be placed in one of the corners, allowing the user to press the button and operate the mount with the same hand. The locking mechanism was to have a ratchet-function so that it could still constrict even though the button was not pressed, but it would not be able to expand.

Several concepts for a button were generated but unfortunately, none of them seemed robust and feasible enough. Therefore the concept is presented without any button, yet with the intention to implement one.

5.1.3 Improvements

Some problems emerged during the design of Cog. The major problems were regarding how thick it would have to be. The arms in two different planes together with the double frame resulted in a mount that was 77.2 mm thick from the front of the frame to the rear of the back piece. That is ten times the thickness of many of today’s tablets. Add to that the thickness of VCC’s interface and the mount would protrude quite a lot. This was not considered acceptable and would therefore have to be improved.

Some material was removed, especially from the back piece which was unnecessarily thick, and the thickness of the mount was reduced to 72,2. This version of the mount can be seen in Figure 46 and was still considered to be too thick.

Figure 46 - Side view of Cog, which was deemed too thick. Front of mount to the right.

The next step in order to reduce the thickness was to make the front frame smaller. The requirement of a minimum radius of 5 mm only applies to areas a head can hit in the event of a crash and thus the frame could be redesigned.

The thickness of the mount with a thinner frame was 66.9 mm which was an improvement of more than 10 mm from the original design. However, it still looked very thick and the two layers of arms was the main cause of the problem. During the concept evaluation phase, see section 4.2, the concept had gained point for its robustness due to the fact that it had to arms and at the same time some concepts with only one arm had been upgraded to instead have two arms because one arm was deemed too weak.

However, when presenting the five finalist concepts to VCC, they said that they had looked into a concept similar to Cog, but with only one arm. The fact that VCC had considered one arm strong enough made the project group change its mind in that matter. Cog was therefore redesigned at this stage so that it would instead only have one arm. The large triangular plates now became even more important in order to stabilise the structure. The one-armed version of Cog can be seen in Figure 47. With only one arm, the distance from the rear of the back piece to the front of the frame became 53.8 mm. This was considered acceptable, especially when the frame accounted for the majority of the thickness with its 34.6 mm.

Having only one arm also meant that the complexity of the product was lowered, especially since this removed the need for the curved gear racks shown in Figure 45. Since the product was already considered very complex, this was definitely a welcome improvement in that aspect.

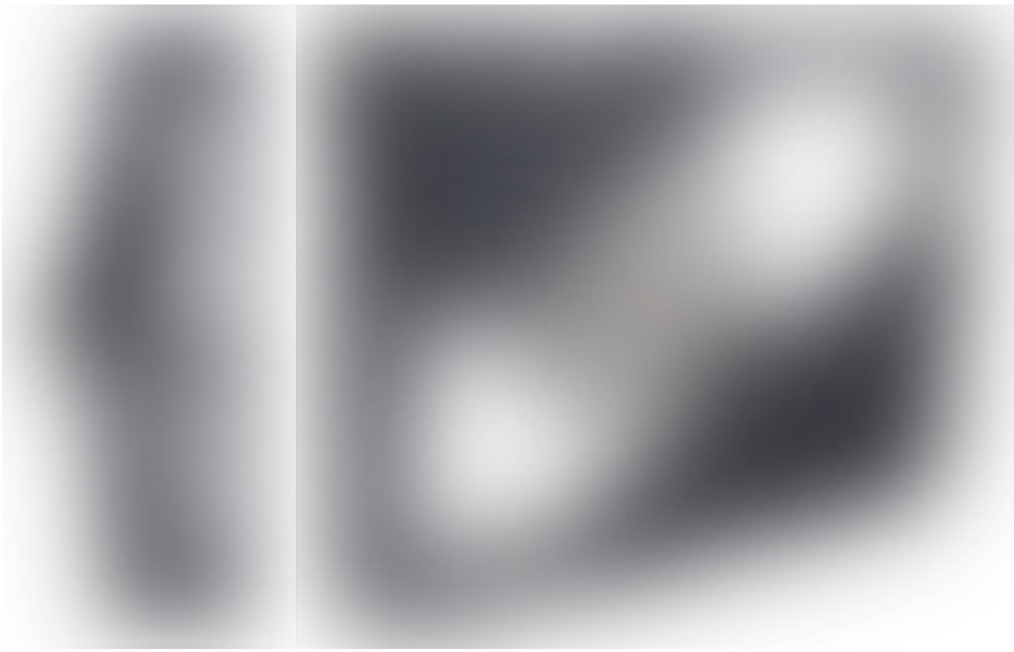


Figure 47 - The one-armed version of Cog

From the tolerance analyses, see section 5.3.1, it became apparent that some changes had to be made. Thus, the distance between the middle arm and the cog wheel was expanded. Additionally, the gaps in all telescopic joints were slightly increased.

When the safety analyses were finished, it became obvious that the frame supports were too weak. In the analyses, the head collided with the mount, which of course is one of the more severe scenarios. Still, the supports were not close to holding together, which can be seen in Figure 48. This was not a problem in that certain collision case, yet it could be a problem in different situations, potentially making the tablet able to slip out of the mount. In order to make the structure more stable and predictable, the frame supports would have to be strengthened. More information about the safety analyses can be read in Report C.

The frame supports were thickened by an additional 4 mm but there was unfortunately no time left for more analyses. An additional improvement would have to be attached to the lower frame section. This was not implemented in the model but could be done by adding a slot to the frame which could hold on to a pin to the frame supports.

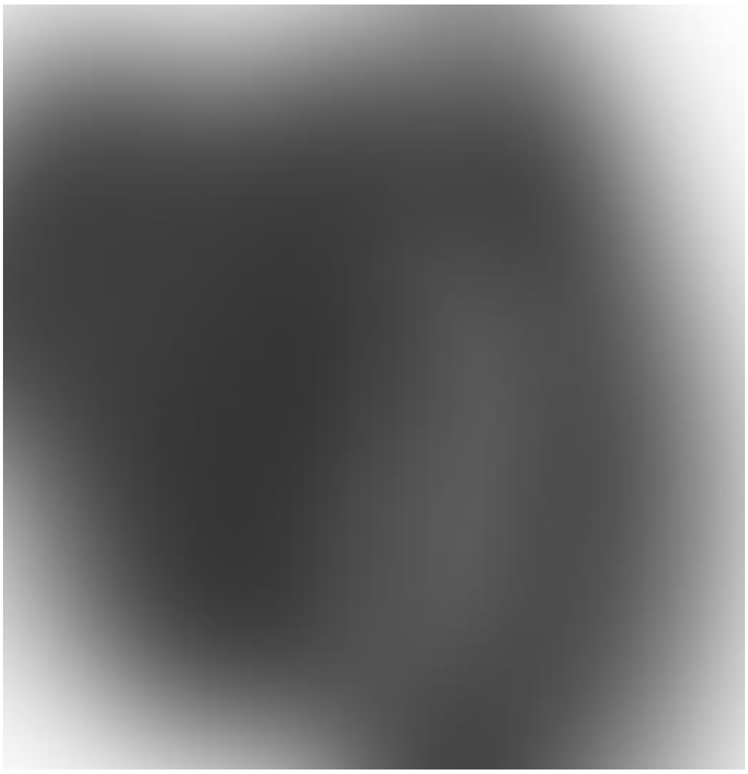


Figure 48 - Image from the safety analysis with a head collision from Report C

5.1.4 Producibility

The producibility of the product was divided into two sections: manufacturing and assembly.

Manufacturing

The assumption from the start was that most parts would be made out of some sort of plastic, most likely a thermoplastic. The exception was the gear rack and the cog wheel as well as all screws, bolts and nuts.

The first idea was that all parts would be injection moulded, since it is a common process for producing plastic parts of more complex geometries. Two other processes were also identified as potential candidates: plastic extrusion and compression moulding.

A meeting was held with professor Antal Boldizard, expert on polymers and composites. He was shown images of the components and asked how they could be produced, he also gave estimations for tooling costs. For the frame parts, which are the most complex parts of the product, he confirmed that they could be injection moulded. It would however require a very complex and costly tool. As an alternative, only the corner piece of the frame could be injection moulded while the frame parts themselves could be extruded. The tool for only the corner piece would then be much cheaper, although the product would require more time for assembly. The tooling cost for the extrusion would be negligible in comparison to that of the injection moulding.

The recommendation for the frame parts are thus to either manufacture them as whole components using injection moulding or to injection mould the corner piece and then manufacture the frame components with plastic extrusion. The frame sections have a good cross section in order to be easily extruded (22) but to be able to make a decision of which process is preferable one would have to further investigate the costs of the alternatives.

The supports on the frame are quite small and there are also six of them for each product, this could make them viable for injection moulding as well. Due to their shape, they could also be made with extrusion as a long tube and then cut into the right size.

In the current model, the rack arm and the gear rack are combined into one part. However, the gear rack would probably have to be made out of another material than the rack arm due to its higher requirements on durability and tolerances. Therefore the two parts would probably have to be separated since it seemed unnecessary to make the entire rack arm in a potentially more expensive material as well. The gear rack would most likely have to be manufactured out of a very wear resistant plastic or a metal. The rack arm cannot be made by extrusion or with compression moulding, due to the two holes where the rack arms enter and should thus be injection moulded.

The manufacturing of the gear rack and the cog wheel will not be investigated. Nor will the manufacturing of screws, nuts and bolts.

The middle arms have a quite simple shape and could be compression moulded. According to CES, compression moulding is generally cheaper than injection moulding (12). However, if there would be reasons to use the same manufacturing process for as many parts as possible, they could also be injection moulded.

The rear back piece has a quite complex shape due to the connection to VCC's interface. It thus has to be injection moulded. The front back piece and the little cap on the other hand have simple shapes and can be made either through compression moulding or injection moulding.

All parts that are to be injection moulded or compression moulded should have draft angles in order to be able to be easily extracted them from the moulds (23). The middle arms already have a shape that makes additional draft angles unnecessary. It is also possible that the rack arms would not need additional draft angles. If the frame parts are to be injection moulded as a whole, they would require draft angles though and these were not included in the model.

Assembly

The centre pieces, with the arms and the back piece could be assembled in parallel with the frame and it is then easy to attach the frame to the arms using bolts.

The back piece is attached to VCC's interface with a screw that goes through both the rear and the front back piece.

A simple walk through for the assembly can be seen in Appendix O. This of course does not include the locking mechanisms since they are yet to be developed. It also does not show the connection to VCC's interface.

5.1.5 Prototype

The concept, as it was in Figure 47, was 3D-printed at Chalmers. The physical prototype was to be used in order to test the functionality of the mount and as a visual representation. All parts were created except the supports along the frame, which were considered irrelevant for the purposes of the prototyped.

Many problems occurred with the prototype. The gaps in the joints were insufficient, thus making the mount difficult to assemble and almost impossible to use without first thoroughly grinding and polishing the parts. Additionally, some of the parts were difficult to create with a 3D-printer, such as the frame parts. The holes in the frame had to be filled with support material and some of the frames were bent and spoiled during manufacturing. This made the process of prototyping take much longer time than expected and the prototype could not be used as much as desired.

The prototype could however at least verify that all buttons and sockets were easily reachable.

More information about the prototype can be found in Report A.

5.1.6 Problems with the concept

During the later stages of de modelling of Cog, it became apparent that the frame can be rotated without around the two connections to the rack arms. By changing the dimension ratios for the frame, it can also be rotated about the Z-axis. This was not a problem for the two-armed version of Cog, and the problem was not detected when the decision was made to remove one of the arms. The problem is visualised in Figure 49, the back piece has the same position in all three images. Due to the changes in dimension ratio required for the unwanted motion, it cannot occur when a tablet is mounted but it was still considered a major problem.

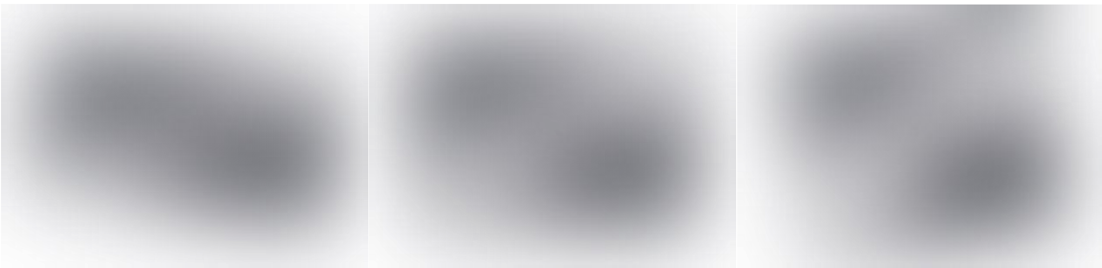


Figure 49 - One of the problems with Cog, that the frame can be rotated

There was another flaw with the concept as well, which was realised through the prototype. The problem was that there would be a play between the middle arms and the back piece. This play had to be there in order to change the dimension ratios of the mount, but it also meant that the mount could be rotated around the Z-axis within certain small limits. The problem can be seen in Figure 50, the centre piece has the same position in both images. This play could not occur on the two-armed version of Cog but once again, the problem was not detected upon making the decision to remove one of the arms.

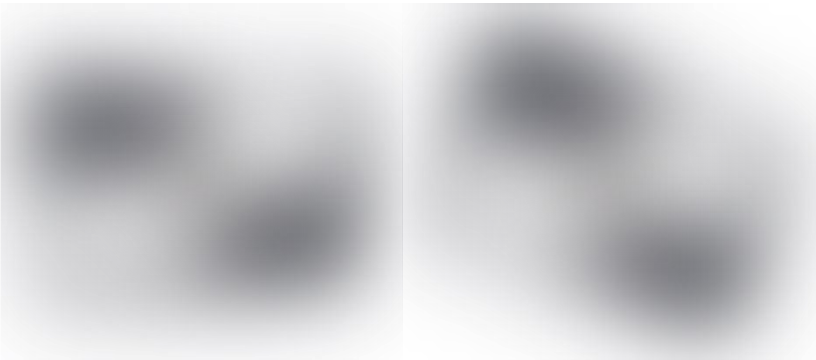


Figure 50 - The other frame-rotation problem with Cog

This play would make the product not feel premium at all and meant that the concept had to be redesigned in order to fix the problem. Going back to two arms could be an option, but since it would make the mount too thick again, it was not considered viable.

The solution would have to be some kind of mechanism locking the middle arm to the back piece. It could either be a setting the user would have to do on the back piece, possibly with different modes such as: 16:9, 16:10, 4:3 etc. It could also be a button or a switch the user has to push in order to be able to readjust the ratio, which then locks again to prevent the play.

These solutions to the problem would however make the concept less user friendly and it would remove many of the positive aspects of the concept, such as the one-handed mounting, the intuitiveness etc. Therefore it was decided to start working on the back-up concept, Side Slot. The idea was to present both Cog, with the need for additional functionality, and Side Slot, thus letting VCC decide which of them they preferred.

5.2 Design of Side Slot

The design of the back-up concept Side Slot started when the problems with Cog emerged, as described in section 5.1.6.

As for Cog, Side Slot was designed with gaps of 0.2 mm between components in joints.

5.2.1 Functionality for the user

Side Slot is mainly adapted for people who will generally use the same tablet each time in the car. The first time the user mounts a tablet, he or she pushes the button on the right side of the frame and pulls down the lower part of the back piece far enough so that his or her tablet fits vertically. The user then pulls the frame apart horizontally and puts the tablet in place. The lower back piece is then pushed upwards until the tablet stops to the frame.

The left and right frames automatically constrict horizontally due to tensional springs. Both sides also move directly dependent of each other. When the user wants to dismount the tablet, he or she opens one of the side supports and pulls out the tablet. This action will also be aided by the springs. The springs then constrict the left and right parts of the frame to their inner state, leaving the vertical position as it was.

To mount the same tablet again later, the user simply lifts one of the side supports and pushes in the tablet, forcing the springs to extend. When the tablet is in place the side support is then pushed down again so that it locks.

5.2.2 The design

Side Slot was designed as in Figure 51 with the frame connected to the back pieces at the top and bottom.

Figure 51 - The detailed design of Side Slot

The frame consists of six unique parts. As for Cog, there is a front frame and a rear frame, where the rear frame’s purpose mainly is to aid as a support when the user mounts the tablet, to stabilise the structure and to make the side supports more rigid in order to hold the tablet in place. The telescopic joints in the frame and between the back pieces enable the structure to be expanded and constricted to the desired size.

When a tablet is mounted it will be in contact with the upper back piece. The connection to VCC’s interface is also located at the back of the upper back piece. Due to safety reasons, the upper back piece was used to connect the mount to VCC’s interface. In the event of a crash, the force from the tablet will mainly be pushing at the upper back piece and its frame section. If this is a rigid part, connected directly to VCC’s interface, there is a much larger chance that it will hold compared to if the force was applied to a part held with a locking button and a telescopic joint. Due to the fact that the connection point is at the upper back piece, the mount will not be vertically symmetrical.

The naming of the components can be seen in Figure 52.

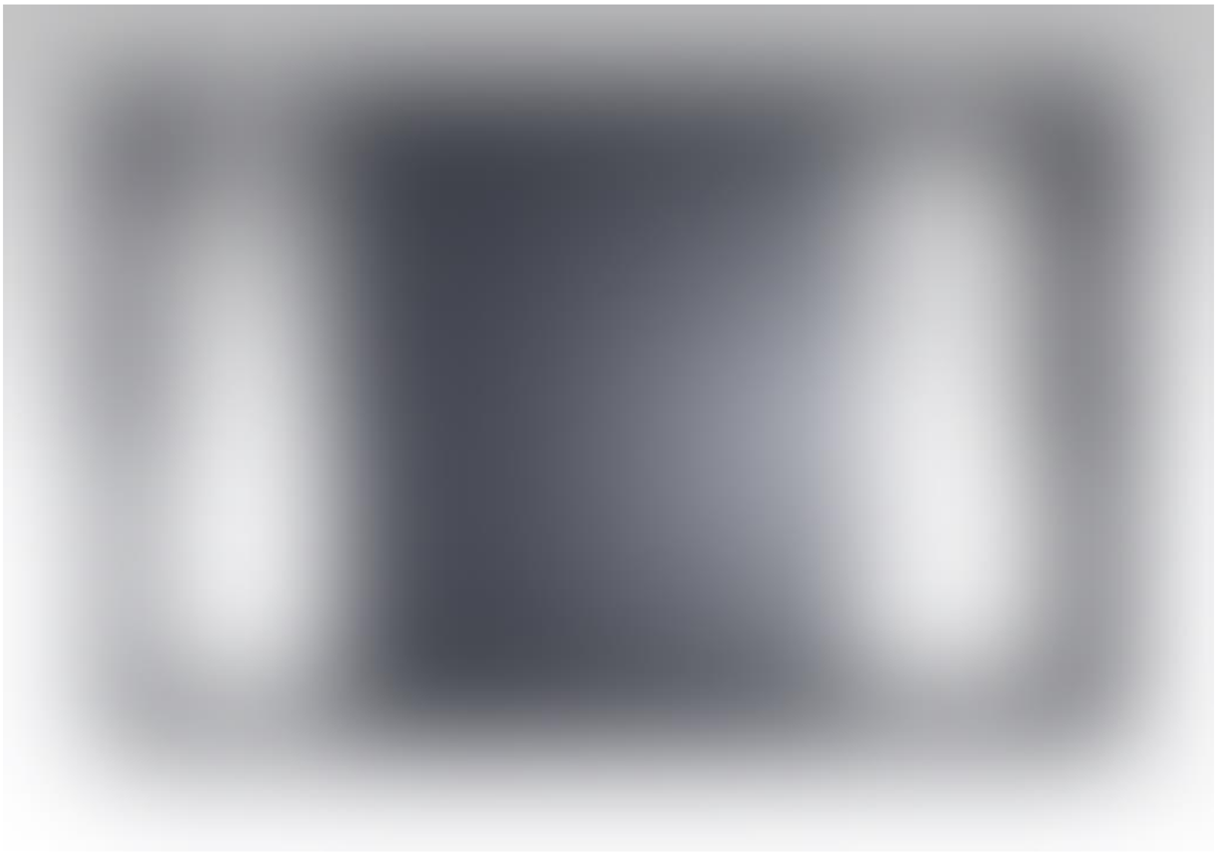


Figure 52 - 1: Upper back piece, 2: Lower back piece, 3: Upper left frame, 4: Upper right frame, 5: Lower left frame, 6: Lower right frame, 7: Locking support, 8: Gear rack, 9: Spring

As can be seen in the figures, there are springs and gear racks extending from the upper back piece to the upper back piece. The gear racks are connected to a cog wheel inside the upper back piece so that the right and left frame parts move dependently of each other. This way the mount is always horizontally symmetric. See Figure 53 for a location of the cog wheel.

The gear racks and the cog wheel have a module of one and the cog wheel is an involute gear with 18 teeth, giving it an outer diameter of 20 mm, just as for Cog.

The tensional springs, number 9 in Figure 52, are there to always constrict the mount to its minimum size or to the edge of a mounted tablet. When no tablet is mounted, it thus looks as in Figure 54.

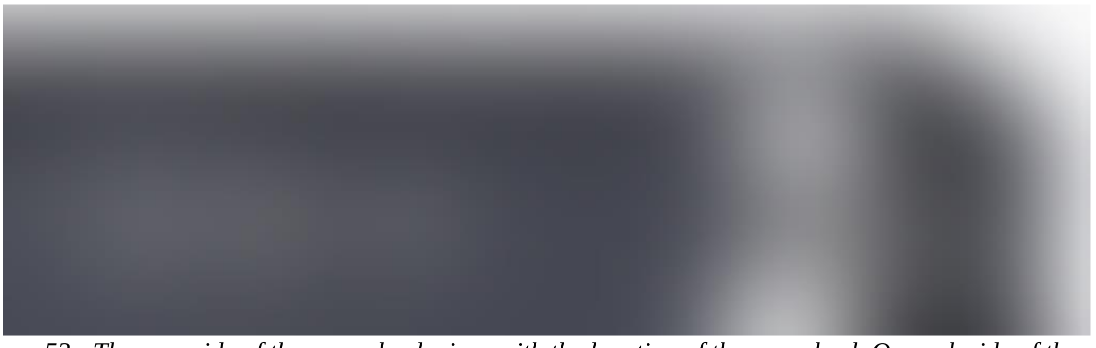


Figure 53 - The rear side of the upper back piece with the location of the cog wheel. On each side of the cog wheel are the attachments for the springs

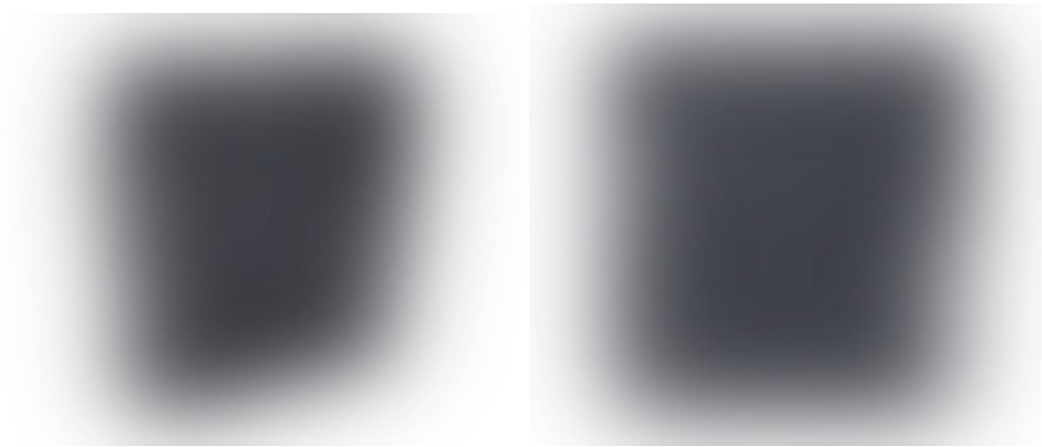


Figure 54 - Side Slot adjusted for a large tablet but with no tablet mounted

There are two locking supports on the tablet mount’s frame, one on each side. These hold the tablet in place vertically, or horizontally when the mount is used in portrait mode. The supports are rotatable about the front frame section and lock into a slot underneath the rear frame section with a pin. To open the locking support, the user simply pushes down the pin and can then fold them up in order to mount or dismount a tablet. This are further explained in Figure 55.

The reason there are two identical locking supports on the mount is so that it should be usable from both the right and the left back seat. It will most likely be difficult to enter the tablet from the right if you are located in the right back seat, and thus it has an opening on each side.

Figure 55 - The functionality of the locking supports

The vertical locking of the frame is made by a button located at the top right frame part, locking on to notches in the lower right frame part. The button is designed so that it is possible to push up the lower back piece without pressing it, but it have to be pressed in order to extend the mount. This can be seen in Figure 56.

Figure 56 - The button locking the mount vertically

As can be seen in the previous figures, there is currently nothing covering the springs and gear racks. Since the mount always returns to its minimum state horizontally when no tablet is mounted the user will not see this unless he or she expands the frame manually without a tablet. Therefore this was not considered a high priority. However, if the user would expand the frame, it does not look very good. Additionally, it is possible for the user to look over the upper frame and at least see one gear rack. It should be investigated further if there is a need for some type of cover there.

Since the modelling of Side Slot started quite late in the detailed design phase, there was no time left to run strength and safety analyses for the model.

5.2.3 Improvements

Only one improvement was made to Side Slot after the design had been complete. From the results of the tolerance analyses, see section 5.3.2, it became apparent that the gaps in certain telescopic joints were too tight. These gaps were thus increased.

5.2.4 Producibility

The producibility was not as thoroughly done for Side Slot as it was for Cog. The production processes required should however be very similar.

Most parts would have to be injection moulded and one negative aspect of this concept is the fact that few of the parts are identical to another. The only identical parts are the locking supports, the rack gears, the springs and some screws and bolts. Thus the product would require almost as many moulds as Cog, even though the concept has fewer parts. Additionally, all of the moulds would be complex. Due to the complexity of the parts, none of the parts could be compression moulded.

Just as for Cog, many of the frame sections could be extruded instead, with just the corner pieces being injection moulded. Again, this would increase the time for assembly but potentially still save some cost for the entire production.

5.2.5 Prototype

Due to the problem with the joints on Cog, some changes were made to Side Slot before it was prototyped. As for Cog, the prototype was 3D-printed, and all gaps between parts were now set to 0.8 mm instead of the previous 0.2 mm. This could result in some play, but it was considered much better than not being able to assemble the prototype at all, or having to spend a lot of time on grinding and polishing.

The prototype for Side Slot was built late in the detailed design phase, and thus it was not used for verification of functionality but instead just as a visual presentation of the concept.

5.3 Tolerance analysis

Tolerance simulations were first run for the one-armed Cog and later also with Side Slot. All simulations were made in RD&T and the results are presented in this section.

To make things simpler at this stage, the assumption was made that all parts except for screws and gears would be made out of injection moulded plastics. According to CES, the tolerances for injection moulded plastics are 0.1 – 1 mm and thus the initial tolerance value was set to 0.5 mm for all plastic components (12). The tolerances for the gears were considered negligible in comparison and were therefore set to zero (24).

The tablet mounts were tested when in a protracted state, i.e. in the position they would have when holding a large tablet.

5.3.1 Cog

Two aspects of Cog were tested for their sensitivity to variations. First the connection from the back piece to the corners of the frame and then the connection between two frame parts.

Back piece to frame

The most variation sensitive parts were deemed to be the connection from the back piece to the corners of the frame. A model was set up with the parts shown in Figure 57.

Figure 57 - The model used for the variation analyses of the back piece with arms on Cog

The connections between the parts were established and all tolerances set to the initial value, 0.5 mm. Ma1, the first measurement, was located in the hole at the end of the rack arm, which is the light blue part in Figure 57. Ma1 was analysed in all directions and the simulation was run with 10 000 iterations. The result can be seen in Figure 58 and the figure shows the amplitude of the deviation of the measurement point. STD stands for standard deviation, commonly written as σ.

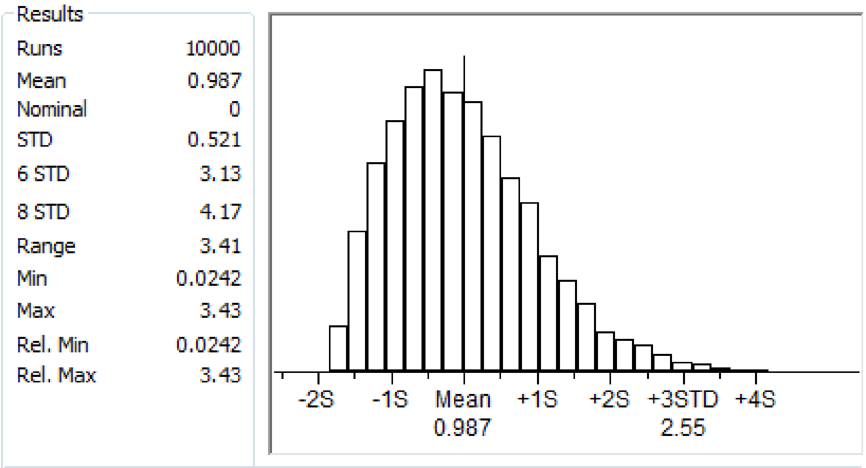


Figure 58 - Variation analysis for Cog, Ma1 in all directions

The connection points mainly responsible for the variations in Ma1 were the ones preventing the arm from rotating. Since that is a movement the arm is allowed to freely do anyway, a more interesting measurement would be to only look at the deflection in the Z-direction. Using otherwise the same setup as in the previous measurement, these results can be seen in Figure 59.

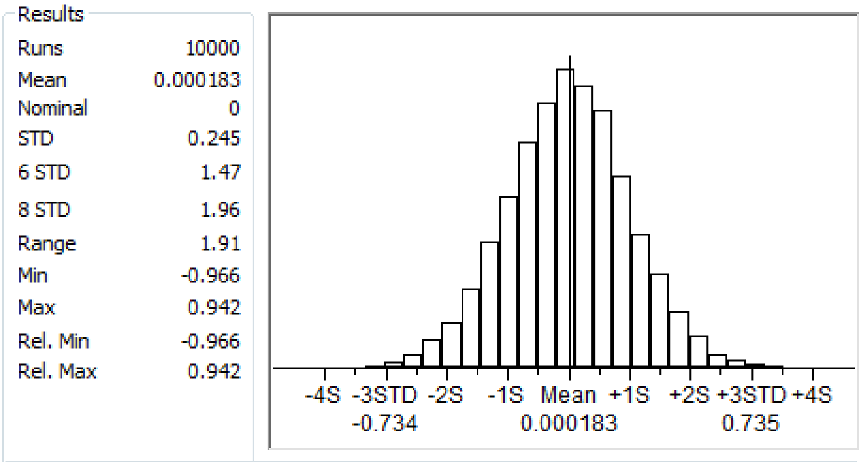


Figure 59 - Second variation analysis for Cog, Ma1 in Z-direction

The variations were considered quite small, 1.47 mm at six STD. It was therefore considered no actions were required to enhance the robustness for the variations in this measurement.

A second measurement was also made for the back piece and rack arm of Cog, concerning the distance between the cog wheel and the inner part of the central hole in the middle arm. This was called Ma2 and can be seen in Figure 60.

Figure 60 - Location of Ma2 at Cog

The nominal value for Ma2 was 1 mm and the analysis was made to test if that distance was enough to ensure that the gears would never scrape against the middle arm. The results from the analysis showed that the gap would be large enough with 0.06 mm margin for six STD, see Figure 61. In order have a greater margin, the gap should however be extended.

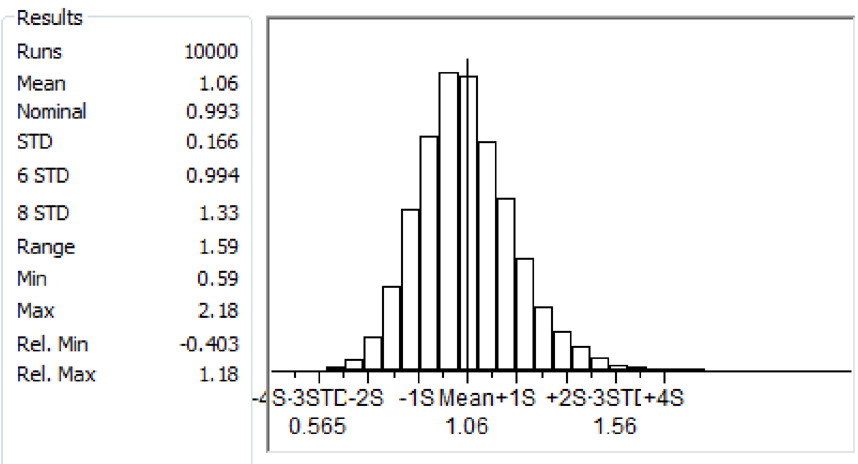


Figure 61 - Variation analysis for Cog, Ma2

Frame

Two parts of the frame were used for the variation analyses, as can be seen in Figure 62.

Figure 62 - The model used for the variation analyses for the frame on Cog

The first measurement, Ma3 was made at the corner of the pink frame part in Figure 62 while the second measurement, Ma4, analysed the gap between the two frame parts. The location of these two measurements can be seen in Figure 63. Ma3 analysed the amplitude of the variation in all directions while Ma4 only analysed the gap in the Z-direction.

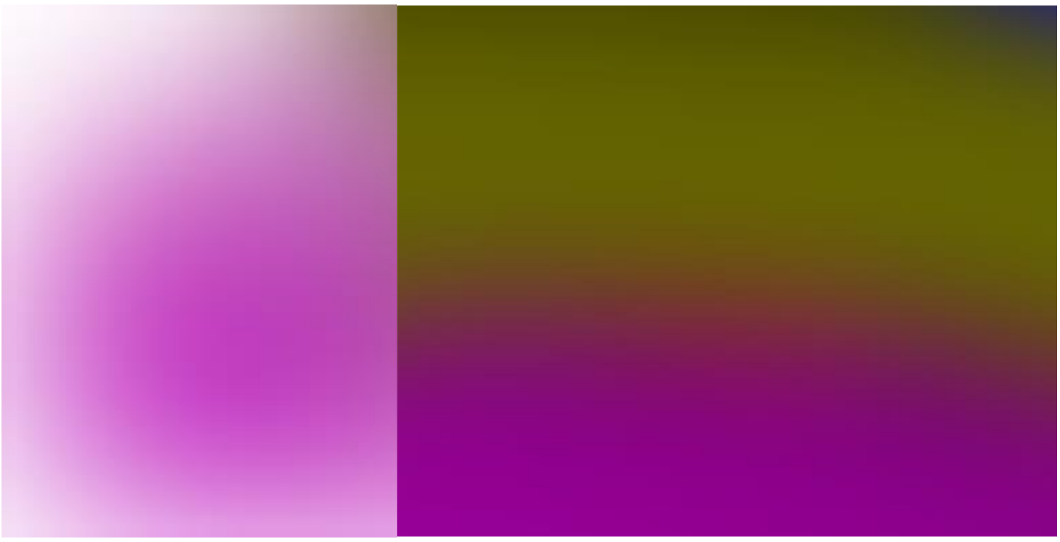


Figure 63 - Location of Ma3 and Ma4 respectively

The results for Ma3 can be seen in Figure 64 and they show a variation of 3.27 mm for six STD with a mean variation of 0.89 mm. This is not terrible and will most likely be something the frame and the gaps between the frame parts could swallow, it is not completely negligible however and should potentially be further investigated. The reason why the curve is skewed and does not have the usual normal deviation-appearance is because it measures the amplitude of the variation compared to the nominal value and the nominal value is in this case of course zero which corresponds to the corner of the frame not moving in any direction.

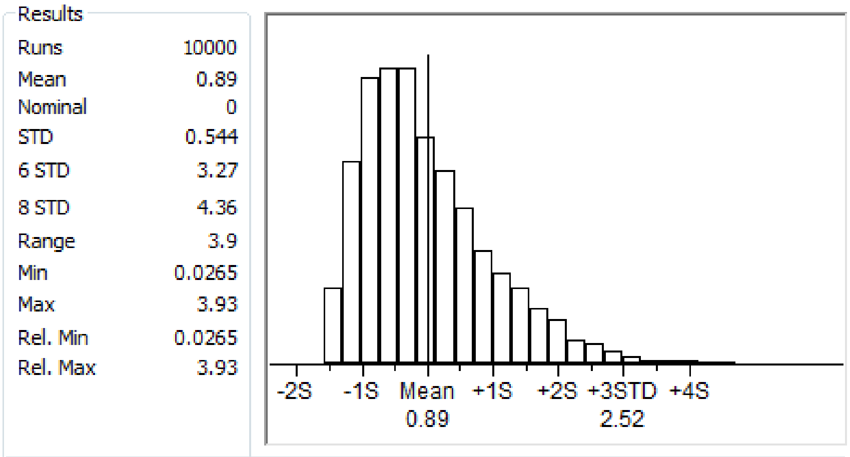


Figure 64 - Variation analysis for Ma3 on Cog

Ma4 was made in order to ensure that the gap between the frame parts would not be able to get too small, making the small frame part unable to slide in the larger one. At the same time the gap must not be too large since that would make the frame rickety.

The gap measured in Ma4 was set to be 0.1 mm at the time of the analyses and the results for this measurement are presented in Figure 65. As can be seen, the gap could vary with ± 0.59 mm for 6 STD, which was beyond the acceptable values.

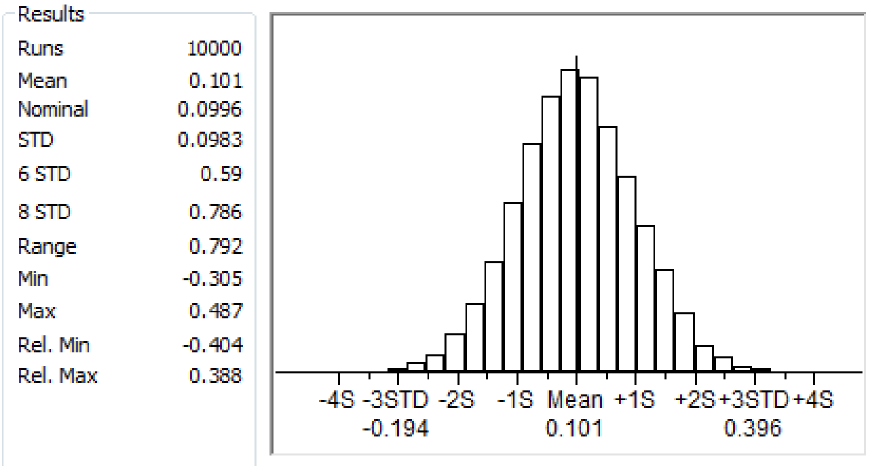


Figure 65 - Variation analysis for Ma4 on Cog

Due to the bad results, another simulation was run for Ma4. This time the tolerances were set to 0.1 mm instead of the previous 0.5 mm. 0.1 mm was the lowest tolerance for injection moulded plastics according to CES (12). The new results can be seen in Figure 66.

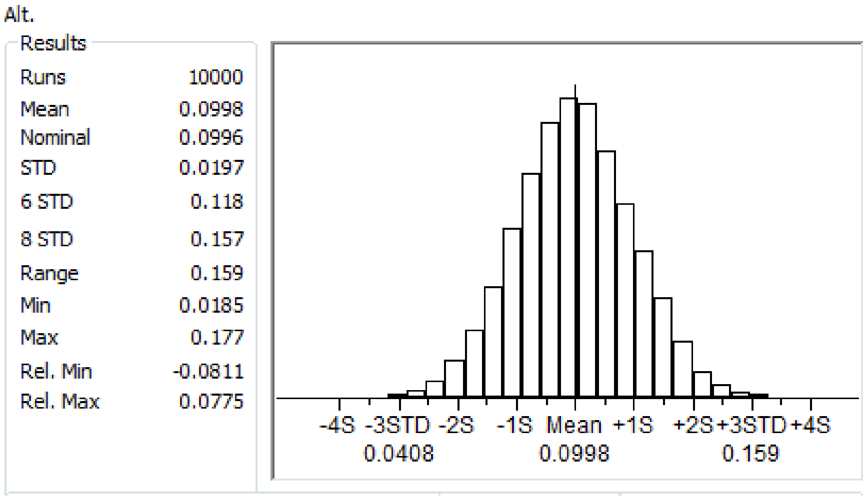


Figure 66 - Second variation analysis for Ma4 on Cog

The new results are much better, even though the value of 0.118 mm for six STD means that there could still be problems in some rare cases. Therefore the gap should be increased, which would also allow a little higher tolerance.

5.3.2 Side Slot

For Side Slot, all major components of the product were used for the simulations, as can be seen in Figure 67. The initial value for the tolerances, 0.5 mm was used for all plastic parts. Several measurements were made in the model and will be presented and explained one by one.

Measurements on the frame were only made on the left side. The conditions for the right and left side were considered to be similar enough to be able to skip the right parts. The locations of the measurements are included in Figure 67.

Figure 67 - The model used for variation analysis on Side Slot with locations of measurements

Mb1 measured the gap between the locking support and the rear part of the frame. If this gap becomes too small, it would be difficult to fold down the support since it may hit the rear part of the frame. The nominal value for the gap was 0.2 mm.

The results, which can be seen in Figure 68, were not acceptable since the gap could vary with 0.766 mm. Thus, this have to be further investigated.

Mb2 measured the variation in the lower left corner of the frame and only in the Z-direction. The results can be seen in Figure 69 and they are considered acceptable since this is not a critical deflection. As for Cog's frame, the gaps between the frame parts will most likely be able to swallow any deviations of this magnitude.

Mb3 measured the variation in the Z-direction for the upper left frame corner. The results can be seen in Figure 70 and the variations are almost twice as high as for Mb2. The reason for this is the connection to the back piece through the rack arm. That connection is simply not as stable as the two frame pieces connecting to the back piece as is the case for the lower part of the frame. The connections in the model could also contribute to this difference.

Mb4 measured the variation in the deflection in the Z-direction at the end of the lower back piece. The values were acceptable with a variance of 2.33 mm for six STD, see Figure 71. The important aspect for this measure is how long the distance is where the back pieces overlap.

Mb5 was the measurement in the telescopic joint between the two back pieces, i.e. where the lower back piece enters the upper. The nominal value for this gap was 0.2 mm. If it would become too large, the entire structure would be rickety and on the opposite, if it would be too small the pieces would not fit together. Figure 72 shows the results, which were not acceptable since a variation of 0.652 mm would be very problematic. Thus the tolerances have to be finer and the distance of the gap should potentially be evaluated.

Mb6 was the final measurement for Side Slot. It measures the variation in the gap between the two frame parts, which had the nominal value 0.2 mm. The frame pieces were not connected to each other in any way in the model, meaning that they could deflect independently of one each other. This was done to see how much their relative position could vary. If the amplitude of this variation were to be large, it would mean that the telescopic joint would be askew which would affect the functionality of the joint.

The results of Mb6 can be seen in Figure 73, with a variation of 17.2 mm for six STD. The large variation was mainly due to the poor fastening of the upper frame part, which was mentioned for Mb3. The main contributor was the rack arm, which in this model is set as fixed to the back piece. In the actual product, that will not be the case and it will be allowed some play against the cog wheel. Thus, the variation will to some extent be swallowed there since moving the rack arm a little will greatly affect the position where Mb6 was measured. However, the variation was still too high to safely say that it will work out in the actual product, and thus the tolerances would most likely have to be made finer.

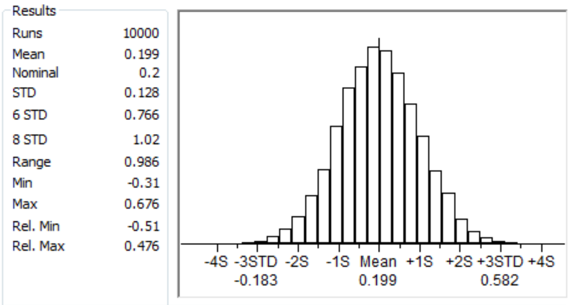


Figure 68 - Variation analysis Mb1 on Side Slot

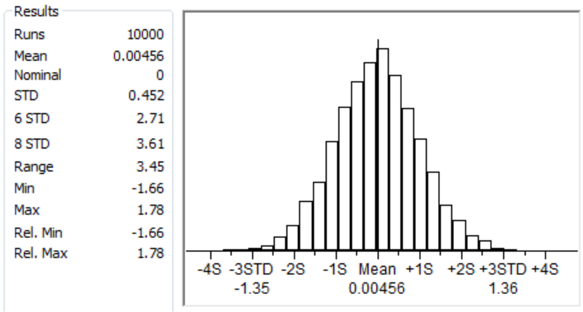


Figure 69 - Variation analysis Mb2 on Side Slot

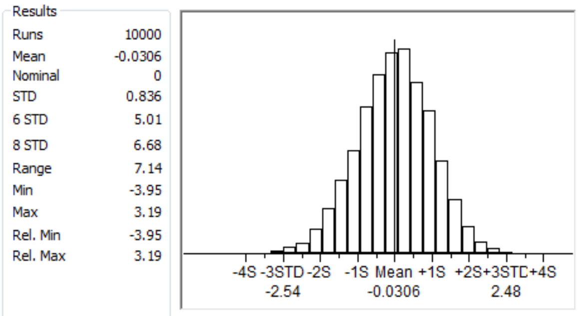


Figure 70 - Variation analysis Mb3 on Side Slot

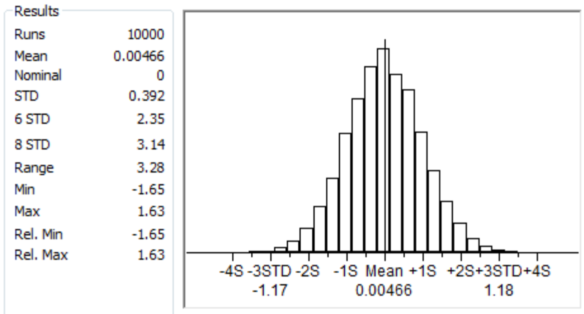


Figure 71 - Variation analysis Mb4 on Side Slot

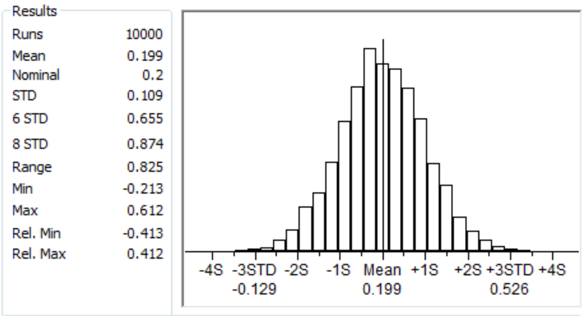


Figure 72 - Variation analysis Mb5 on Side Slot

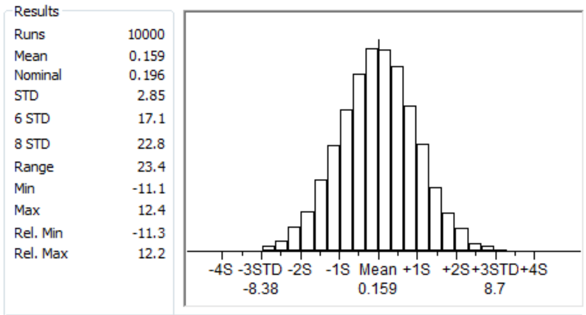


Figure 73 - Variation analysis Mb6 on Side Slot

Three of the measurements were rerun with new tolerances of 0.1 mm instead of the previous 0.5 mm and these were Mb1, Mb5 and Mb6. The result of the new simulations can be seen in Figure 74, Figure 75 and Figure 76.

For Mb1, the variation was still a little too large, with 0.27 mm for six STD, and thus the gap would have to be increased with at least 0.1 mm depending on the tolerance of the final manufacturing process.

For Mb5, the variation was reduced to only 0.216 mm for six STD. That was very close to acceptable but even here the gap would most likely have to be slightly increased.

The variations for Mb6 were still not very satisfying, varying with 7.09 mm for six STD. Due to the problems with the connections and the fact that the rack arm will not be fixed, it is difficult to interpret how large the impact of this value will be. It would most likely have to be tested on a physical prototype and Mb6 is therefore disregarded from in the following steps of the detailed design.

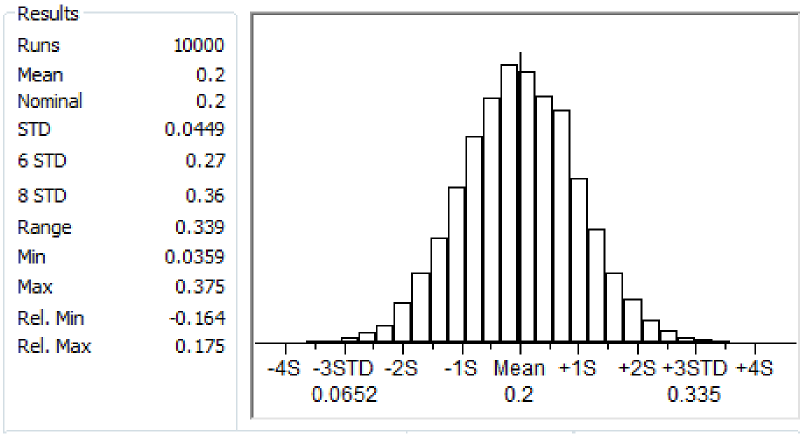


Figure 74 - Second variation analysis for Mb1 on Side Slot

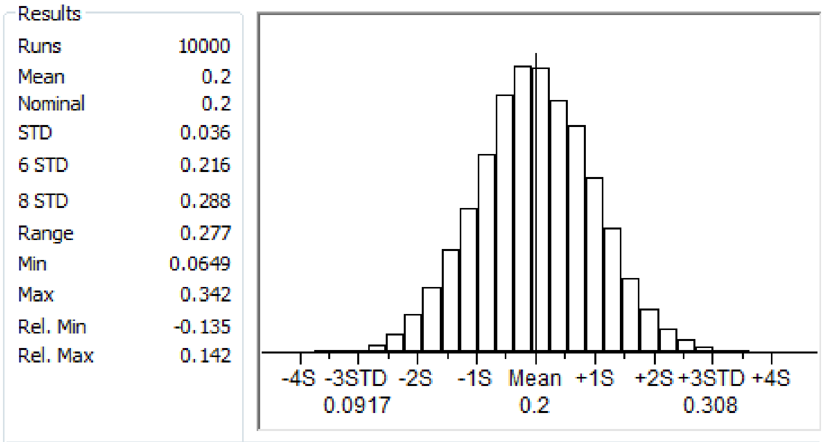


Figure 75 - Second variation analysis for Mb5 on Side Slot

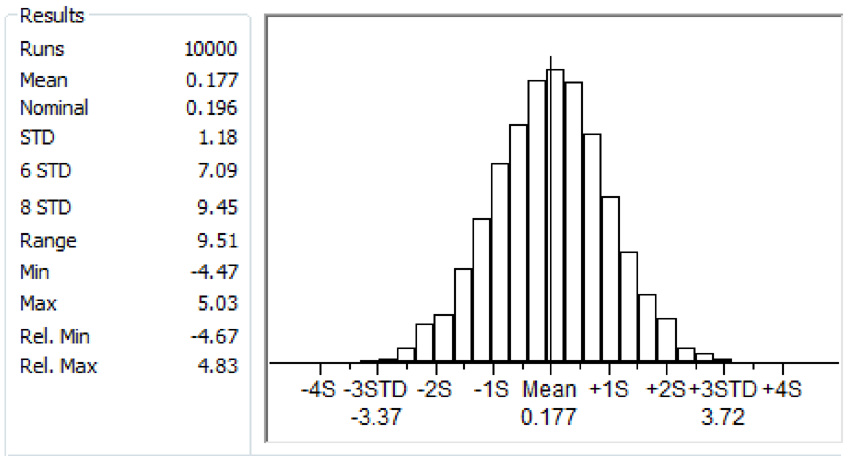


Figure 76 - Second variation analysis for Mb6 on Side Slot

5.4 Choice of material

Strength analyses were made for several load cases on the mount and these are explained in Report C. The analyses were only made for Cog and it is unclear how much different the values would be for Side Slot. The most demanding load case provided the following stress values for the mount:

- Rack arm – 39.4 MPa
- Middle arm – 27.6 MPa
- Outer frame – 15.5 MPa
- Inner frame – 18.7 MPa

These were the parts with the highest stresses although there were some uncertainties with the models and thus also with the values. The values for the frame parts will most likely be a little higher than presented above due to the fact that these values had not completely converged for their mesh sizes. They are still much lower than the values for the middle arm and the rack arm though so that a material suitable for those parts would with no doubt also work well for the frame.

There was a problem with the analysis for the connection between the outer frame and the rack arm. A bolt is connecting those two parts and at the points close to the screw, there were some large stress concentrations. Additionally, the stress values diverged towards infinity with smaller mesh size. These stress concentrations can be seen in Figure 77. As one can see in the figure, the stresses levels are highly concentrated to a few elements and quickly drop a few elements away.

Due to this problem, the stresses in the holes' surfaces could not be calculated and instead the stresses were calculated close to the holes and those are the values seen above. This are more thoroughly explained in Report C.

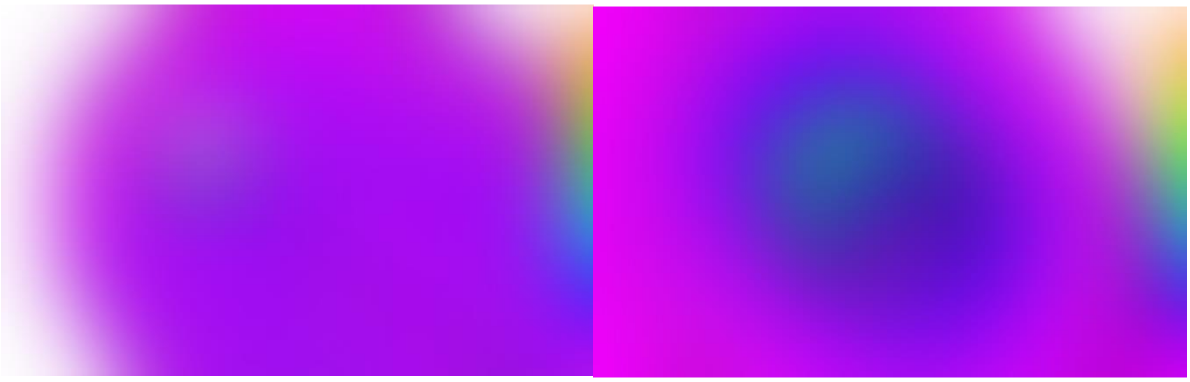


Figure 77 - The stress concentrations in the connection between the rack arm and the frame, from Report C

It was decided that all parts of the mount would be made out of the same material. The exception from this was the cog wheel, potentially the gear racks and the screws, bolts and nuts. The primary reason for choosing the same material for all parts was the coherence in design. It is important that all components look like they belong together. Some parts could be supposed to have different surfaces and colour and then would probably not be a problem. However, materials that should look similar should not be of different materials since it could cause differences in surface roughness, gloss and colour. Secondary reasons were simplicity and because it would most likely be cheaper to just use one material from one supplier for the production.

Due to the decision to use the same material for all the parts, the highest of the stress values, 39.4 MPa, was used as the value that all components would have to be able to withstand without plastically deforming. In order to add a safety margin, the required stress value is increased by 33%. Thus, the requirement on yield strength for the material was 52.4 MPa.

In the safety analysis, the mount was tested for a head collision. Materials of different stiffness were used for the tests in order to see how stiff the mount could be and still not be harmful for the user. If the mount was too stiff the deceleration of the head could be too high in the collision, which would be harmful. The stiffness values tested were 1 GPa – 30 GPa and all results were within the legal limits. Additionally, a higher stiffness did not necessarily mean a worse collision results. Thus, the material stiffness will not be considered particularly important for the choice of material, even though a material with a Young’s modulus between 1 GPa – 30 GPa would be desirable since it has been tested. The safety analyses are explained in much more detail in Report C.

Some additional requirements came from the prestudy, and were:

- Must not be a material prohibited or limited from use
- Should not burn or propagate flames
- Must not corrode
- Should be able to withstand common cleaning agents

Additionally, it had been previously decided that only to look into plastics for manufacturing processes. Thus, it was set that the material should be able to manufacture with both polymer extrusion and polymer moulding.

Lastly, it was decided that the material should at least be fairly resistant to sun light. There are several additives that can be used with polymers in order to increase their resistance to sun light but since it was unclear how much these can improve the polymers’ resistance, it was considered good if they are at least slightly resistant.

Based on all these criteria, the following was used in CES (12):

- Yield strength ≥ 52.4 MPa
- Manufacturable with polymer extrusion
- Manufacturable with polymer moulding
- Resistance to UV radiation (sun light): fair
- Resistance to weak alkalis: limited
- Flammability: Self-extinguishing

The axes were set as price compared to yield strength and the result can be seen in Figure 78.

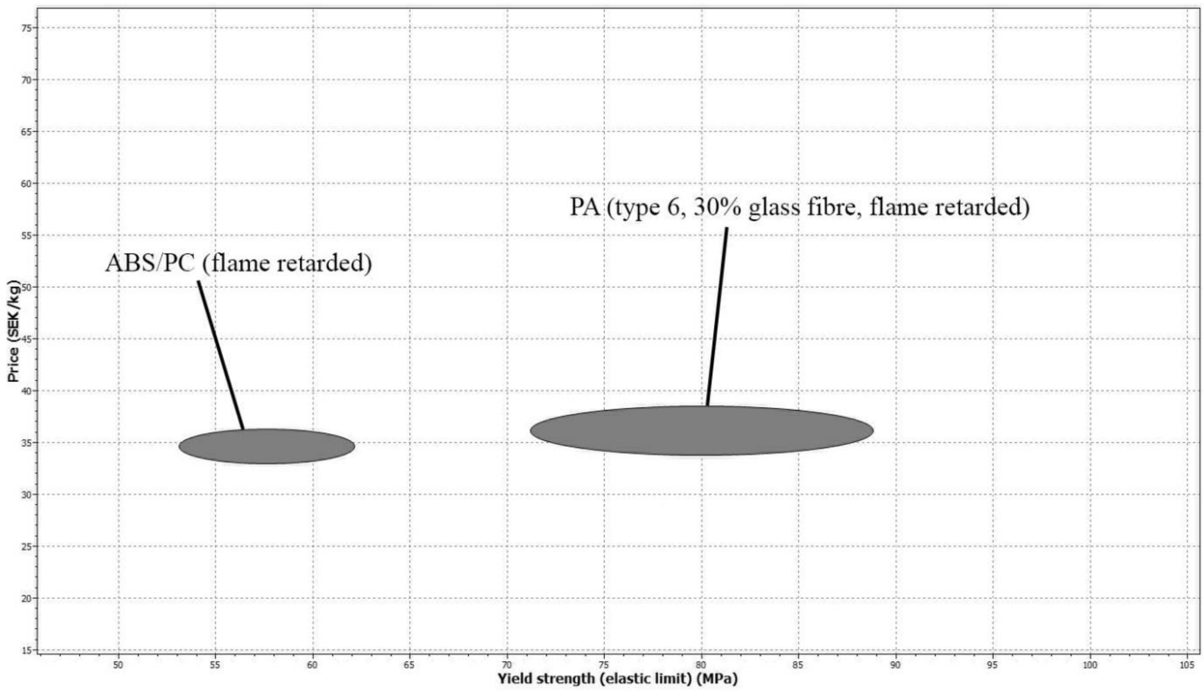


Figure 78 - The only two materials in CES's database fulfilling the requirements

Only two of the materials in CES’s data base could fulfil these criteria. The first is acrylonitrile butadiene styrene with polycarbonate, ABS/PC, and the second is polyamide, PA, with 30% glass fibre. As could be seen in the figure, they are almost equally expensive and PA has higher yield strength. Some other comparisons regarding properties can be seen in Table 8.

Table 8 - Comparison of the two possible materials

Property	ABS/PC	PA, 30% gf
Polymer class	Amorphous thermoplastics	Semi-crystalline thermoplastics
Density (kg/m^3)	1170 – 1230	1530 – 1560
Price (SEK/kg)	33 – 36.3	33.9 – 38.5
Young’s modulus (GPa)	2.41 – 3.14	6.8 – 8.48
Fatigue strength* (MPa)	16 – 25.6	35.1 – 38.8
Moulding energy (MJ/kg)	19.2 – 21.2	18.3 – 20.2
Extrusion energy (MJ/kg)	5.84 – 6.45	5.81 – 6.42
Melting temperature (°C)	178 - 271	217 - 293
Recyclable	Yes	No
Typical use	Helmets, car instrument panels, housings	Gears, bearings, nuts, bolts, power tool housings, fuel tanks, kitchen utensils

* At 10^7 cycles

In the Process Selection book there are tables for estimating the tolerances for injection moulding different polymers (25). To make a comparison, four components with different dimensions were used. The results are presented in Table 9. The tolerances for both materials were deemed sufficient enough when compared to the tolerance studies in section 5.3.

Table 9 - Comparison of the two materials tolerance properties for injection moulding

Dimension	ABS/PC	PA, 30% gf
2 mm	± 0.10 mm	± 0.11 mm
20 mm	± 0.18 mm	± 0.22 mm
100 mm	± 0.43 mm	± 0.65 mm
200 mm	± 0.82 mm	± 1.20 mm

Two major upsides of ABS/PC are the lower weight and better tolerances, especially at larger dimensions. The primary benefit however, is that it is recyclable. On the other hand, PA has higher yield strength and a stronger mount seemed desirable. This was especially important when there were some uncertainties in the strength analyses, for example with the stresses around the holes in the rack arm and the outer frame. Due to this factor of uncertainty, PA with 30% glass fibre was chosen as the material for the mount to ensure that it will hold for the load cases.

Additional improvements

A threaded metal cap should be glued into the hole in the outer corner in order to ensure that the surface of the hole does not deform. The metal cap will spread out the load over the entire surface, thus preventing the stress concentrations. The stresses in the screw connecting the rack arm to the outer frame were very high too, demanding a strong material. In order to make the structure stable, it is also good with a stiff screw, to make the mount feel stable and robust. Therefore it is recommended to use a metal screw. The same is also true for the screw connecting the mount to the back piece.

The inside of the frame supports should be coated in a softer material. The purpose would be both to protect the tablet but mostly to hold it better in place so that it cannot shake or move around when mounted. The frame supports should also be made so that there is quite some friction between them and the frame.

During the safety analyses, it also became apparent that the frame supports sometimes slid over the stop block and onto the inner frame part in the event of a crash. When on the inner frame, the supports' ability to hold the tablet was severely decreased. Therefore, the friction between the frame and the supports should be managed in order to prevent this from happening. It could be done by adding some type of coating to the supports in those areas too.

6 Discussion

This section will present important aspects of the project process and the results. It will also contain recommendations for future work.

The division of the project into three different theses did work well. The workload was naturally somewhat uneven during the course of the project but this was considered unavoidable since all work cannot be conducted concurrently. For example a finished CAD model was required for the strength analyses but at the same time the CAD model was continuously improved and then a material for the product could not be chosen until those analyses were finished.

6.1 Prestudy

Some documents for the prestudy, especially those regarding legal restrictions for East Asian countries were unavailable, and were thus not covered. This would however most likely not be a problem for the implementation of the product. The content mostly covered material requirements and an assumption were made that the laws and regulations in that field are tougher in Europe and Sweden.

The prestudy resulted in an extensive document of target specifications. This was necessary in order to cover all aspects of the product but it did make the concept selection more time-consuming since it was difficult to choose and rate which aspects are most important. Additionally, some of the requirements were irrelevant for the concept selection and only applied to the detailed design. There was a distinct risk that many of the requirements would be irrelevant even then, depending on how far the project would reach. For example the results of the observations will only be left as a recommendation to VCC due to the fact that the positioning of the mount already was set and there was no time to implement extra functionality to the mount.

It was important that the prestudy was extensive and thorough enough so that later decisions would not be based on assumptions but instead on facts. Also, even if some pieces of information did not directly affect the outcome of the project, they still contributed to learning the greater picture of the product and its environment. This extended knowledge allowed the developers to further familiarise with the product.

After all, the project group never had any problems in the concept development phase that depended on deficiencies in the prestudy.

6.2 Concept development

All through the concept development, and further on in the detailed design, the concepts were always improved. No concept ever felt complete, new problems or opportunities always emerged and even now when the project is done it feels like there are a lot of aspects that could be improved.

One problem all throughout the concept evaluation was how easy it was to get favourites. The project group members got their favourites and even though everyone tried hard to be as objective as possible, it is hard to keep it from occasionally affecting the results.

When it came to the concept evaluation, a pattern emerged quite early among which concepts that made high scores in the matrices and in the final five, all concepts were flexible frames. The reason was of course that the project group and all other information available pointed at flexible frames being the best solution. It could however have been a good idea to still keep more different concepts longer in the evaluation to get a larger variety.

All through the concept evaluation, there were uncertainties with the feasibility of concepts. The functionality of some technical solutions could not be established which meant that some concepts were rated on the basis of how good they would be if they worked This was a risk that also lead to problems later in the detailed design phase.

Concept generation and screening

A thorough job was conducted in order to cover the entire solution space, together with several iterations of refinement. After this phase, the project group was confident that no viable solutions had been overlooked.

The concept screening matrix was a good tool in reducing the number of concepts. However, the chosen criteria made the results a little uneven. The problem was that the fastening of the tablet got rated twice. It was a major aspect both for robustness and for safety and thus the concepts were evaluated twice for this criterion. This became even more problematic when the project group were unsure of how well certain technical solutions would work for holding the tablet, for example using only springs. One additional, minor problem was that while most tablets had the same functionality for mounting a tablet and readjusting the size of the mount there were some concepts where this was two separate operations. It therefore became difficult to compare the two with only one criterion.

Concept scoring

Due to the necessary design compromises that had to be done for the concepts, getting a good score on one criterion generally meant getting a negative score in another. For example simplicity and ease of use often gave opposite scores. Due to the weighing of criteria, this was not a major problem and the results from the first scoring matrix did correspond well with the project group's opinion as the top eight concepts from the matrix were kept for further refinement and evaluation which means that the method worked well.

For the second concept scoring, the project group's opinion did not really match the results. However, no concept really stuck out, for good or bad. All concepts got very similar scores, it only differed 0.38 points out of five between the highest and the lowest score. This was of course because of the problems mentioned for the first scoring matrix, that a good score in one category meant a worse score in another. It was also difficult to compare flexible solutions to for example rigid frame. The flexible solutions generally did not get enough credit for their flexibility.

Additionally, the fact that not only the top concepts were chosen for further evaluation shows that the matrix was only used for guidance and not for definitive selection. Since there are not definite answers in product development, this is also how the methods should be used.

The CAD models were also done by all members of the project group which had their own view of the concept and how it could look. The effort put into design and verification of functionality varied between the concept models, which lead to some slight misinterpretations and skewed results.

Since the project group had thorough discussions for each concept after the scoring, this was not considered to have affected the results and the best five concepts made it through.

Final selection
The feedback received from VCC was on some points slightly contradictory. This could be because it was most likely too much to grasp the functionality of each concept in the short time they were presented. Still, they highlighted a lot of important aspects which were kept in mind for the final selection even though the decision was not made in complete accordance with VCC's recommendations.

No evaluation method seemed good enough for making the final decision. Too many aspects weighed in to be able to gather them into one method and the project group's own opinions, supported by the prestudy, VCC's feedback, the user feedback and the previous methods stood for the decision.

6.3 The final concepts

The two final concepts will be discussed in this section.

6.3.1 Cog

Cog was one of the concepts which were kept after all evaluations on the basis that if it worked, it would be a really great concept, even the best. The functionality of the gear system turned out as desired and it was by most people considered as the best looking concept. However, some problems occurred.

The thickness of the mount was a major problem in the early detailed design phase. When the project group decided to remove one of the arms in order to solve this problem, many other problems emerged which would be detected later. The decision was made quite quickly and in retrospect, the effects of removing one arm should have been investigated much more carefully. The problem with the two possible ways of rotating the frame both came from the removal of one arm and led to the project group starting to work on the back-up concept Side Slot.

The problems with Cog could still be solved even though it would make the concept a little less user friendly or thicker. There are some other minor issues that would also have to be dealt with in such a case though. If the mount is set to be very narrow and high with its current design, the frame parts on the short sides will be pulled to far apart. This could quite easily be solved however by changing the gap in the back piece. If the arms do not allow the mount to be set into this narrow and high position, the frame will still hold together.

If a gear skips one tooth, the whole structure on Cog will be skewed. This is why the tolerances for the gear system will need to be very high. The gear system must also be assembled so that both rack arms are equally far from the middle, otherwise the same skew will be built into the structure.

There was also the problem with the button for Cog which is yet to be developed. Due to the structure of the frame, and the fact that it was desired that the user only uses one hand to operate the mount, no viable solution was found.

After all though, Cog has quite some problems but it is a concept of great potential. If the problems can be fixed, Cog would be very user friendly, it would fit well into a Volvo car, it would cover the edges without ever risking covering any buttons and it would feel intuitive. That is also why it ended up as the final concept, it has some great potential.

6.3.2 Side Slot

Many people liked the idea of only having to adjust the size of the tablet once when using the same tablet. This was unfortunately contradicting with VCC's request that the mount should always constrict to its minimum size when a tablet is not mounted. The compromise for Side Slot was to minimise the long frame section when no tablet is mounted and still be able to keep the vertical distance set for the same tablet.

There were however some problems remaining with Side Slot as well. The major concern is a safety issue. If a tablet is mounted in portrait mode and the car crashes, the tablet will push towards a frame section held only by springs. The frame will then naturally be extended and due to the gear system the opposite frame section will also extend away from the tablet. This way the mount will let go of one of the tablets edges. There would still be three sides holding the tablet, but there is a risk that the two long sides would be bent slightly apart and if that would happen the tablet would be released from the mount. There is also a risk that the pins on the locking supports are too weak and would have to be strengthened in order to be able to hold in a crash. Since there was no time left to analyse Side Slot, its behaviour in a crash is still unknown and this is something that have to be further investigated.

Another concern for the safety aspect is that it only locks the frame vertically on one side. This means that the other side could be bent apart. This could be solved by adding a button to the other side as well, but it would make the mount really difficult to adjust since the user would have to push two buttons and at the same time. It could also be solved by putting the button on the back piece, locking the two back pieces together. That means that the user would not be able to readjust the mount when the tablet is in place, but since the mount can still be constricted vertically even without pushing the button, it could actually be a viable solution.

At the moment, there is nothing hindering the telescopic joints on Side Slot from being pulled apart, disassembling the structure. The best idea for solving this was to add stop blocks that fit into slots on the frame parts and back pieces. These would have to be added after the mount had been assembled though since manufacturing the parts with built in stop blocks would make assembly very difficult. The idea did not seem optimal though, and was thus not implemented in the model.

The decision to remove the pin and instead adding the locking supports to Side Slot made it less user friendly in favour of safety aspects. This was never thoroughly analysed though and it could be investigated if the same level of safety could be achieved with a pin or some other solution which would make it easier to mount and dismount the tablet again.

After all, Side Slot was a solid concept built from an appreciated function and idea for mounting the tablet. Solving the problems for Side Slot would most likely not cause any changes in functionality, making it a reliable concept.

6.3.3 Tolerance analyses and choice of material

In order to be able to measure the tolerance sensitivity of the models, they had to be connected. These connections locked the parts together in all directions, even for joints which are supposed to be able to move in some direction. It is unclear if this had any impact on the analyses and it is also possible that there are better connection methods to use which does not require the parts to be locked to each other in all directions.

It also becomes a little difficult to assemble the product properly when each part is only connected to another other part. This makes it impossible to make two parts dependent of each other, which would actually be the case for the frame.

There were some additional problems with the analyses of Side Slot. The upper parts of the frame were difficult to connect in a good manner, which made the results for the measurements on the upper left frame and the gap between the left frame parts larger than it would probably have been in reality. The values for the left frame were also considered applicable for the right frame as well. This should probably have been tested first since the different placement of the gear rack maybe makes the upper right corner behave differently than the left.

Regarding choice of material, one can see in Table 8 that the fatigue limits for the materials are lower than the stress from the load case. This was not considered to be a problem since the load case was a quite severe scenario for the tablet mount. That scenario will not occur very often and the fatigue limits are based on 10^7 repetitions, which is far more than the tablet mount will ever be exposed to.

6.4 Alternative solutions

Many concepts were discarded during the concept evaluation and it is always difficult to know what problems each concept will encounter further down the way. There could be discarded concepts, such as Modular or Flag, which also could have been viable final solutions if their problems would be solved.

As an alternative, one could also look into having a few different mounts for different sizes. A major problem, especially in the detailed design, was that the size span for tablets between 7” – 10.1” is quite large. This makes the need for flexibility very large, leading to compromises and sub-optimal solutions for other aspects. Having for example one mount for small tablets and one for large tablets would make the development easier.

7 Conclusion

The project was executed within the time schedule and two final concepts have been developed. Both of them hold great potential of being good products and they fulfil nearly all of the user requirements from the target specifications. They have been designed to be coherent with VCC’s core values and they have been designed for good producibility. Additionally, Cog was assigned material in order to fulfil the safety and strength requirements. The concepts have also been tested and verified for variation sensitivity and tolerances.

Both of the final concepts have some unresolved issues that have to be fixed in order to make them viable for becoming a product in VCC’s accessories assortment. The further development will be continued by VCC based on the content of this project. When they implement this product it will gain them a market advantage because there is no product on the market today that can hold any tablet and at the same time cover its edges.

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Appendix A

Approach for observations

Preparation

The car had to be prepared for the tests. The car was parked on a flat surface. The angle of the driver's seat was adjusted so that the back of the seat was completely vertical. The angle of the front back rest was then measured relative to the seat so that the test could be carried out even if the car would be parked on an inclined surface. Tapes were placed on the right side of the back headrest and on the right side of the driver's seat headrest. The front seat was then positioned so that the distance between the tapes was 1100mm. Another tape was also placed on the roof, straight above the line passing between the other two tapes. All tapes were placed so that they would be as close as possible to the plane made up by the closest edge of a tablet held by the user. It was also noted from which corners of the tapes the measurements were made.

The tapes were never removed and replaced during the testing, however the front seat's angle and position had to be readjusted between every test.

Execution

The interviewees were asked to sit down in the left back seat. A tablet was presented to them, held by the interviewer, and they were asked to position it as they would have wanted it to be positioned for their optimal use. A photo was then taken from the right side, which would then be used to measure the position of the tablet relative the car's interior.

Before starting the actual observations of the interviewees, tests were carried out where the tablet was rigged and thus held in the same place for each photo. Between every photo the camera was lowered and the seat was moved and then adjusted back to the original position. These measurements were used to verify the precision of the measurements.

Provided the interviewee had a driver's license, he or she was also asked to move to the driver's seat and adjust the seat so it fit his or her driving position. The angle of the back rest, relative to the seat, was then measured. Additionally, the horizontal distance between the tapes on the headrests was measured.

The measurements from the photos were conducted with Adobe Photoshop in the following way:

1. The coordinates for each tape was measured in pixels and noted in the excel file.
2. The coordinates for the upper and lower edge of the tablet was measured and noted. In some photos the lower edge was covered by the interviewee's hand and in those cases the coordinates for the middle of the tablet was used instead, together with a comment.
3. The angle of the camera had to be compensated for since not all photos were taken absolutely horizontal. This was done by calculating the angle between the two tapes on the headrests, d, according to Figure A.1.

4. The horizontal distance from the upper edge of the tablet to the back headrest was calculated as $\frac{y}{1100} * x * \cos d$. Measurements x and y are explained in Figure A.1. The reason for the cosine-term is because of the compensation for the camera angle.
5. The vertical distance from the upper edge of the tablet to the roof was calculated as $\frac{186}{\sqrt{(t2-t4)^2+(t1-t3)^2}} * \frac{z}{\cos d}$, where t_1, t_2, t_3, t_4 and z are measurements explained in Figure A.1 and 186 mm is the length of the tablet used. In the cases where measurements on the tablet could only be made to the middle of the tablet, t_3 and t_4 represents that middle point and the tablet length was halved. The cosine-term is once again to compensate for the angle of the camera.
6. The angle of the tablet was calculated as $\tan\left(\frac{t2-t4}{t1-t3}\right) - d$, where d once again is to compensate for the angle of the camera.
7. All calculations and values were documented for comparisons. The mean values and differences were then calculated.

Figure A.1 - Explanation of measurements made for the observations

Appendix B

Material requirements

This appendix includes restrictions on use of certain materials and substances. The substances are listed in the table below and are marked with either *prohibited* or *limited*. Prohibited materials must not be used while limited means that there are limitations to how the material can be used, generally this means that the material must not be used in concentrations higher than a set value.

Material group	Material, abbreviation (CAS-number)	Source	Revision	Restrictions
	Asbestos	AFS 1996:13 (26)		Prohibited
PCB-materials	Polychlorinated biphenyls polychlorinated terphenyls monomethyltetrachloritediphenylmethane monomethyldichloritediphenylmethane monomethyldibrominediphenylmethane	SFS 2007:19 (27)	SFS 2011:1003 (28)	Prohibited
Ozone-depleting substances	Chlorofluorocarbon, CFC Hydrochlorofluorocarbon, HCFC	SFS 2007:846 (29)	SFS 2011:825 (30)	Prohibited Prohibited
	Mercury	SFS 1998:944 (31)	SFS 2013:503 (32)	Prohibited
	Cadmium	KIFS 1998:8 (33)	KIFS 2008:1 (34)	Prohibited
Chlorinating solvents	Methyl chloride Methyl trichloride Tetrachloroethylene	SFS 1998:944 (31) & KIFS 1998:8 (33)	SFS 2013:503 (32) & KIFS 2008:1 (34)	Prohibited
	Lead	KIFS 1998:8 (33)	KIFS 2008:1 (34)	Prohibited
Volatile organic compounds	Formaldehyde Benzene (71-43-2) 1,4-dichlorobenzene Chloroform (67-66-3)	KIFS 1998:8 (33) EEC 1907/2006 (35) KIFS 1998:8 (33) EEC 1907/2006 (35)	KIFS 2008:1 (34) KIFS 2008:1 (34) 	Prohibited Prohibited Prohibited Prohibited
	Hexavalent chromium	KIFS 1998:8 (33)	KIFS 2008:1 (34)	Prohibited
	1,3-Dichloro-2-propanol (92,23-1)	EEC 1907/2006 (35)		Limited
	2-Ethoxyethanol (110-80-5)	EEC 1907/2006 (35)		Limited
	2-Ethoxyethylactetate (111-15-9)	EEC 1907/2006 (35)		Limited
	2-Methoxyethanol (109-86-4)	EEC 1907/2006 (35)		Limited
	2-Methoxyethylacetate (110-49-6)	EEC 1907/2006 (35)		Limited
	2-Propennitril, aka acrylonitrile (107-13-1)	EEC 1907/2006 (35)		Limited
	Dimethylformamide (68-12-2)	EEC 1907/2006 (35)		Limited
	Dimethylacetamide (127-19-5)	EEC 1907/2006 (35)		Limited
	Tetrachloroethylene (127-18-4)	EEC 1907/2006 (35)		Limited
	Trichloroethylene (79-01-6)	EEC 1907/2006 (35)		Limited
	Hexabromocyclododecane, HBCD	VCC		Limited
	Decabromodiphenyloxide, Deca-BDE	VCC		Limited
	Nickel	EUNICK 2013 (36)		Prohibited

	Polyvinyl chloride, PVC	VCC		Limited
	Strontium-chromat	VCC		Prohibited
	Lead-chromat	VCC		Prohibited
	Zink-chromat	VCC		Prohibited
	Polycyclic aromatic hydrocarbon	VCC		Prohibited
	Diphenylamine	VCC		Prohibited
	Chlorparaffines	VCC		Prohibited
	Brominated flame retardant	VCC		Prohibited

Appendix C

Requirements on plastics

Requirements on plastics to prevent hazard and unhealthy substances in the compartment air.

Compartment emissions	**Volatile Organic Compounds max.**	**Formaldehyde**	**Odour**	**Fogging**
Material/part	µg carbon/g material	mg formal./kg dry material	Odourl (1-6)*	mg condensate
Coated fabrics)	≤ 20	≤ 10	≤ 3	≤ 1
PP	≤ 30	n.a.	≤ 3	≤ 0,3
PE	≤ 20	n.a.	≤ 3	≤ 0,3
ABS	≤ 50	n.a.	≤ 3	≤ 0,3
PC	≤ 20	n.a.	≤ 3	≤ 0,3
POM	≤ 20	≤ 10	≤ 3	≤ 0,3
PA	≤ 20	n.a.	≤ 3	≤ 0,3
PC/ABS	≤ 30	n.a.	≤ 3	≤ 0,3
PC/ASA	≤ 30	n.a.	≤ 3	≤ 0,3
PP/EPDM	≤ 30	n.a.	≤ 3	≤ 0,3
PA/ABS	≤ 30	n.a.	≤ 3	≤ 0,3
PBT	≤ 20	n.a.	≤ 3	≤ 0,3
PET	≤ 20	n.a.	≤ 3	≤ 0,3
Elastomers	≤ 20	n.a.	≤ 3	≤ 1,0

* 1 = no smell, 3 = noticeable, 6 = unbearable

Appendix D

Observations

The precision of the measurements are presented in Table D.1. These were based on six observations made with the tablet held in the same position.

Table D.1 – Precision of observations

Measurement	Mean value	Max. dif. +	Max dif. -	Highest-Lowest
Distance to back headrest	546.3	12.8	-14.5	27.3
Distance to roof	544.1	12.2	-8.0	20.2
Angle	30.5	1.3	-0.5	1.8

Potential sources of error

There are some potential sources for errors for these observations. First of all, more measurements should have been made to validate the test method's precision. The reason why only six measurements were made is because the tablet fell down from the rig after the sixth attempt.

Secondly, the tests were carried out in two different vehicles, with two different tablets and with two different cameras. These factors are considered to have minor, or no, influence on the results since both tablets used had the same dimensions, the cars used were of the same model and the difference between the cameras are considered to not affect the results in any significant way.

As mentioned earlier, in some of the photos the interviewee covered the lower edge of the tablet with his or her hand. Since there are a marking, button or socket in the middle of the tablet the measurements made from the middle should still be accurate. Some of the photos were also dark or slightly blurry so that the edges of the tablet and tapes were not always completely sharp, which could cause errors in the measurements. However, this will only cause the measurements to differ with a few pixels, which will not have any major impact on the results. One thing that could cause significant errors though, is the fact that some photos were taken from a slight angle relative to the tablet, so the tablet screen could be seen in the photo. This causes the angle of the tablet to appear larger than it actually is. It is unclear how much this has affected the results.

The interviewees only put the tablet in their favoured position after which they exited the car. There is a risk that the position they choose is not optimal for use over a long time.

Lastly, when the interviewees adjusted the front seat to their favoured driving position there is a risk that they kept the seat more vertical than they usually would due to the fact that the seat back was vertically placed when they entered the front seat.

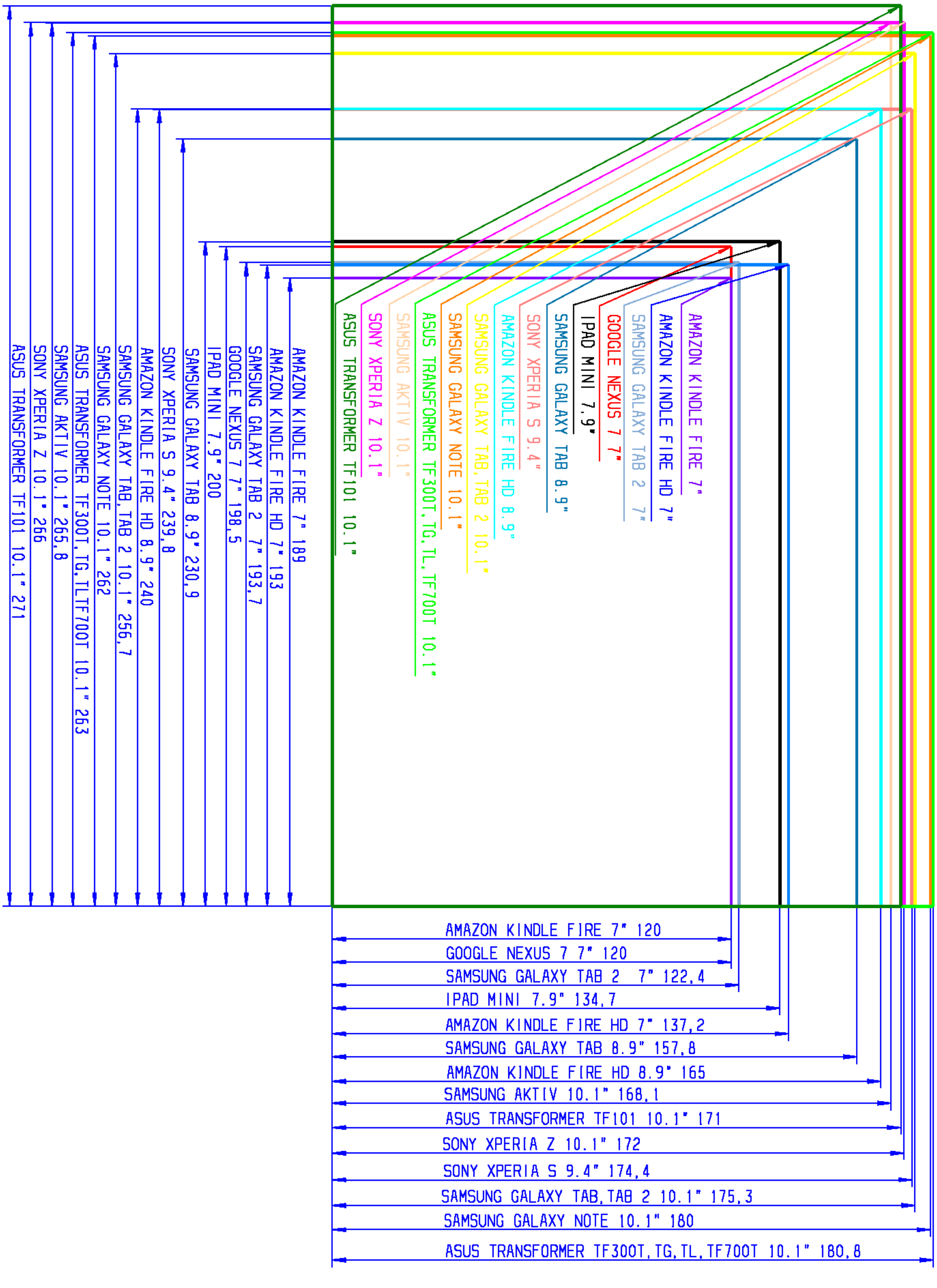
Overall though, the purpose of the observations was not to gather statistical data but rather to show how big the differences can be and how much the position of the tablet changes, and should change, between different users. This in combination with the fact that most sources of error most likely had little effect on the results, they are still considered valid for their purpose.

Measurement			Coordinates (in pixles from upper left coner)									
			Rear head rest		Front head rest		Roof		Tablet bottom		Tablet top	
Car	Nr	Photo	x	y	x	y	x	y	x	y	x	y
V70	1	DSC_0441	286	1433	4701	1169	2872	160	3307	2086	3502	1729
V70	2	DSC_0444	328	1164	4621	1578	3084	366	2772	2608	3320	2064
V70	3	DSC_0445	594	1229	4420	1039	2963	156	2861	1956	3093	1723
V70	4	DSC_0449	723	1161	4490	975	2998	134	2742	2408	3305	2003
V70	5	DSC_0451	605	1096	4219	1052	2867	181	2794	1973	3207	1500
V70	6	DSC_0454	687	1124	4260	1224	2939	333	2964	2212	3206	2002
V70	7	DSC_0457	838	1218	4547	1027	3066	211	2701	2191	3125	1708
V70	8	DSC_0460	253	1425	4605	904	2829	134	2666	2568	3216	2020
V70	9	DSC_0462	187	1408	4458	1025	2709	166	2501	2581	2979	1940
V70	10	DSC_0465	649	965	4725	1194	3201	169	2673	2352	3223	1864
V70 (2006)	11	IMG_0005	381	1453	3157	1414	1732	541	2276	1629	2353	1404
V70 (2006)	12	IMG_0010	407	952	3269	1044	1844	109	1984	1739	2268	1308
V70 (2006)	13	IMG_0013	224	1132	3379	1127	1776	162	1856	2253	2256	1831
V70 (2006)	14	IMG_0018	290	1077	2830	1126	1604	276	1814	1640	2003	1255
V70 (2006)	15	IMG_0019	508	1037	3199	1117	1868	215	1824	1825	2045	1439
V70 (2006)	16	IMG_0020	462	1126	2993	1207	1759	352	1788	1711	1981	1344
V70 (2006)	17	IMG_0022	709	1107	3246	1152	1972	302	2270	1600	2473	1220
V70 (2006)	18	IMG_0025	620	1126	3208	1039	1905	268	1816	1686	1984	1284
V70 (2006)	19	IMG_0026	327	1197	3119	1116	1706	278	1931	1681	2142	1236
V70	20	DSC_0541	650	1188	4638	1074	3087	211	2985	2325	3417	1721
V70	21	DSC_0544	524	1202	4469	1082	2937	249	2800	2325	3321	1819
V70	22	Dsc_0545	752	1445	4411	1156	1983	439	2949	2247	3321	1645

Camera angle	Tablet position (mm)				Seat position	
(radians)	Horisontally		Vertically	Angle	Position	Angle
	From back hea rest	From front	(från taket)	(grader)	(from rear head rest)	(compared to seat)
-0,059725033	799,8397338	300,1602662	359,3486784	57,93382476	841	103,4
0,096138767	763,1031879	336,8968121	410,913296	50,29847187	976	101,2
-0,049619457	717,5945306	382,4054694	443,7596817	42,28023108		
-0,049336094	753,0512627	346,9487373	501,8583772	32,90300149	936	99,3
-0,012174274	791,9169605	308,0830395	390,7307918	48,17662576	884	95,3
0,027980381	775,2072207	324,7927793	484,6187597	42,55357605	908	97
-0,051450912	677,3715175	422,6284825	433,8110707	45,77390458	1013	90,3
-0,119148035	743,610393	356,389607	455,0473282	38,06895669	793	100,9
-0,089435329	716,2082451	383,7917549	414,3156533	48,16347728	994	99,7
0,056123531	693,5578819	406,4421181	429,4487013	44,79741139	969	101,7
-0,014048067	781,3349999	318,6650001	337,5242147	70,30301874	843	102,8
0,032134288	714,8997765	385,1002235	432,2902377	58,45896487		
-0,001584785	708,4618679	391,5381321	533,8970451	46,44229622		
0,019288946	741,7123903	358,2876097	424,6501281	64,95833396		
0,029719972	628,0019981	471,9980019	512,0736544	61,91001479		
0,031992242	659,836028	440,163972	445,2059603	64,0937865		
0,017735625	764,7200746	335,2799254	396,3915772	62,90457447	843	102,8
-0,033604038	579,4253981	520,5746019	433,9820548	65,39407085		
-0,029003326	714,778058	385,221942	361,9629202	62,96992114	904	99,8
-0,028577975	762,9030062	337,0969938	378,3712478	52,78904774	874	103,5
-0,030408874	779,5380476	320,4619524	402,2644557	42,42091737	856	108,8
-0,078819699	769,9170616	330,0829384	317,9682314	53,77037816	939	102,7

Appendix E

Tablet sizes



Appendix F

Target specifications

No.	Requirement	Importance	Target value	Units	From
1	**Legal requirements**				
1.1	Not conflict with any material restrictions or regulations	*		Binary	Laws
1.2	Minimum radii a head can hit during crash	*	5	mm	Laws
1.3	Minimum radii for components for the mount and tablet	*	2.5	mm	Laws
1.4	Maximum head deceleration for a head during crash	*	120	g	Laws
1.5	Maximum head deceleration for longer than 3 ms for a head during crash	*	80	g	Laws
1.6	No local deformations that might be harmful for occupants are allowed after a crash	*		Binary	Laws
1.7	Holds the tablet securely locked in the mount during a crash	*		Binary	Laws, VCC
1.8	No exposed sharp edges during or after a crash	*		Binary	Laws
1.9	All accessories shall remain attached during and after impact	*		Binary	Laws
1.10	Head Injury Criteria (d)	*	1000	HIC	Laws
2	**Volvo Cars Corporation requirements**				
2.1	Usable for a wide variety of commercial tablets	**		%	VCC
2.2	Feels and looks like a Volvo product	**		Subjective	VCC
2.3	Has a premium handling	**		Subjective	VCC
2.4	Has a premium appearance	**		Subjective	VCC
2.5	Not damaged in any way during normal handling	**		Binary	VCC
2.6	Has a linear, soft, muffled damped and non-chafing motions	4		Subjective	VCC
2.7	Consistent forces over the operation	3		N	VCC
2.8	Fits VCC's interface	**		Binary	VCC
2.9	Withstands VCC's standard tests	**		Binary	VCC, Interviews
2.10	Resistant to common chemicals and substances that are regularly used in the car	**		Binary	VCC
2.11	No corrosion	**		Ocular	VCC
2.12	Does not loose functionality over time	**		Binary	VCC
2.13	No unwanted sounds during normal operation	**		Aural	VCC

No.	Requirement	Importance	Target value	Units	From
3	**User requirements**				
3.1	Headphone socket accessible	5		Binary	Interviews, VCC
3.2	Buttons accessible	5		Binary	Interviews, VCC
3.3	Sound distortion	2		Subjective	Interviews
3.4	Volume deviation	2		dB	Interviews
3.5	Wifi performance	4		%	Interviews
3.6	Bluetooth performance	4		%	Interviews
3.7	Charging accessible	4		Binary	Interviews, VCC
3.8	Mic and front camera performance	2		Subjective	Interviews
3.9	Prevent reflections on screen	2		Subjective	Interviews, VCC
3.10	Optimal initial angle for average user	3	57	Degrees	Interviews, Observation
3.11	Optimal initial position for average user	3	300	mm	Interviews, Observation
3.12	Design coherent with VCC's interior design	4		Subjective	Interviews, VCC brand identity
3.13	Aesthetically appealing	4		Subjective	Interviews, Project Group
3.14	Unit manufacturing cost	5	< 1000	SEK	Interviews, Project Group
3.15	Tilt adjustment range	4	± 30	Degrees	Interviews, Observation
3.16	Minimum vibration while typing on the tablet	4		Subjective	Interviews
3.17	Instils safety	4		Subjective	Interviews, VCC brand identity
3.18	Time to mount and dismount tablet	4	2-8	s	Interviews, VCC, Project Group
3.19	Instils quality	4		Subjective	Interviews, Project Group
3.20	Tablet flexibility range for the mount	4	Height: 180-280 Width: 110-190	mm	Market study
3.21	Time to adjust mount for different tablet sizes	3		s	Interviews

No.	Requirement	Importance	Target value	Units	From
4	**Design requirements**				
4.1	Holds as high quality as the rest of the car's interior	5		Binary	VCC Brand Identity
4.2	Intuitive to use	3		Subjective	VCC Brand Identity
4.3	Functionally robust	5		%	Project Group
4.4	Aesthetically robust	4		%	Project Group
4.5	Uses standard components	3***		%	Project Group
4.6	Designed to allow for variance in production	4***		%	Project Group
4.7	Does not have negative effects on the driver	5		Binary	Project Group
4.8	Has as few components as possible	4		Number	Project Group
4.9	Has as simple shapes as possible	2		Subjective	Project Group
4.10	Has a simple product architecture	2		Subjective	Project Group
4.11	Contains as few different materials as possible	2***		Number	Project Group
4.12	Easy to assemble	2		s	Project Group
4.13	No hazardous contamination during the life cycle	5***		g/m^2/year	Project group, VCC
4.14	Made from materials and manufacturing processes with low environmental impact	4***		ELU	Project group, VCC
4.15	Low environmental impact after product life	2***		%	Project group, VCC
4.16	Recyclable	2***		%	Project group, VCC
5	**Strength requirements**				
5.1	Withstand a force to the side without any plastic deformations	****	443	N	Project group, Interview
5.2	Withstand a force in the direction of the arm without any plastic deformations	****	160	N	Project Group
5.3	Withstand a force in direction xxx without any plastic deformations	****	*****	N	Project Group

* Laws and regulations have to be met and are not graded in importance
** Requirements from VCC that have to be fulfilled
*** Requirements for detailed construction (irrelevant for early concept evaluation)
**** Requirements from the Project Group
***** Cannot be explained due to confidentiality reasons

Appendix G

Morphological matrix

Connection to interface	Attachment	Flexibility
Velcro	Band	Elastic
Non-permanent glue	Flexible arms	Springs in structure
Nothing	Non-permanent glue	Deformable
Magnet	Clamping supports	Threaded rods
Snap function	Clamps	Separate, built-in solutions for different sizes
Suction cup	Cushion	Nothing
Screwed	Magnets	Module-based
Glue + solvent	Glue + solvent	Different attachment locations
Rigid	Case	Adjustable band
Clamp	Slot	Automatic roll
Straps	Suction cup	Manual roll
	Resting supports	Rail system
	Clamping frame	Slidable in track
		Track with springs
		Telescopic inwards
		Telescopic in tablet's plane with springs
		Telescopic in tablet's plane with gears
		Telescopic in tablet's plane with, manual
		Telescopic along rigid structure
		Rotatable parts in tablet's plane
		Attached to frame

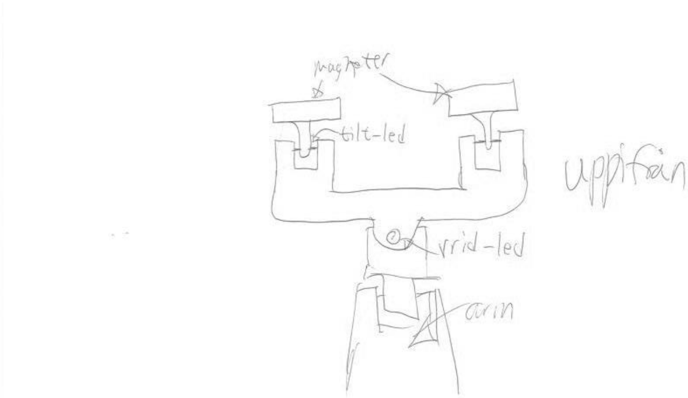
Mount/Dismount	Cover edges	Allow access to buttons & sockets
Direct lever	Hashtag	Bend away
IKEA-lock	Straps along the edges	Zippers along the sides
Fitting	Pulls away the mount	Does not cover sides, only corners
Button, pushable	Vacuum cleaner function in neck	Holes adapted to common tablets
Button, sliding	Accordion frame	Holes with slidable partitions
Button, pullable	Elastic frame	Nothing
Ski boot function	Rigid frame in front of tablet	Bend away or push through
Rotary control	Rigid frame in tablet's plane	Awesome viscoelastic material
Rotary control with lever	Helmet	Modular with holes
Rotary control with button	Edge protection tape	Slidable windows
Force	Thick, short arms	User punches holes
Ski binding	Airbag	Large holes along the sides
	LL	Separable structure
	Air pulse	VHS-hatches
	Long arms along the edges	Hatches opening outwards
	Modular frame	Adjustment of structure
	Modular case	
	Several point coverages	
	Many short arms	
	Headbands attached to seat	
	Frame module	
	Screen in front of tablet	
	Telescopic arms-frame	
	Tilts the tablet 180 degrees at crash	
	Cover edges when crash-function	
	Intercept head when crash	
	Stretched frame	
	Structure extends along the sides	

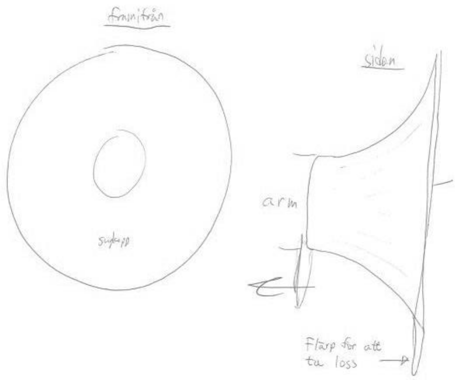
Appendix H

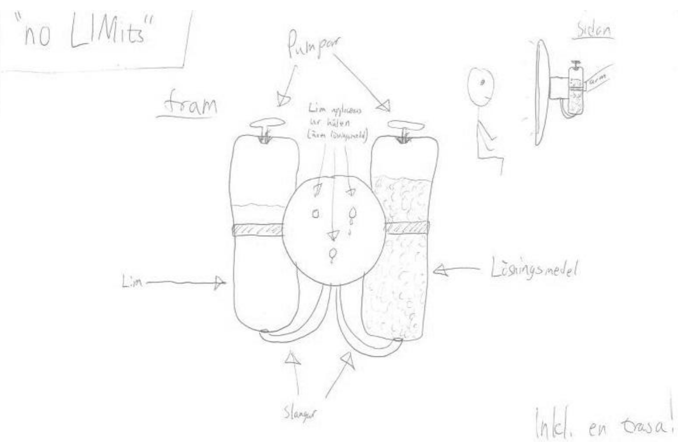
Concepts discarded in the initial screening

The concepts in this section were discarded during the initial screening.

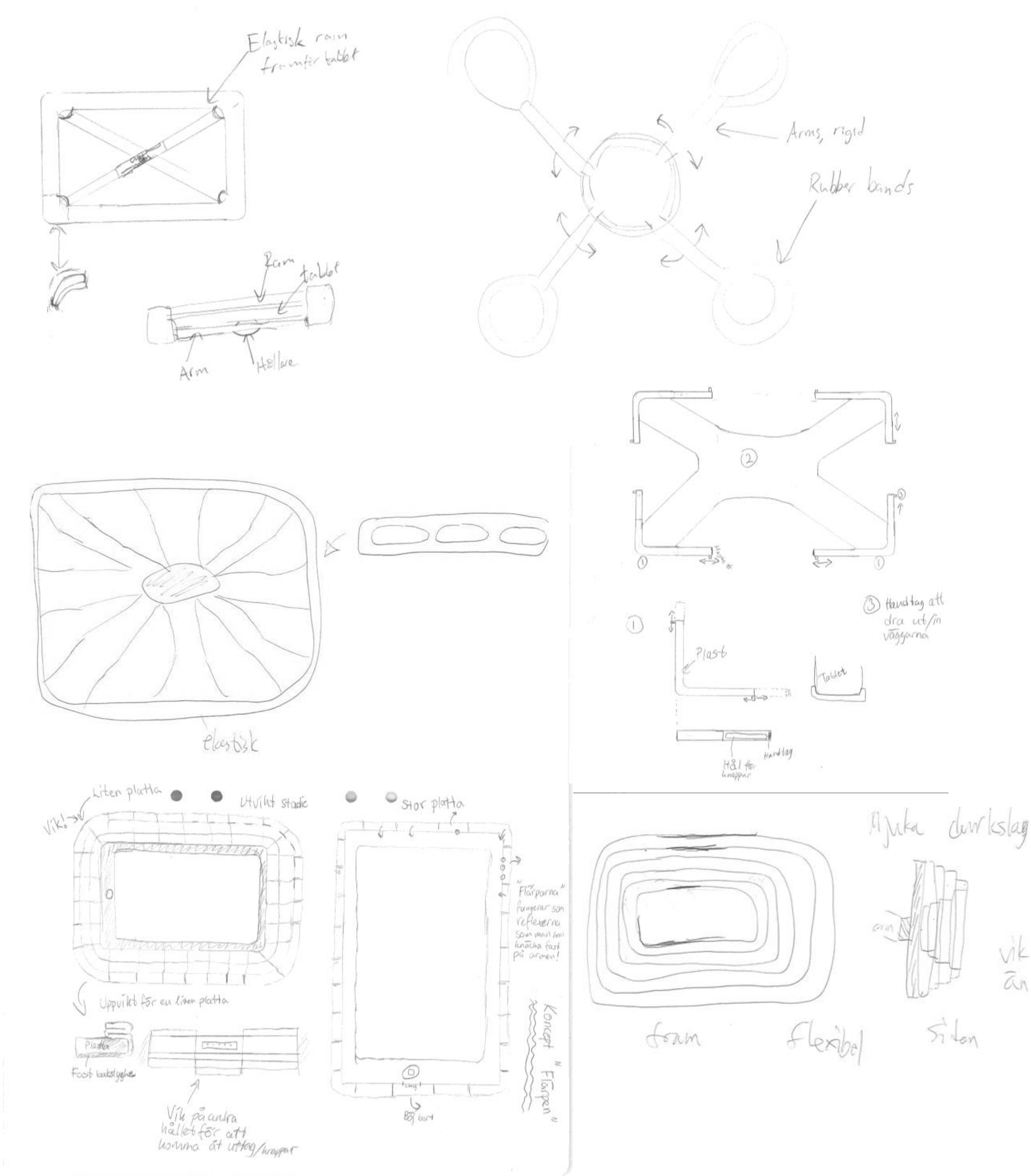
Back-attachment mounts



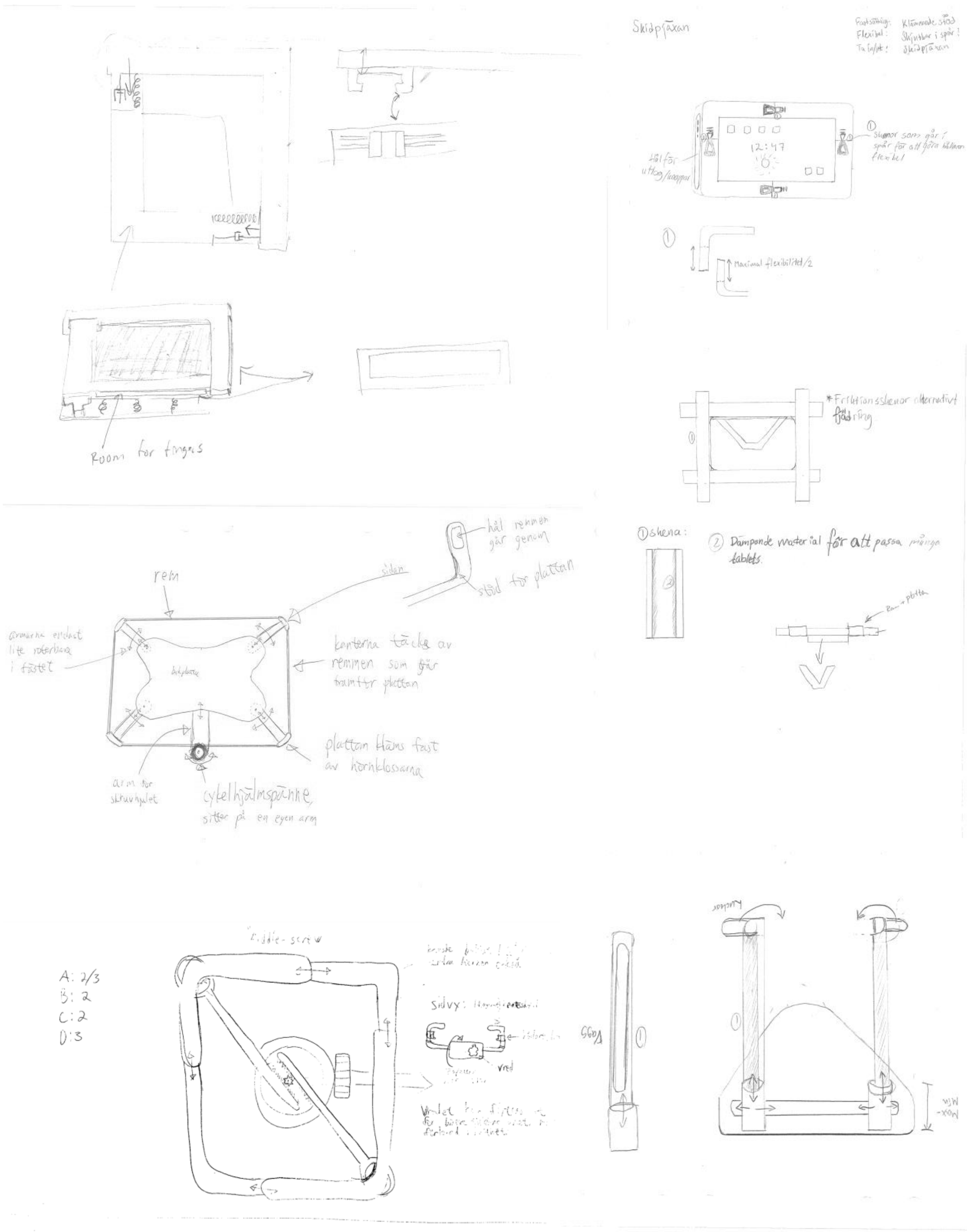


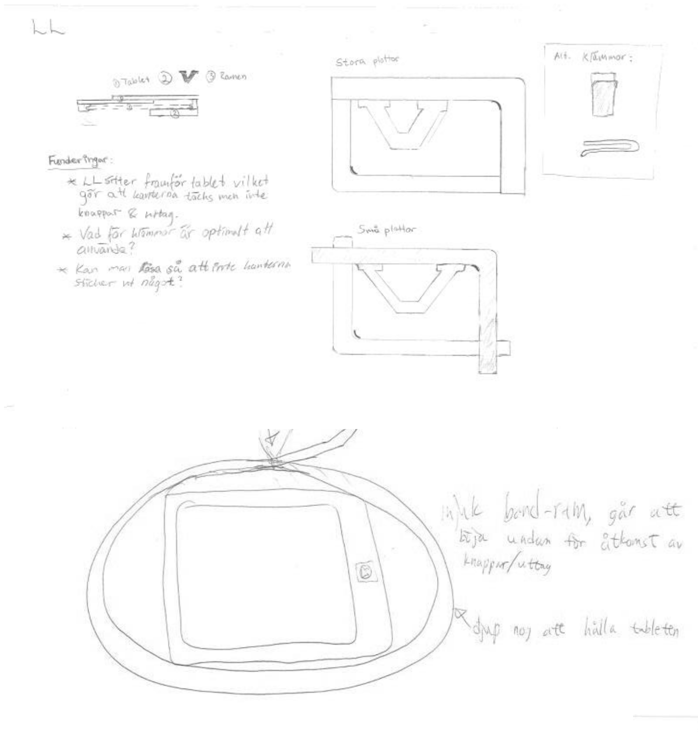


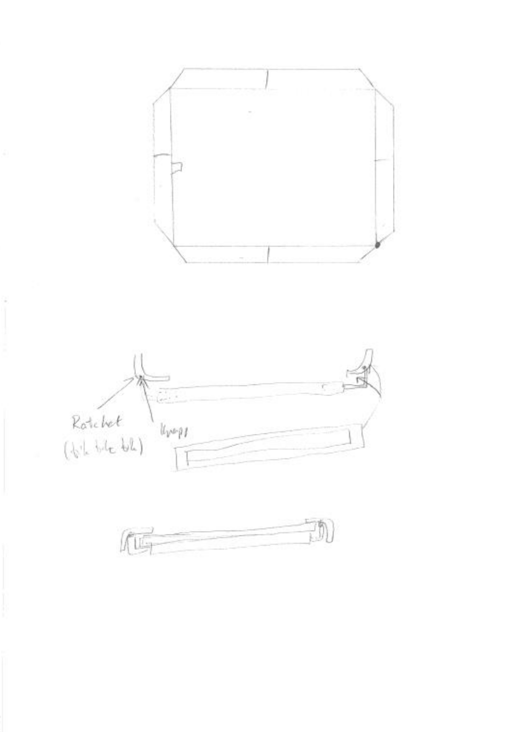
Deformable mounts

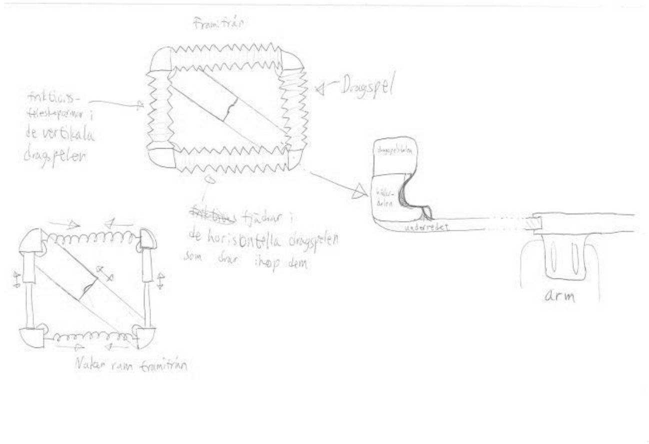


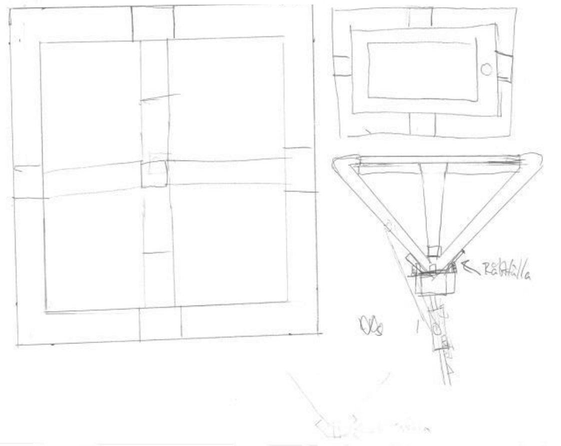
Flexible mounts

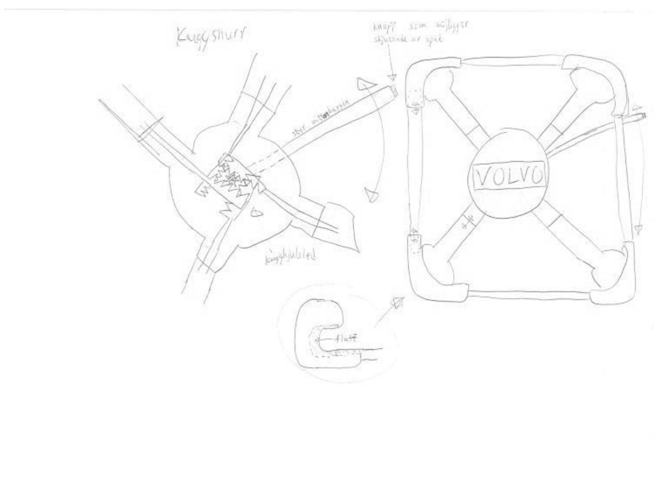


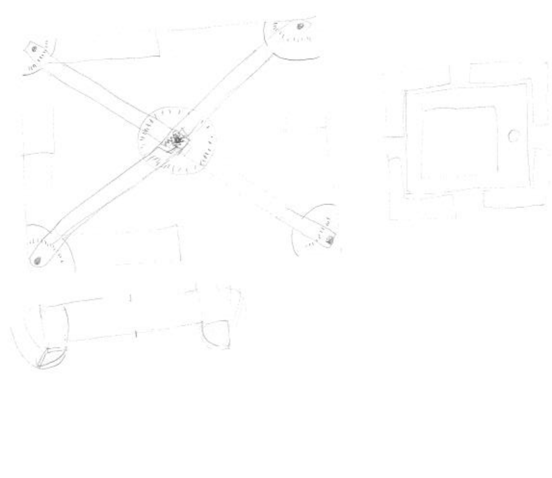

LL
Stora plattor
Alt. Klämmor:
Små plattor
Funderingar:
* LL sitter framför tablet vilket gör att kanterna täcks men inte knappar & uttag.
* Vad för klämmor är optimalt att använda?
* Kan man lösa så att inte kanterna sticker ut något?
Mjuk band-ram, går att böja undan för åtkomst av knappar/uttag
djup nog att hålla tabletten

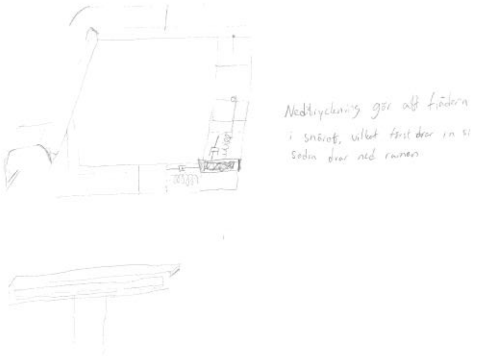

Rotchet
Knapp

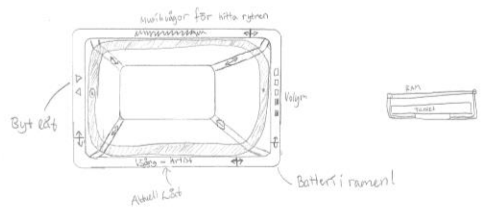

Framifrån
Dragspel
friktions-teleskoprör i de vertikala dragspelen
fjädrar i de horisontella dragspelen som drar ihop dem
arm
Naken ram framifrån

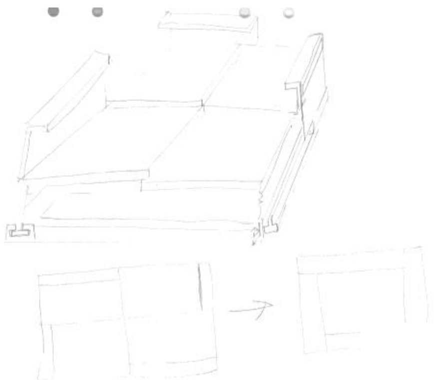


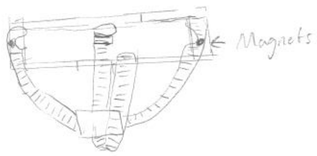

VOLVO
fluff

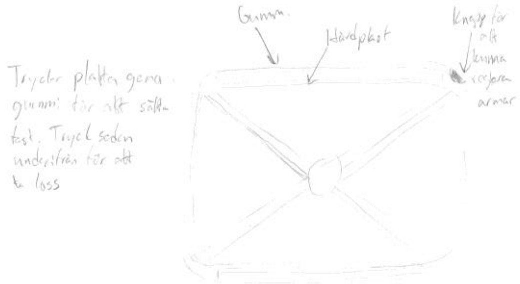


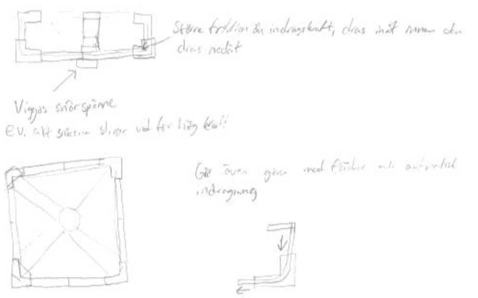

Nedtryckning gör att fjädern
i snävet, vilket först drar in si
sedan drar ned ramen

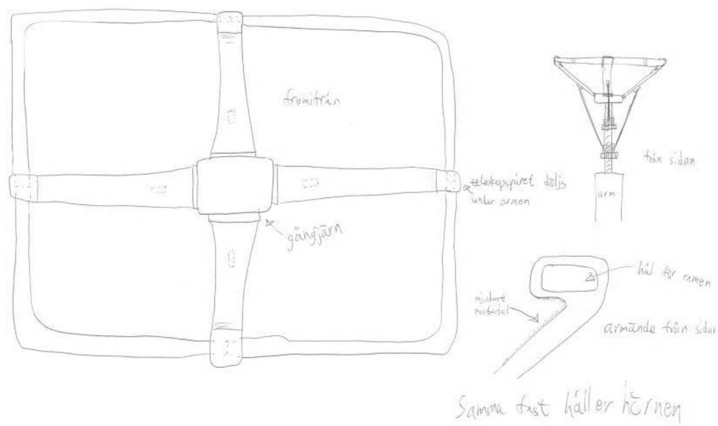

för hitta rytmen
Byt låt
Volym
Batteri i ramen!
Låt – Artist
Aktuell Låt



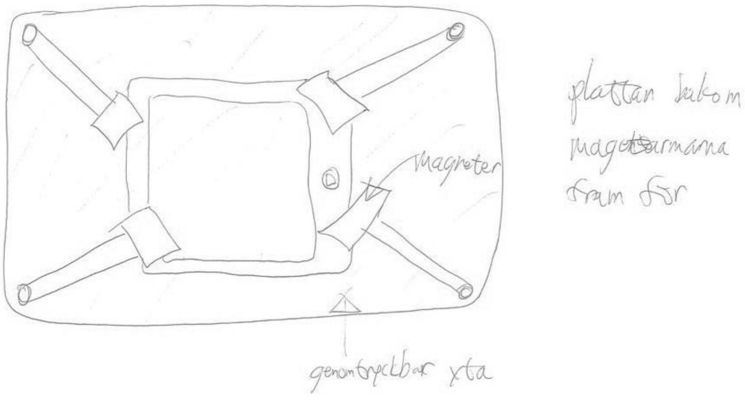

Magnets


Gummi
Hårdplast
Trycker plattan genom
gummi för att sätta
fast. Tryck sedan
underifrån för att
ta loss

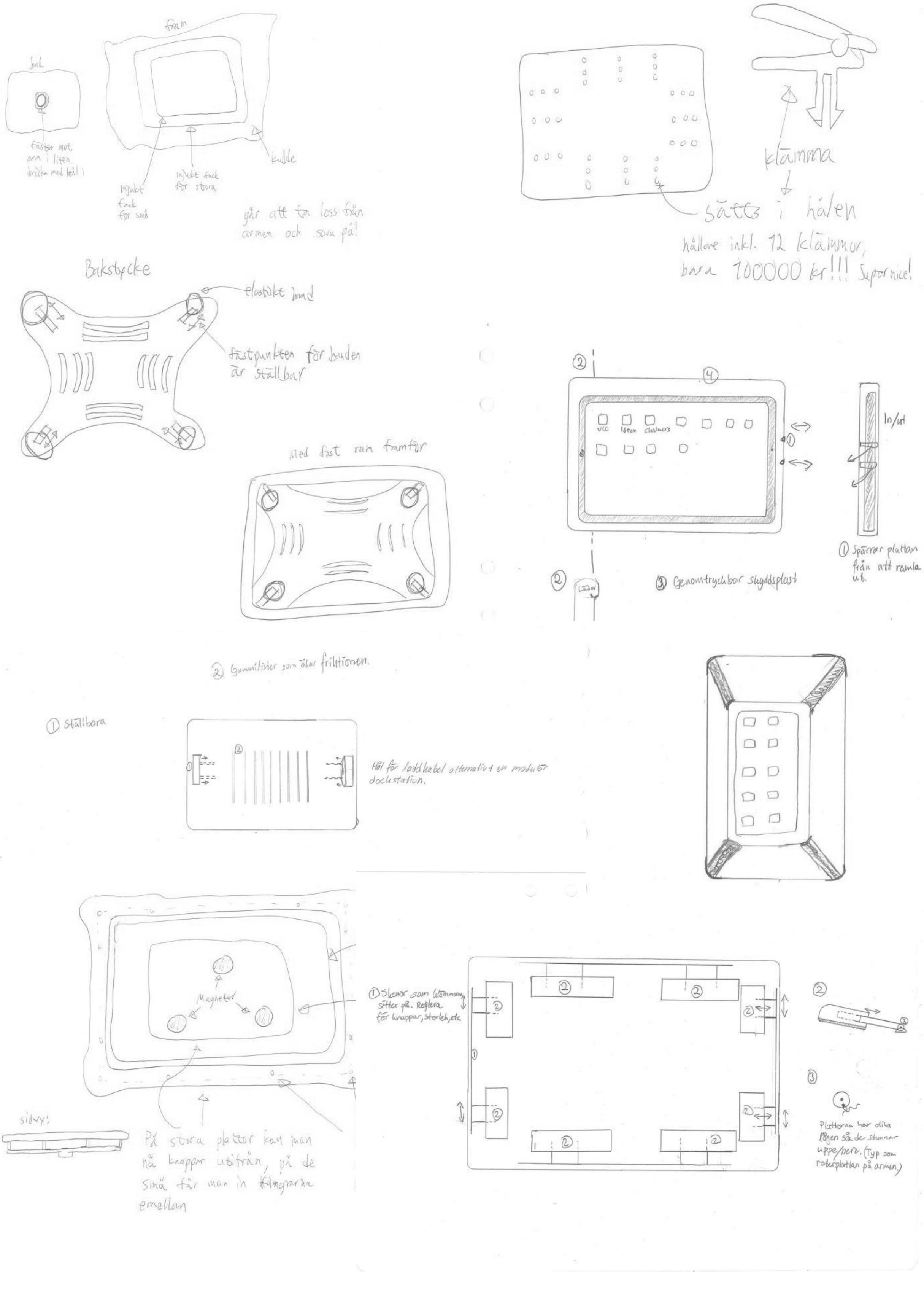

dras nedåt


Framifrån
gångjärn
teleskopspåret döljs
under armen
från sidan
arm
hål för ramen
armände från sidan
Samma fast håller hörnen

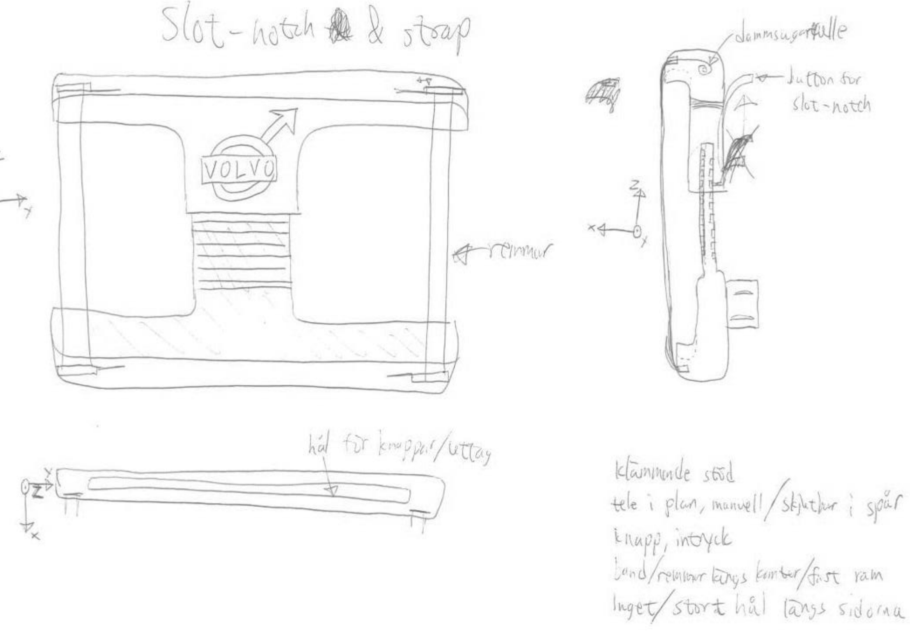
Point attachment mounts

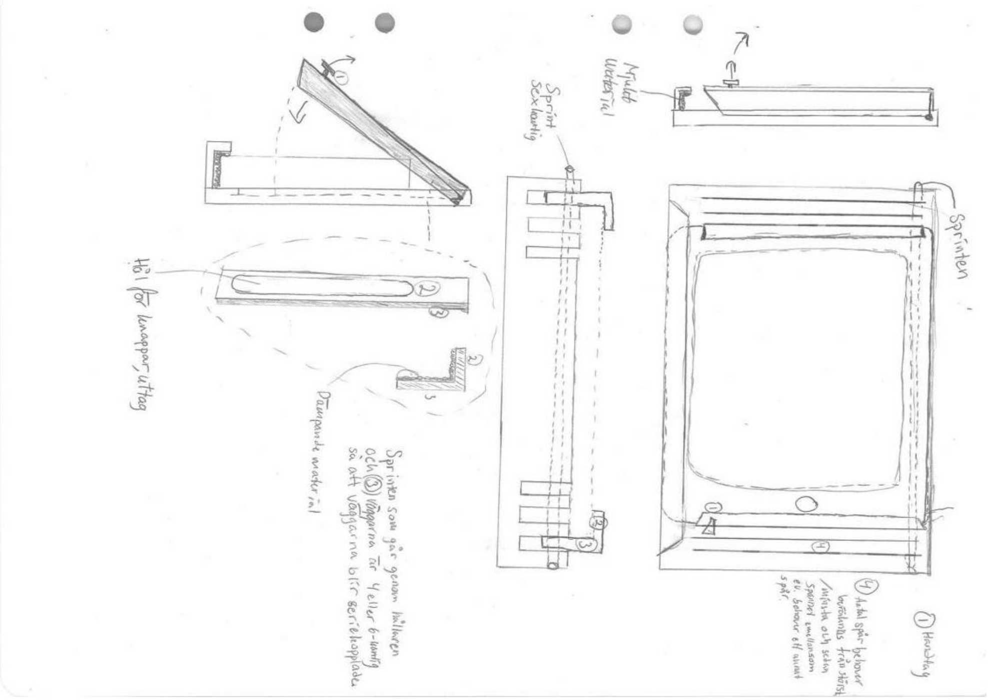


Rigid frame mounts



Semi-flexible mounts





Appendix I

Screening matrix

No.	Requirement	Judgement criteria	Covered requirements
1	Crash safety	Coverage of edges, secure holding, unsafe deformations, protrusion	1.2-1.9, 3.29
2	Aesthetically appealing	Coherent with Volvo's design, instils quality/safety, good looking	2.2-2.4, 3.12, 3.17-3.19, 4.1, 4.4
3	Ease of use and flexibility	Intuitiveness, time, simplicity in use, range of flexibility	2.1, 3.18, 3.20, 3.21, 4.2, 4.3
4	Physical robustness	Strength, fastening strength, structural stability, stability in usage	2.5-2.7, 2.12, 3.16, 4.3, 5.1-5.3
5	Simplicity	Number of parts, complexity of connections	3.14, 4.5, 4.8, 4.9, 4.10, 4.11, 4.12
6	Accessibility to buttons/sockets	Charging, audio, volume buttons, on/off, home button, speakers	3.1-3.8
			Sum+
			Sum0
			Sum-
			Net score
			Rank
			Continue?

The row called *continue?* show which concepts were discarded, combined or chosen for further refinement:

R: The concept was for further refinement

N: The concept was discarded at this stage

C#: The concept was combined with the other concept with the same number.

FL13	FL1	FL2	FL3	FL4	FL5	FL6	FL7	FL8	FL9	FL10	FL11	FL12	FL14	FL15	FL16	FL17	FL18	FL19	FL20	P1	P2	FA1	FA2	FA3	FA4	FA5	FA6
0	0	-1	0	1	1	0	1	1	-1	-1	-1	1	1	1	0	0	0	1	-1	-1	-1	1	0	0	-1	-1	-1
0	-1	-1	1	-1	1	1	-1	-1	-1	-1	0	1	0	0	1	-1	0	-1	-1	-1	0	0	0	0	-1	0	-1
0	1	0	-1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	1	-1	-1	0	0	0	1	1	1	-1
0	-1	0	1	0	1	0	0	0	-1	0	-1	1	0	1	0	0	1	0	0	-1	0	1	1	1	1	1	0
0	1	0	-1	-1	-1	-1	-1	1	0	1	1	-1	-1	-1	-1	-1	-1	0	1	-1	1	1	0	-1	1	1	1
0	1	0	0	1	-1	-1	1	-1	0	-1	1	-1	1	0	0	0	-1	0	1	0	1	-1	-1	-1	-1	-1	1
	3	0	2	3	3	2	2	2	1	1	2	3	3	3	2	1	2	2	2	0	2	3	1	2	3	3	2
	1	4	2	1	1	2	2	2	2	2	2	1	2	2	3	3	2	3	1	1	3	2	4	2	0	1	1
	2	2	2	2	2	2	2	2	3	3	2	2	1	1	1	2	2	1	3	5	1	1	1	2	3	2	3
0	1	-2	0	1	1	0	0	1	-2	-2	0	1	2	2	1	-1	0	1	-1	-5	1	2	0	0	0	1	-1
3	2	5	3	2	2	3	3	2	5	5	3	2	1	1	2	4	3	2	4	7	2	1	3	3	3	2	4
R + C2	R	N	N	C2	C3	C3	R	R	N	N	N	R	R	R	R	N	R	R	N	N	R	R	C1	C1	N	N	N

FA7	FA8	FA9	FA10	D1	D2	SE1	SE2	SE3	SE4
-1	-1	0	0	0	0	-1	-1	0	0
1	0	-1	-1	-1	0	1	0	-1	1
1	-1	1	1	-1	-1	1	1	1	1
1	1	1	0	-1	-1	1	1	0	1
1	1	1	1	1	1	1	0	0	0
-1	0	0	-1	-1	1	-1	-1	-1	-1
4	2	3	2	1	2	4	2	1	3
0	2	2	2	1	2	0	2	3	2
2	2	1	2	4	2	2	2	2	1
2	0	2	0	-3	0	2	0	-1	2
1	3	1	3	6	3	1	3	4	1
R	N	N	N	N	N	R	N	N	R

Appendix J

Concepts discarded after the screening matrix

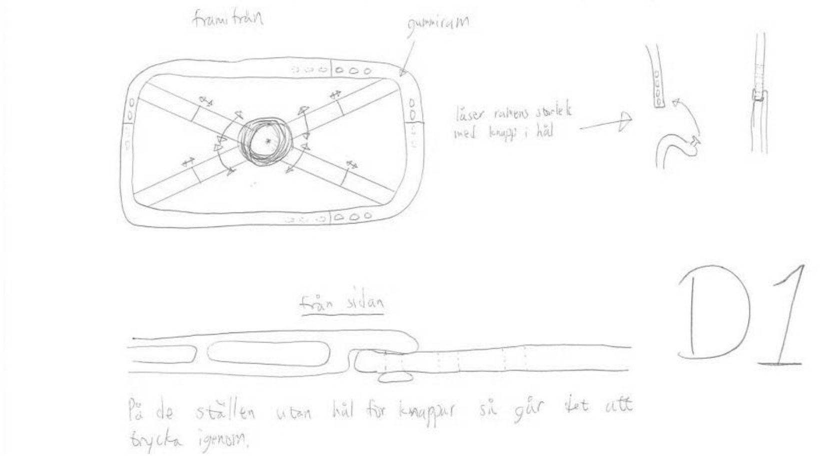


Figure J.1 - Concept D1

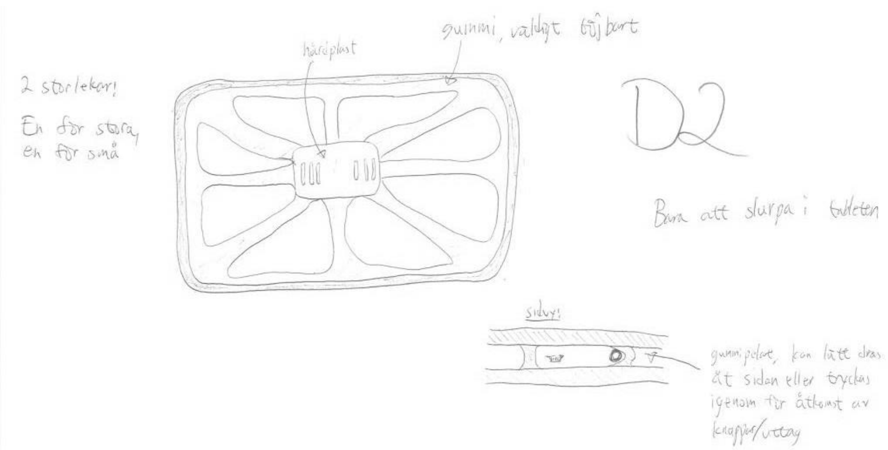


Figure J.2 - Concept D2

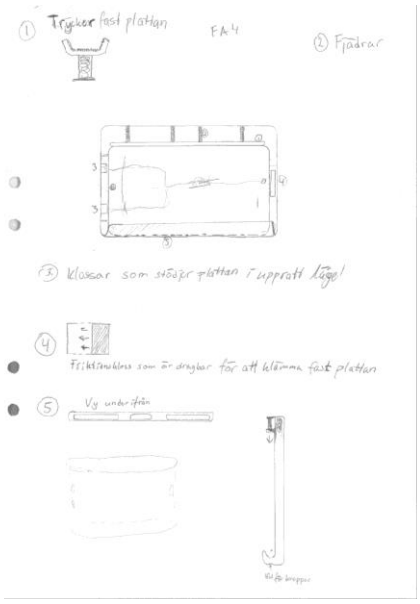


Figure J.3 - Concept FA4

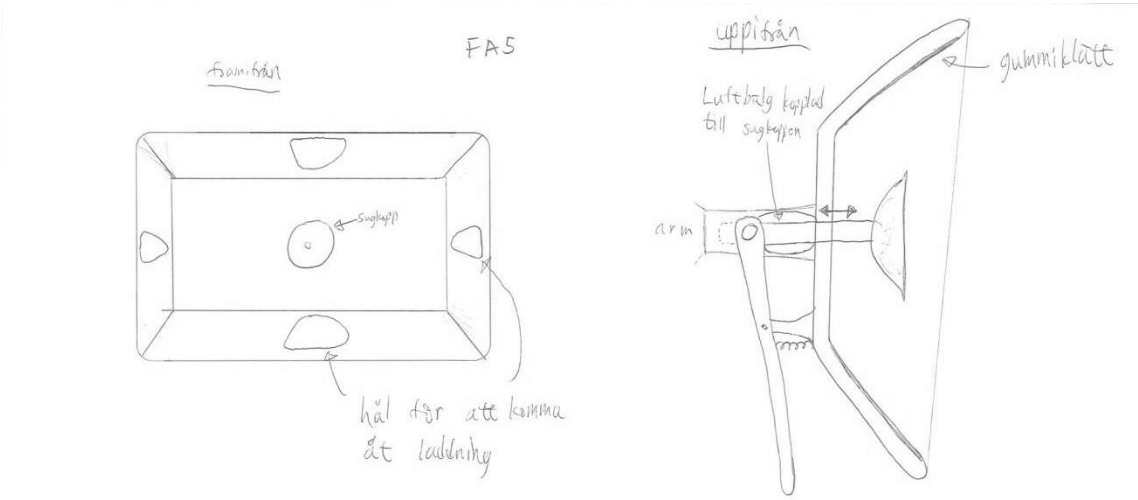


Figure J.4 - Concept FA5

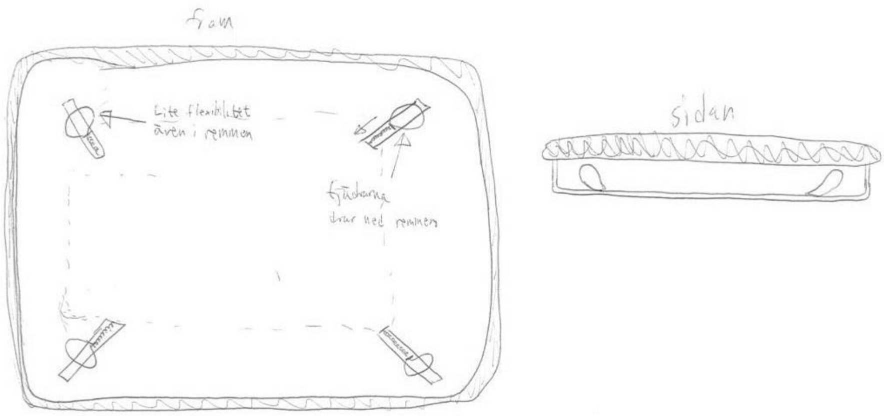


Figure J.5 - Concept FA6

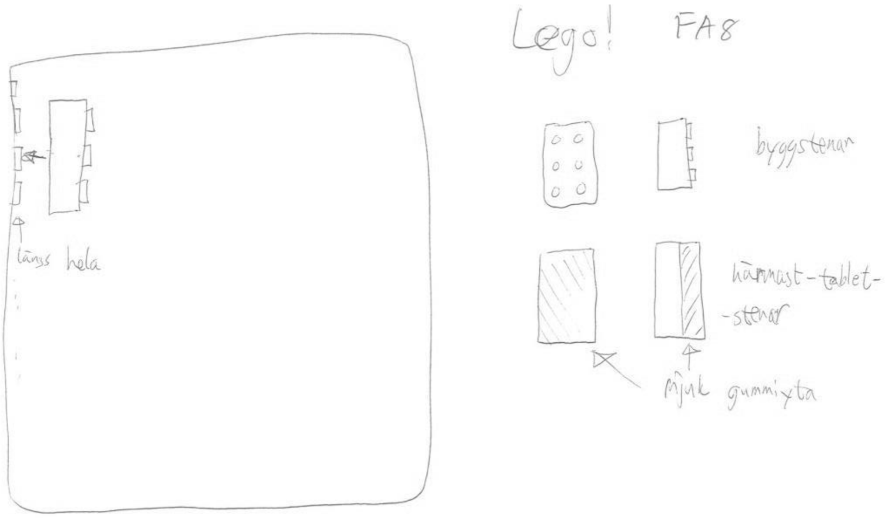


Figure J.6 - Concept FA8

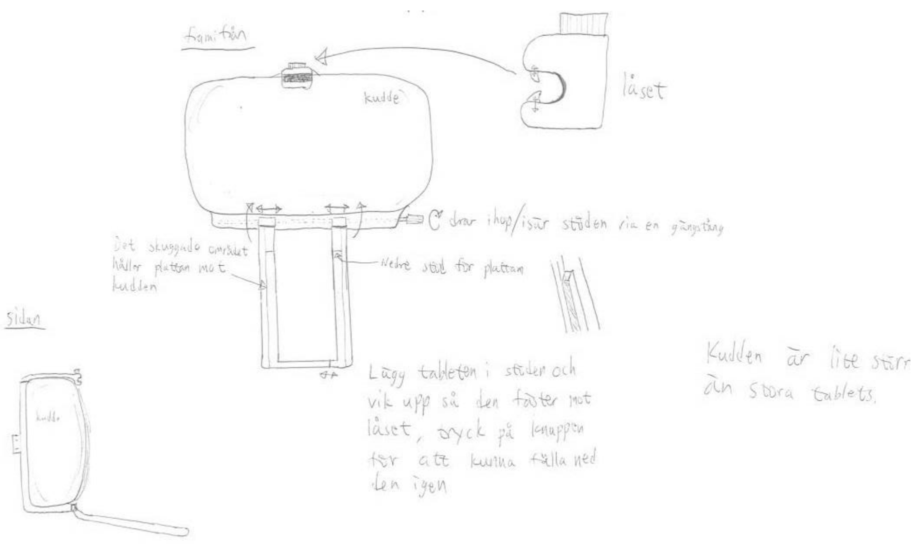


Figure J.7 - Concept FA9

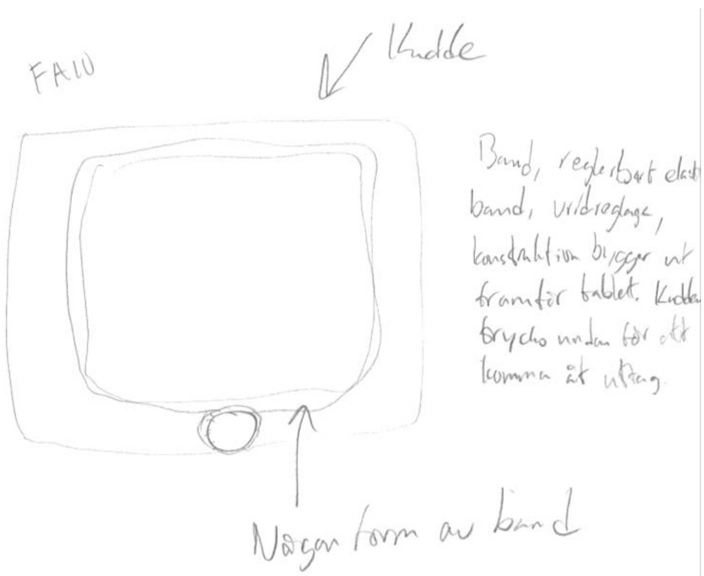


Figure J.8 - Concept FA10

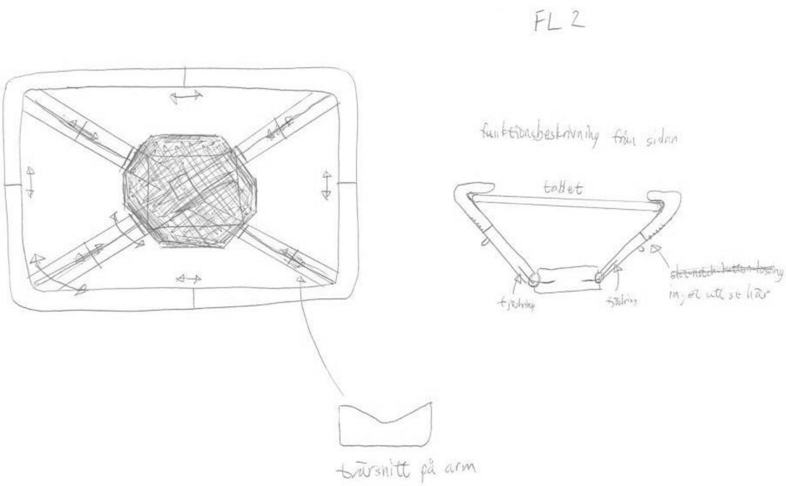


Figure J.9 - Concept FL2

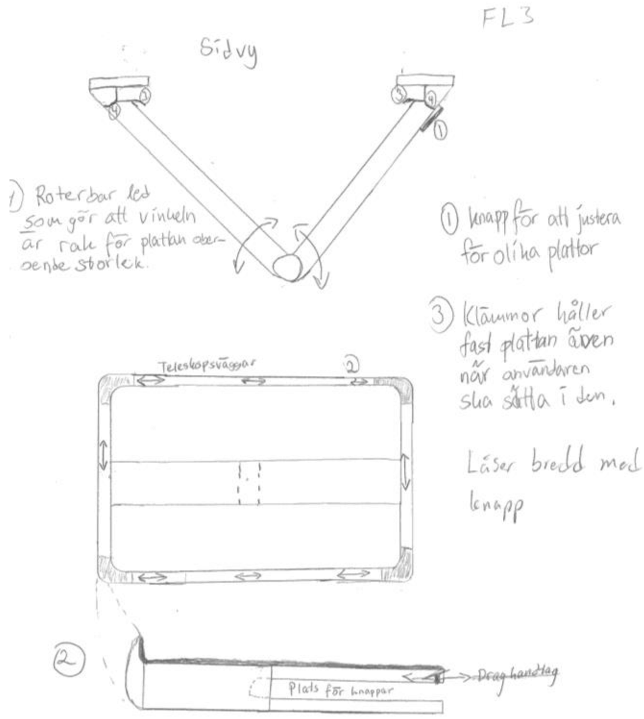


Figure J.10 - Concept FL3

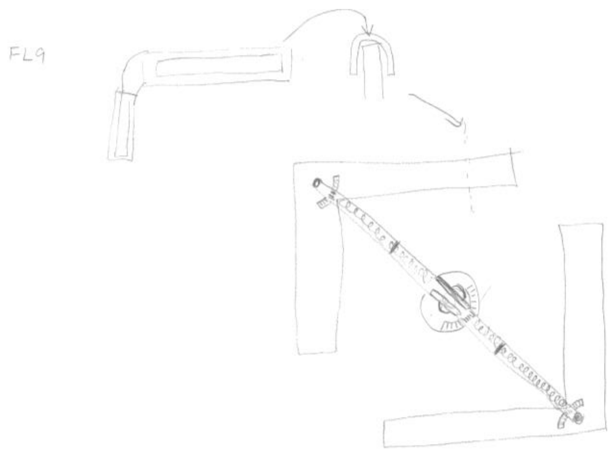


Figure J.11 - Concept FL9

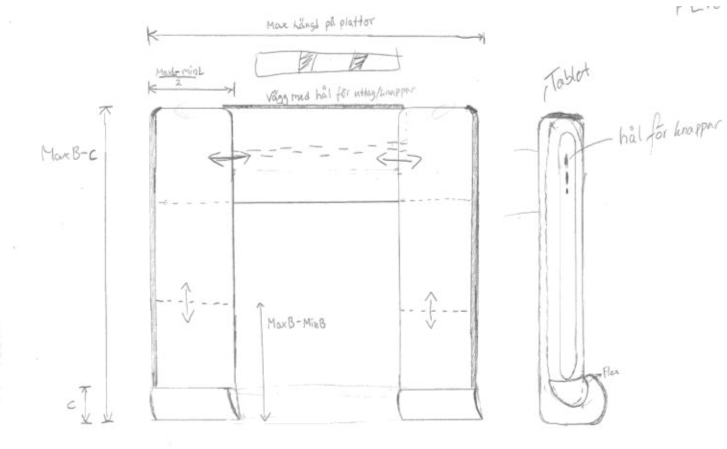


Figure J.12 - Concept FL10

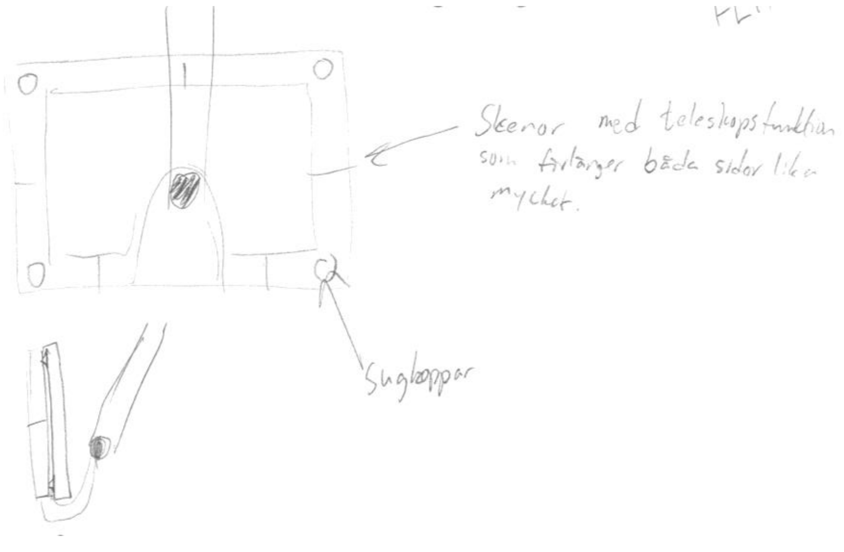


Figure J.13 - Concept FL11

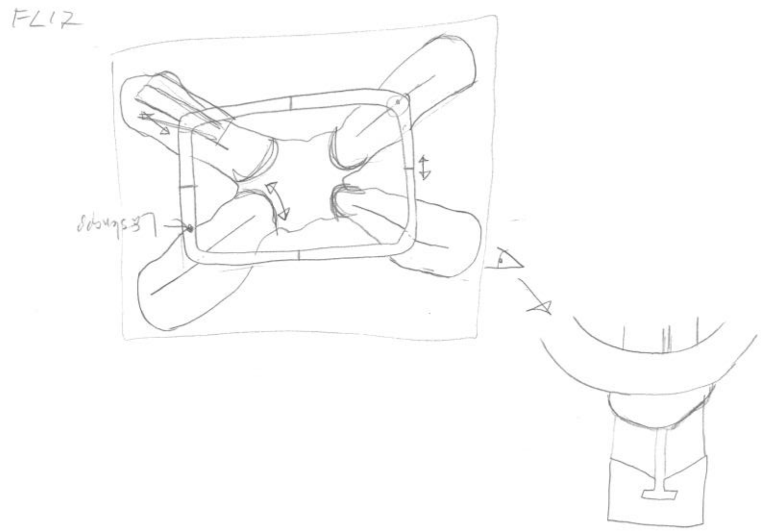


Figure J.14 - Concept FL17

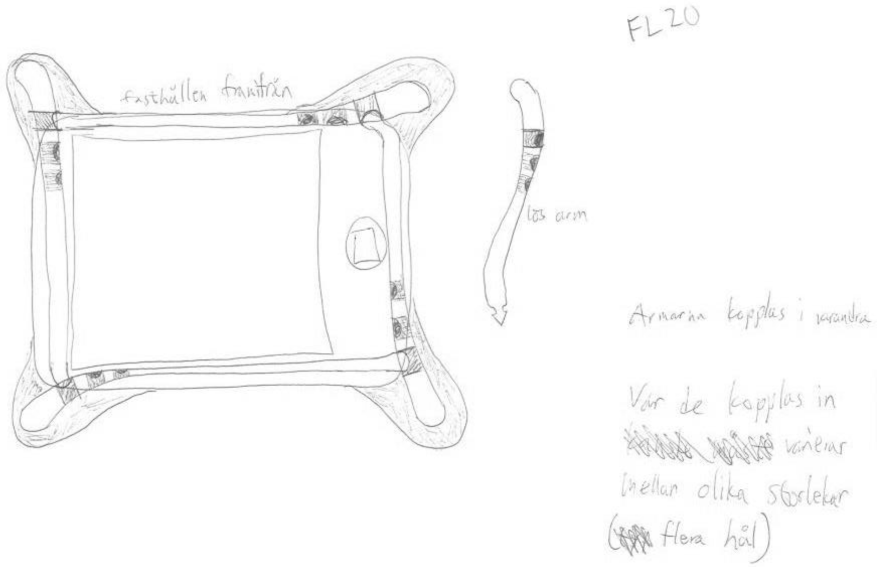


Figure J.15 - Concept FL20

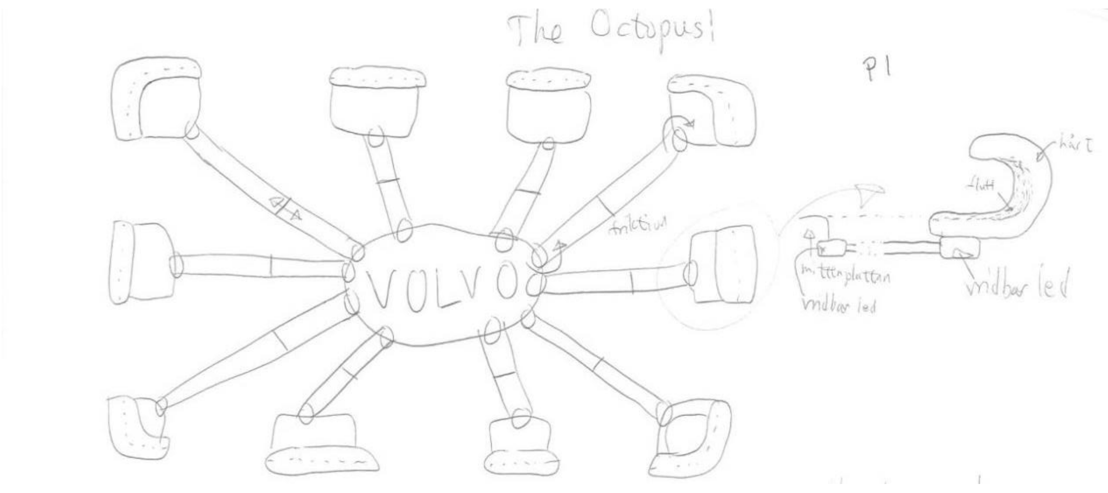


Figure J.16 - Concept P1

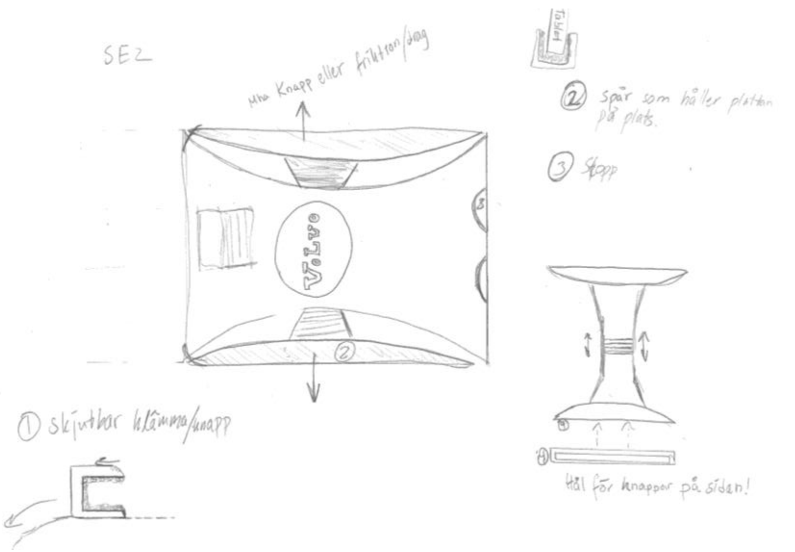


Figure J.17 - Concept SE2

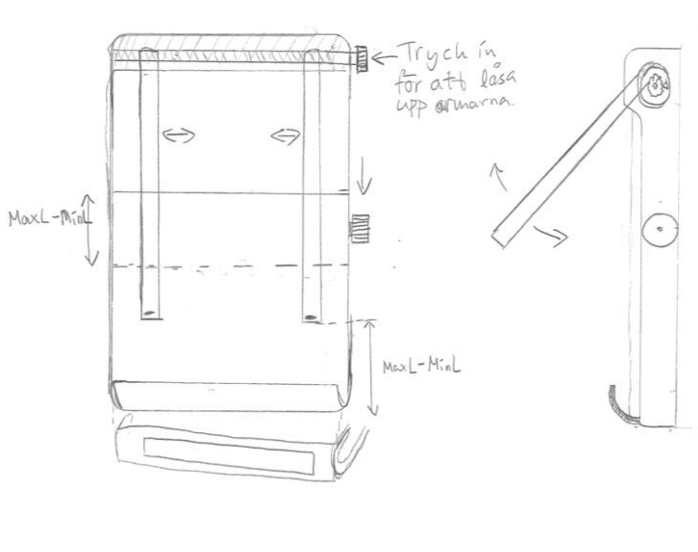


Figure J.18 - Concept SE3

Appendix K

Concepts kept after the screening matrix

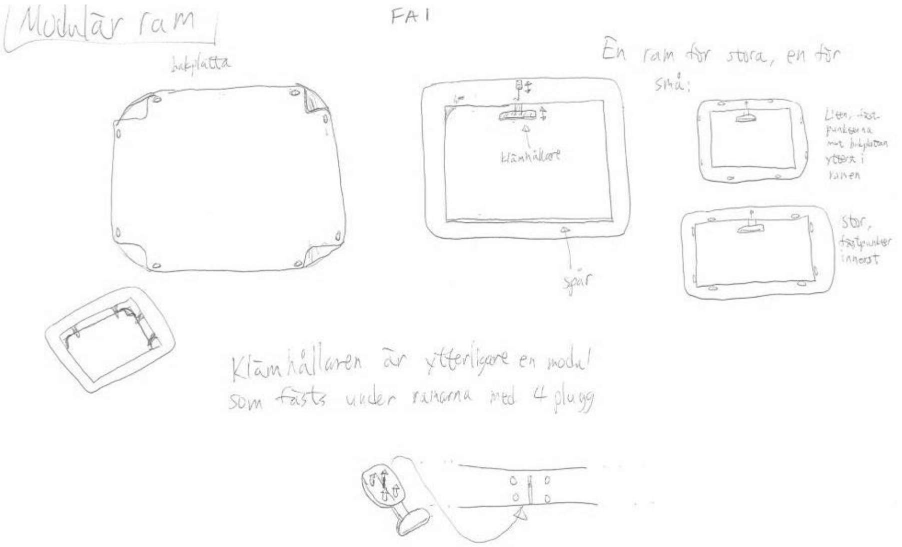


Figure K.1 - Concept FA1

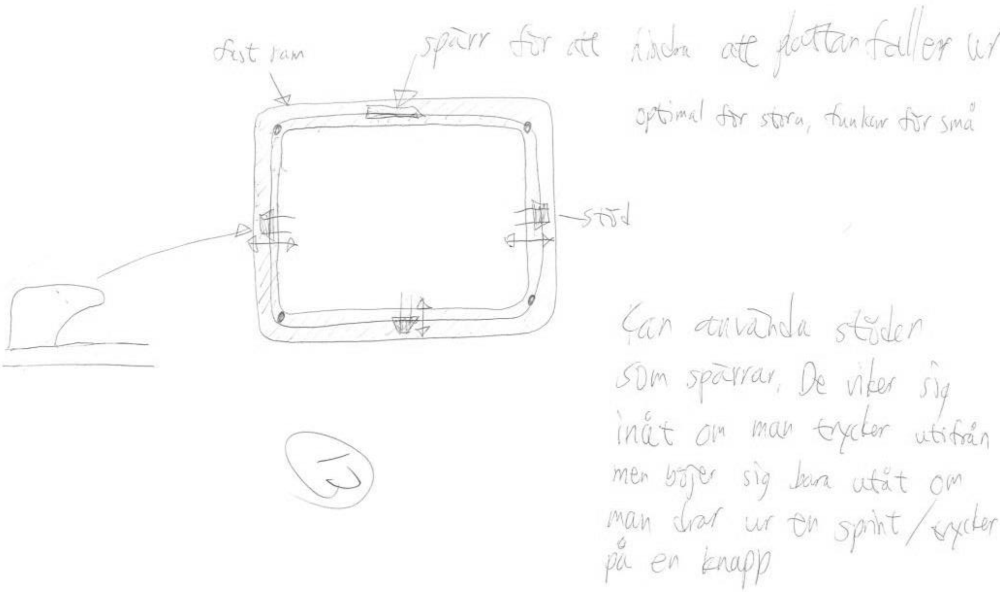


Figure K.2 - Concept FA2

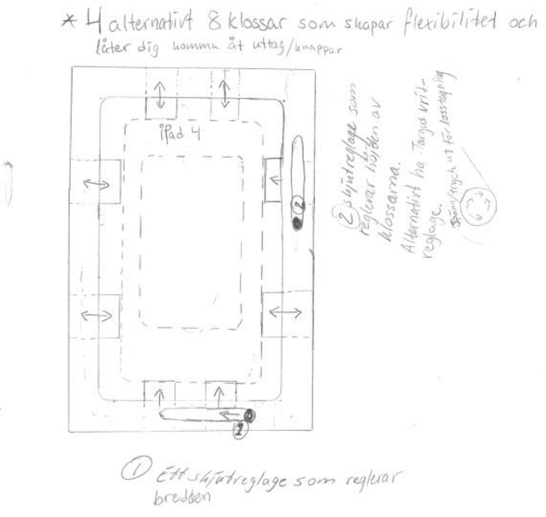


Figure K.3 - Concept FA3

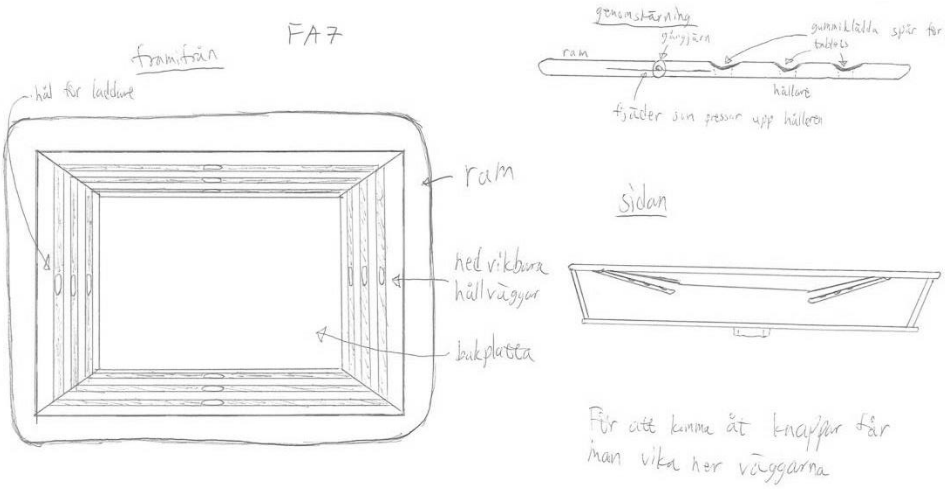


Figure K.4 - Concept FA7

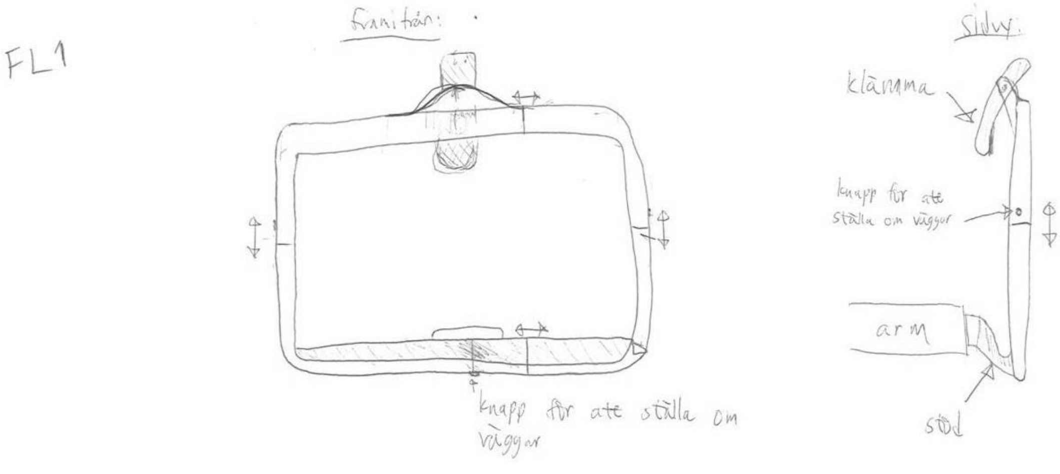


Figure K.5 - Concept FL1

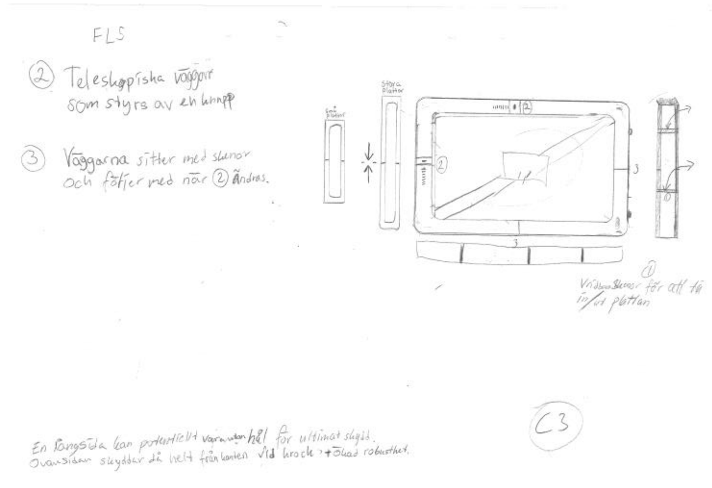


Figure K.6 - Concept FL5

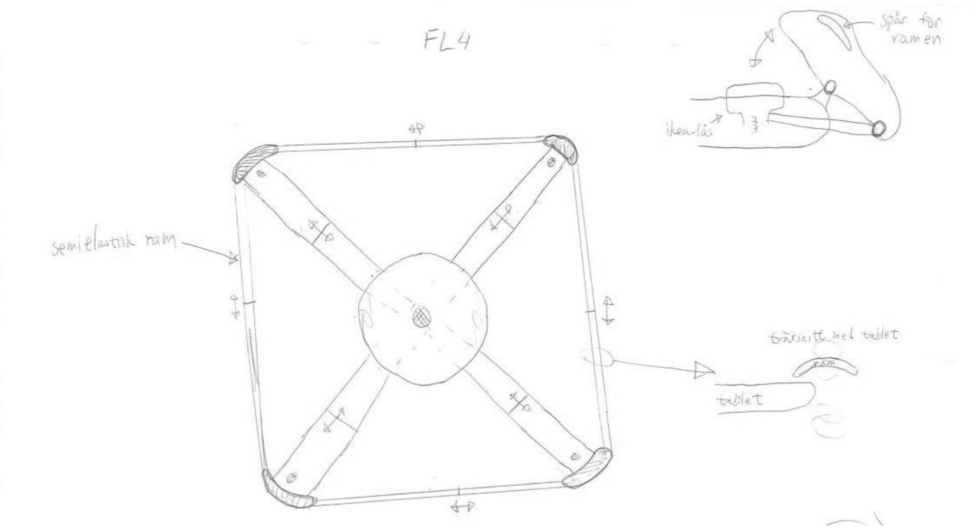


Figure K.7 - Concept FL4

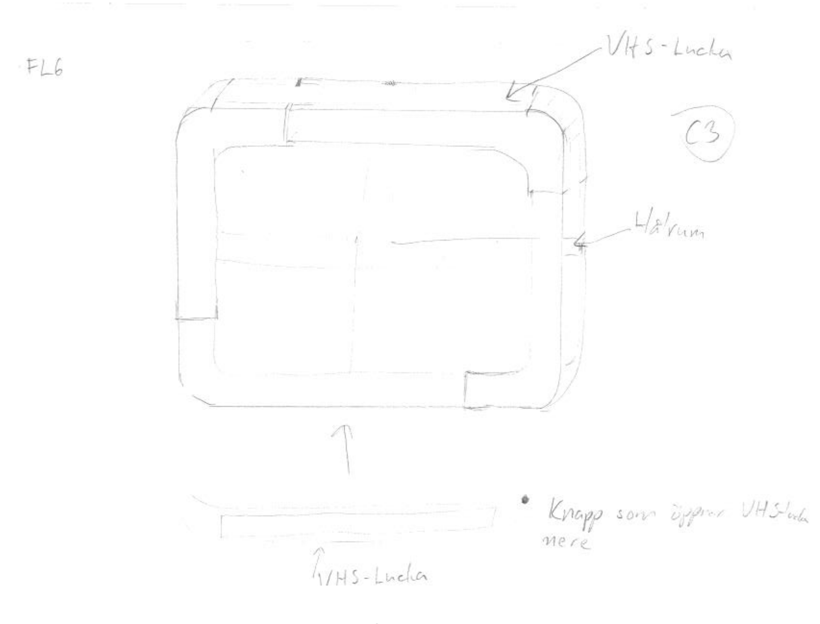


Figure K.8 - Concept FL6

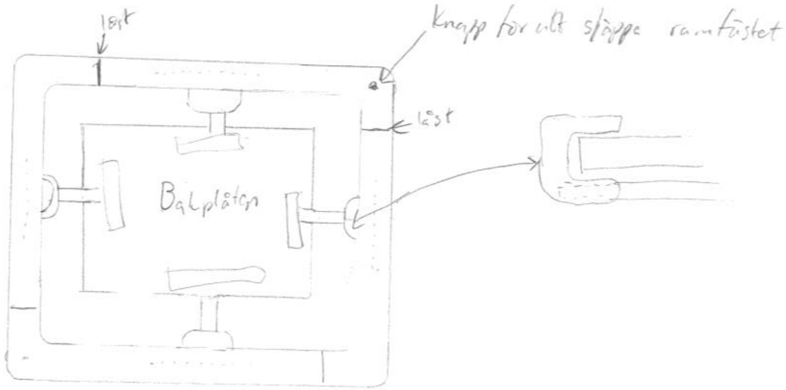


Figure K.9 - Concept FL7

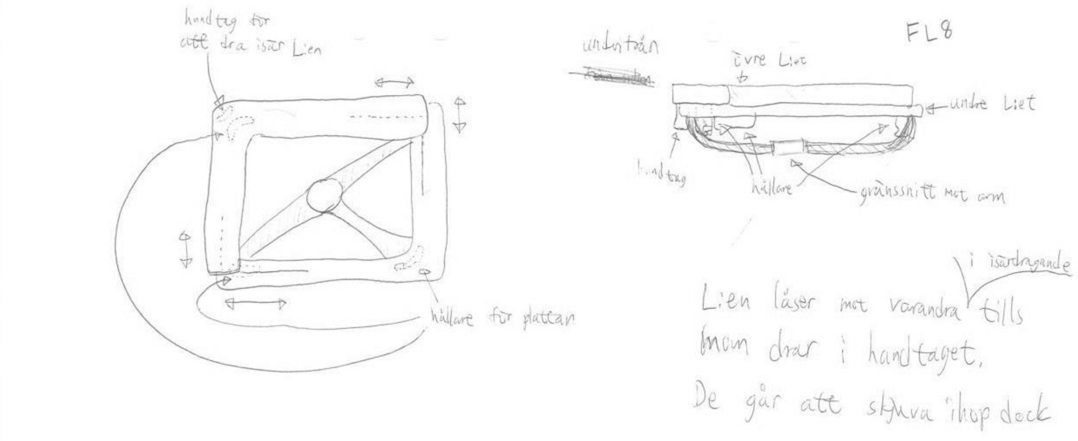


Figure K.10 - Concept FL8

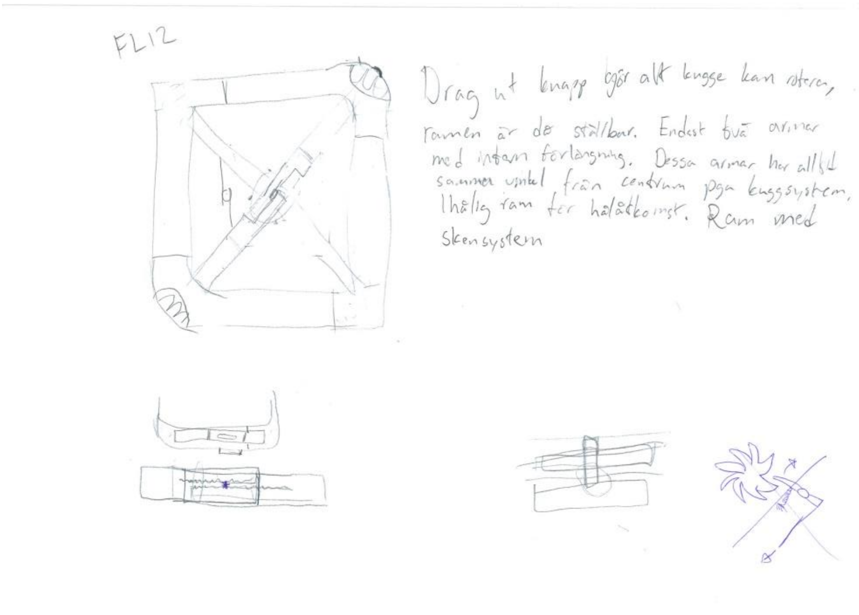


Figure K.11 - Concept FL12

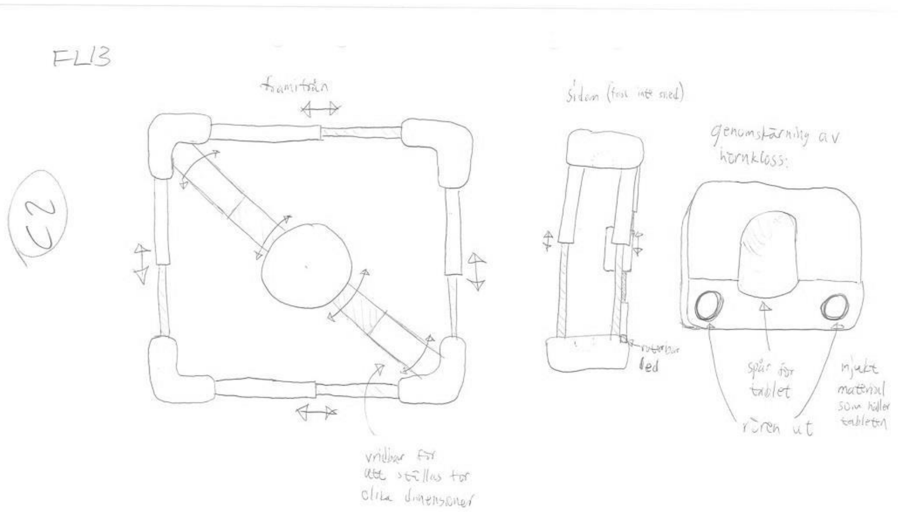


Figure K.12 - Concept FL13

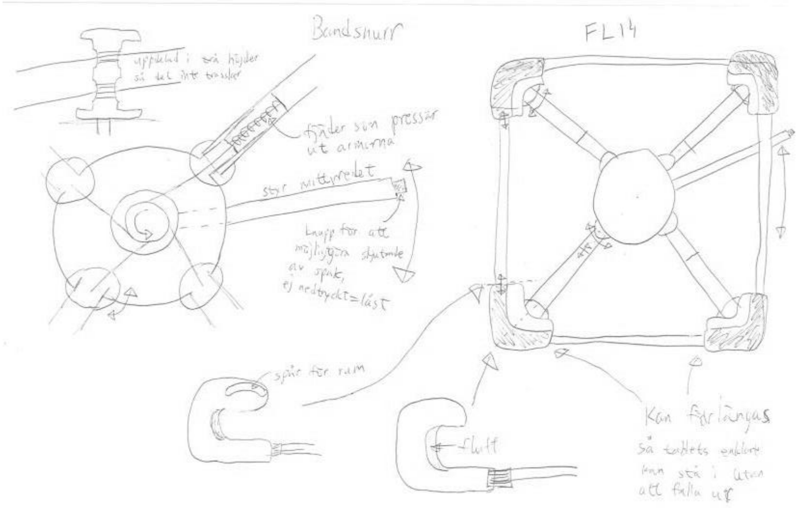


Figure K.13 - Concept FL14

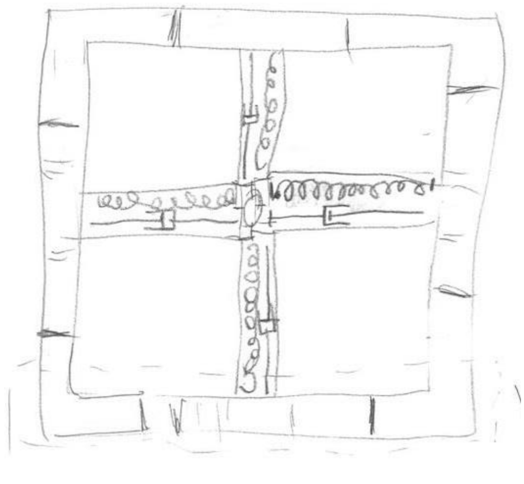


Figure K.14 - Concept FL15

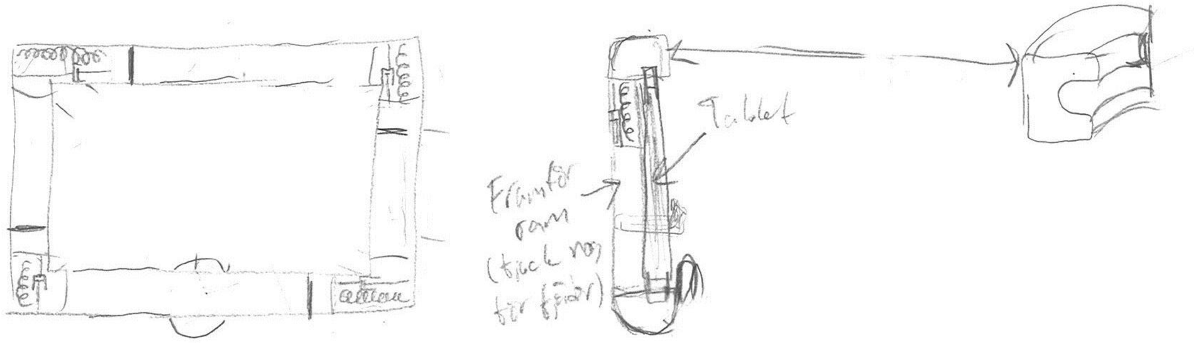


Figure K.15 - Concept FL16

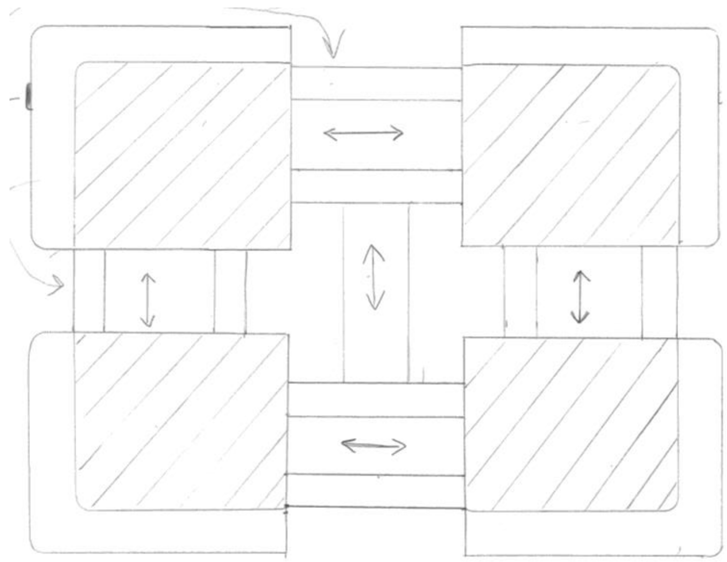


Figure K.16 - Concept FL18

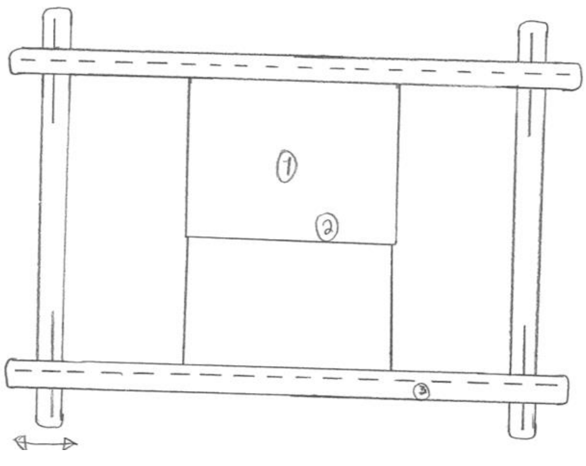


Figure K.17 - Concept FL19

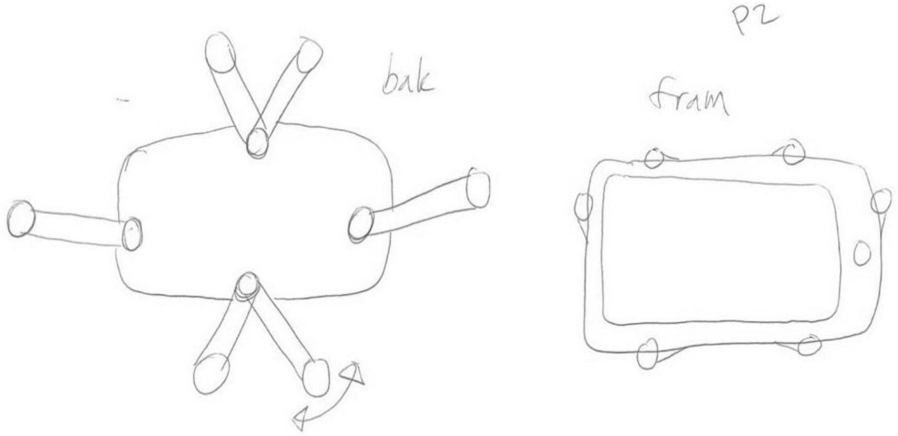


Figure K.18 - Concept P2

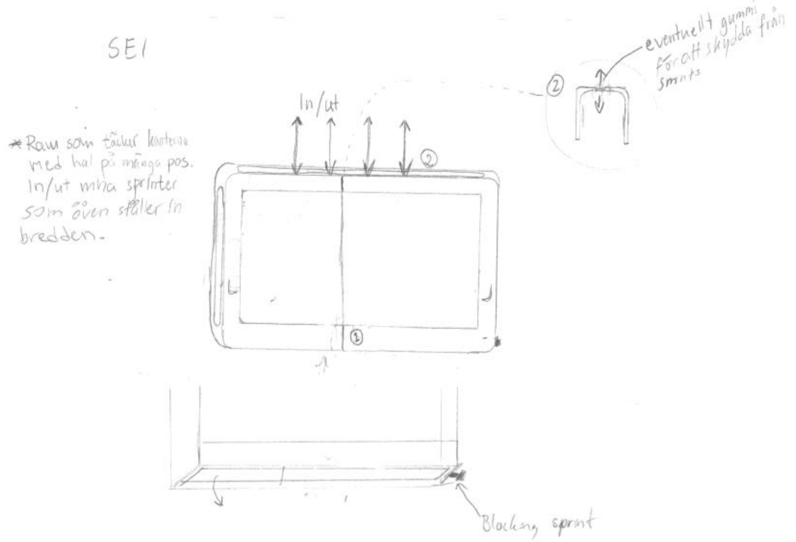


Figure K.19 - Concept SE1

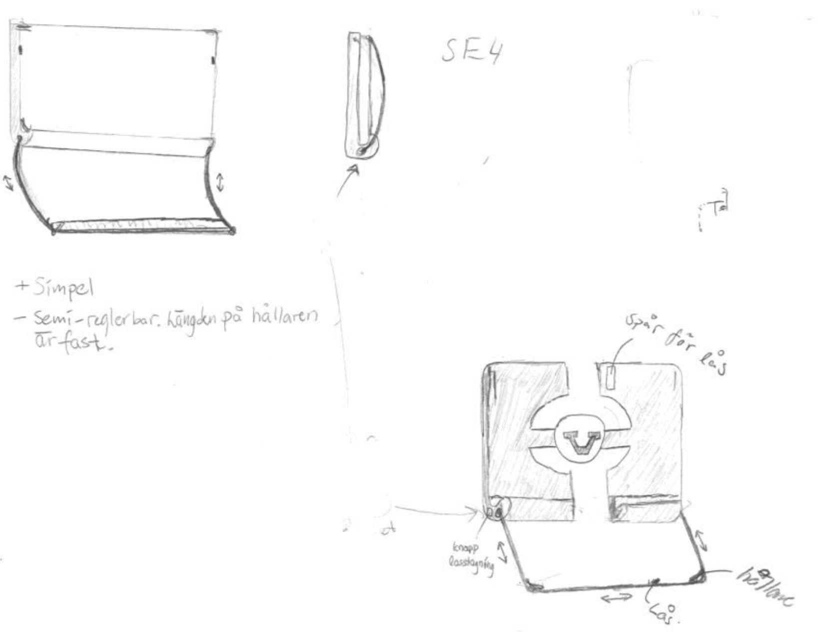


Figure K.20 - Concept SE4

Appendix L

Final 16 concepts

Figure L.1 - Concept Ref

Figure L.2 - Concept Cog

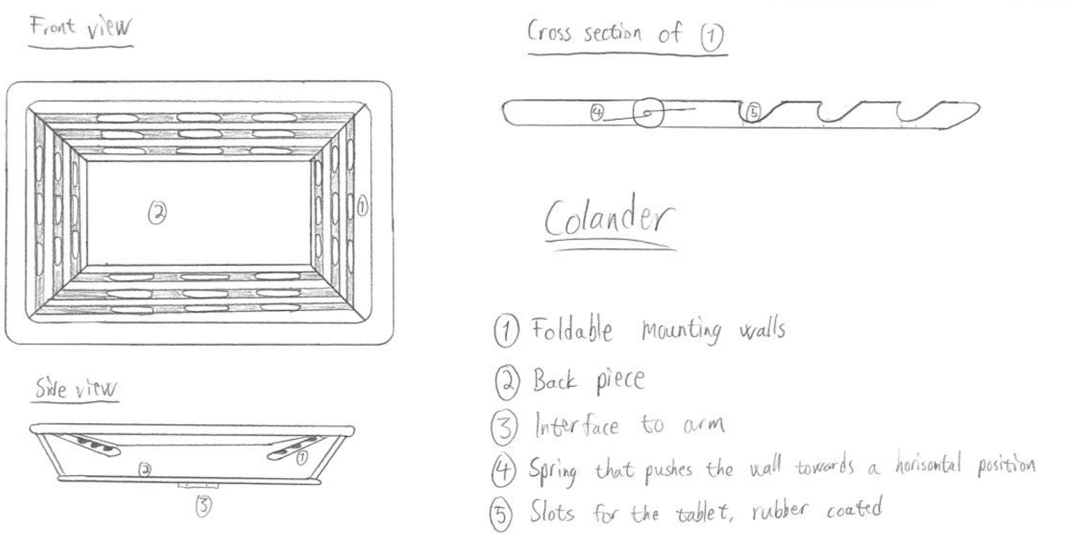


Figure L.3 - Concept Colander

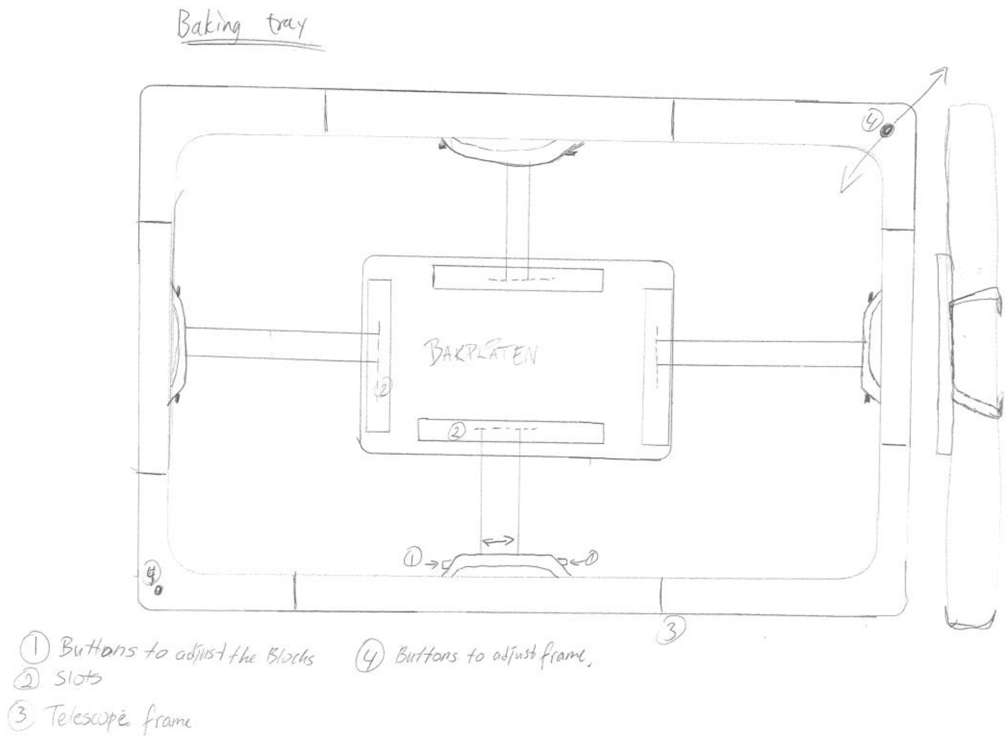


Figure L.4 - Concept Baking tray

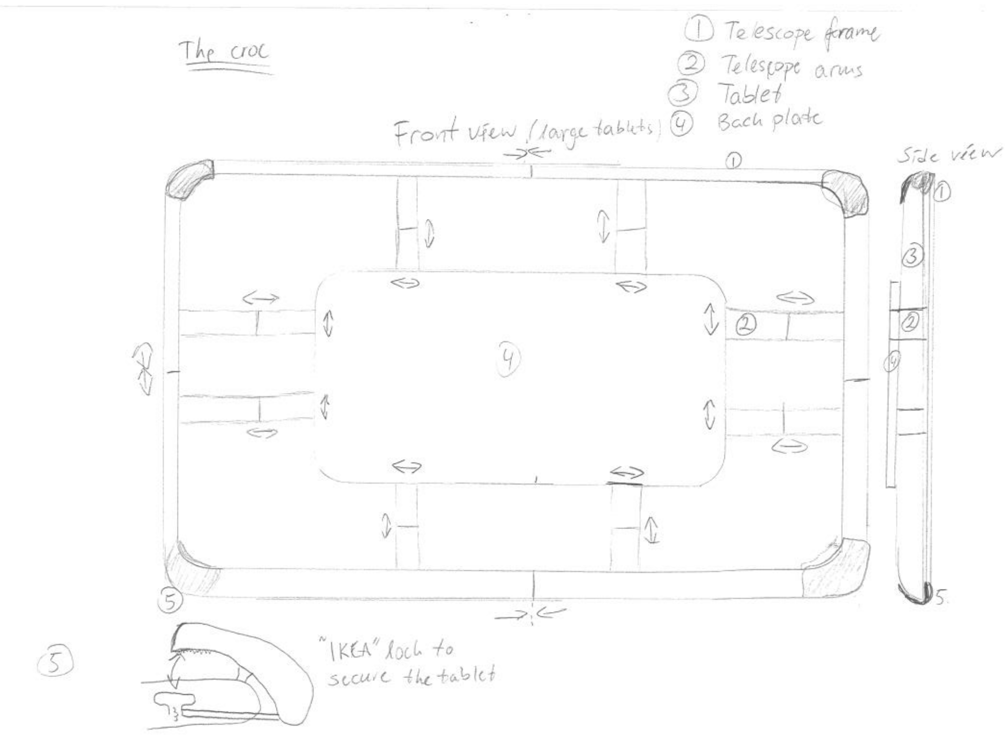


Figure L.5 - Concept Croc

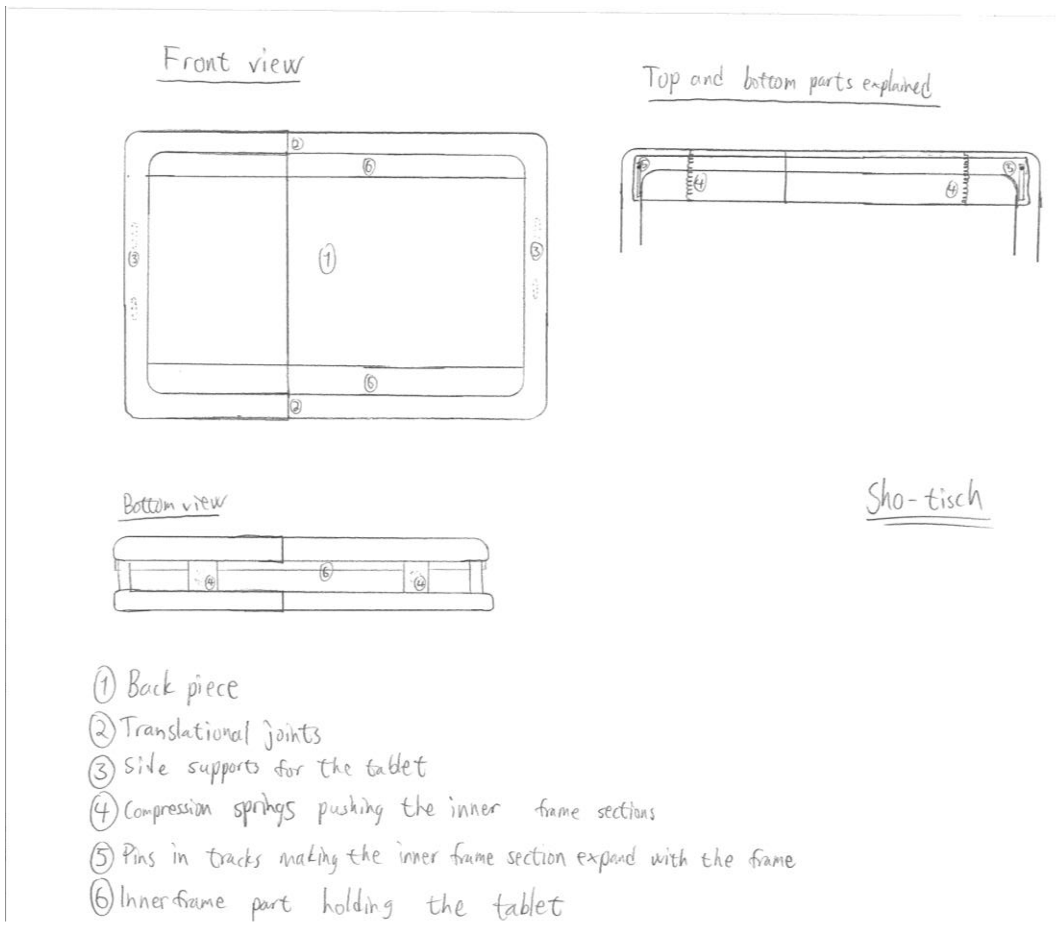


Figure L.6 - Concept Sho-tish

Figure L.7 - Concept Side slot

Figure L.8 - Concept PBR

Figure L.9 - Concept Flag

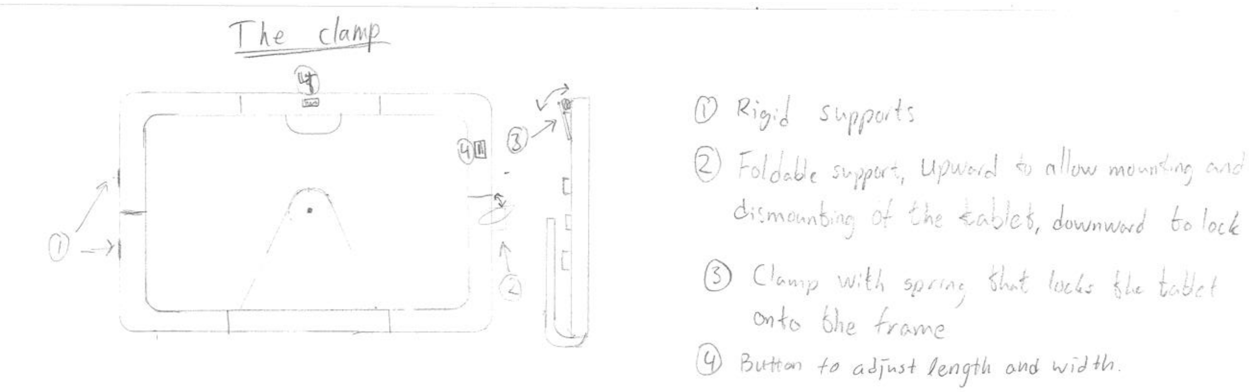


Figure L.10 - Concept Clamp

Figure L.11 - Concept Lever

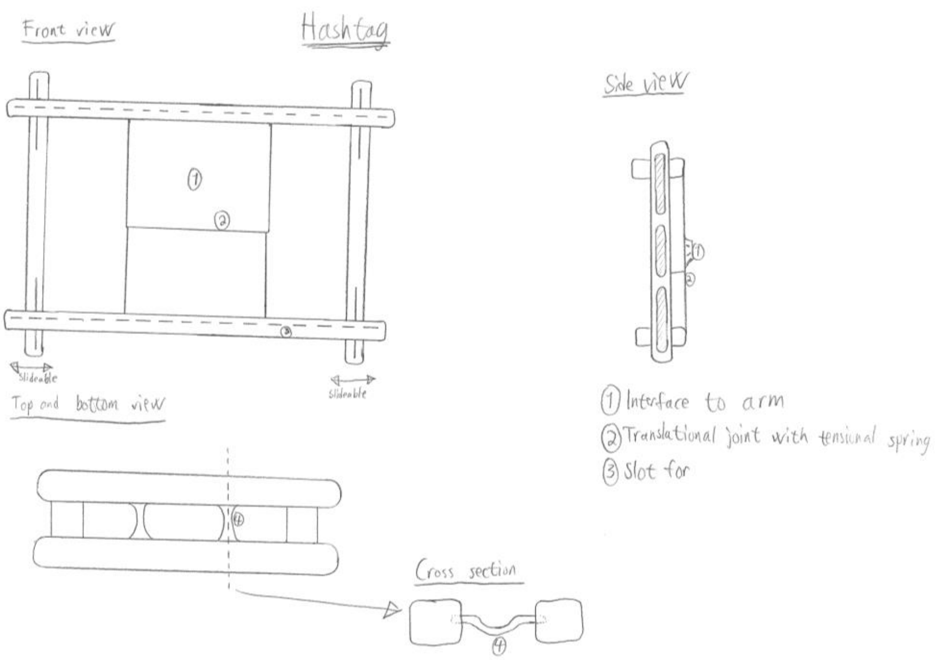


Figure L.12 - Concept Hashtag

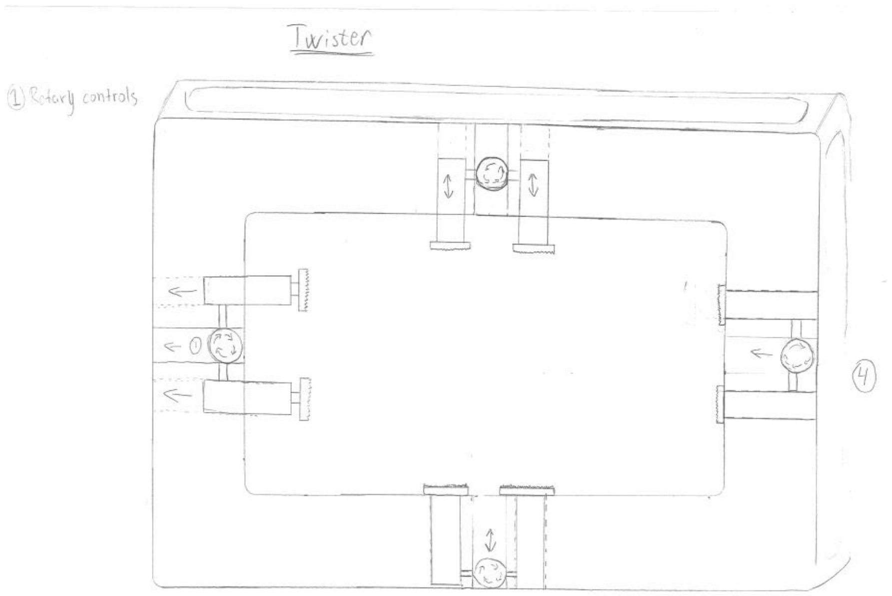


Figure L.13 - Concept Twister

Figure L.14 - Concept Modular

Figure L.15 - Concept Swatch

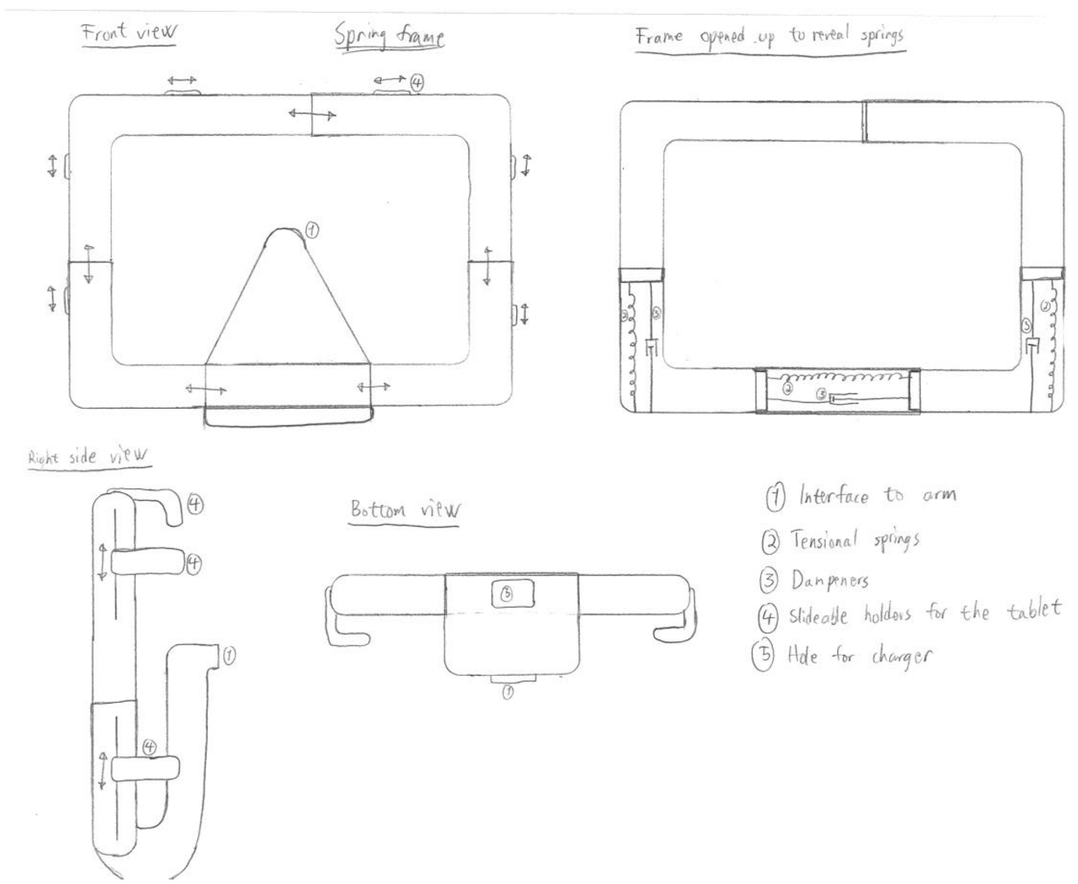


Figure L.16 - Concept Spring frame

Appendix M

First scoring matrix

Criteria	Judgement aspects	Weight	The ref	
Aesthetically appealing	Coherent with Volvo's design, instills quality/safety, good looking	**22,00%**	4	0,88
Ease of use and flexibility	Intuitiveness, time, simplicity in use, range of flexibility	**18,00%**	3	0,54
Physical robustness	Strength, fastening strength, structural stability, stability in usage	**26,00%**	3	0,78
Simplicity	Number of parts, complexity of connections	**13,00%**	4	0,52
Accessability for buttons & sockets	Charging, audio, volume buttons, on/off, home button, speakers	**21,00%**	5	1,05
			19	3,77
				2
		Continue?		Y

The cog		Colander		Baking tray		The croc		Sho-tisch		Side slot		PBR		The flag		The clamp		The lever	
4	0,88	1	0,22	3	0,66	3	0,66	2	0,44	4	0,88	2	0,44	4	0,88	3	0,66	4	0,88
4	0,72	2	0,36	3	0,54	1	0,18	3	0,54	3	0,54	4	0,72	3	0,54	3	0,54	4	0,72
3	0,78	5	1,3	1	0,26	1	0,26	4	1,04	3	0,78	4	1,04	3	0,78	3	0,78	3	0,78
1	0,13	5	0,65	1	0,13	1	0,13	4	0,52	3	0,39	4	0,52	3	0,39	4	0,52	2	0,26
5	1,05	1	0,21	5	1,05	4	0,84	2	0,42	3	0,63	3	0,63	4	0,84	3	0,63	4	0,84
17	3,56	14	2,74	13	2,64	10	2,07	15	2,96	16	3,22	17	3,35	17	3,43	16	3,13	17	3,48
	3		14		15		16		11		8		7		6		10		5
	Y		N		N		N		N		Y		Y		Y		N		Y

L

Hashtag		Twister		Modular		Swatch		Spring-frame	
2	0,44	1	0,22	2	0,44	5	1,1	4	0,88
3	0,54	1	0,18	3	0,54	5	0,9	2	0,36
2	0,52	5	1,3	5	1,3	3	0,78	2	0,52
4	0,52	5	0,65	5	0,65	2	0,26	3	0,39
4	0,84	2	0,42	3	0,63	4	0,84	5	1,05
15	2,86	14	2,77	18	3,56	19	3,88	16	3,2
	12		13		4		1		9
	N		N		Y		Y		N

Appendix N

Second scoring matrix

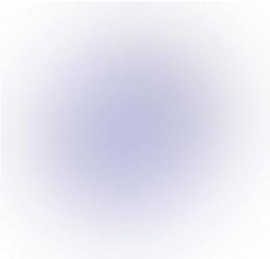
	Weight	Ref		Cog	
Aesthetically appealing	**22,00%**	**14**	**0,755**	**16**	**0,865**
Instills quality	7,00%	3	0,21	3	0,21
Instills safety	4,00%	4	0,16	4	0,16
Design with tablet	5,50%	4	0,22	4	0,22
Design without tablet	5,50%	3	0,165	5	0,275
Ease of use and flexibility	**18,00%**	**11**	**0,477**	**13**	**0,576**
Time and simplicity to mount/dismount tablet	6,30%	2	0,126	3	0,189
Intuitiveness	1,80%	3	0,054	3	0,054
Range of flexibility	6,30%	3	0,189	3	0,189
Time and simplicity to adjust size between tablets	3,60%	3	0,108	4	0,144
Physical robustness	**26,00%**	**10**	**0,65**	**13**	**0,845**
Strength	5,20%	3	0,156	3	0,156
Fastening strength	6,50%	3	0,195	3	0,195
Structural stability	7,80%	3	0,234	3	0,234
Stability in usage	6,50%	1	0,065	4	0,26
Simplicity	**13,00%**	**14**	**0,4784**	**7**	**0,2561**
Number of parts	3,77%	3	0,1131	2	0,0754
Number of unique parts	4,42%	5	0,221	3	0,1326
Complexity of connections	2,86%	3	0,0858	1	0,0286
Has as simple shapes as possible	1,95%	3	0,0585	1	0,0195
Accessability for buttons and sockets	**21,00%**	**29**	**0,7623**	**28**	**0,7581**
Charging	2,94%	4	0,1176	4	0,1176
Audio jack	3,36%	4	0,1344	4	0,1344
Volume buttons	2,31%	4	0,0924	4	0,0924
On/off	4,20%	4	0,168	4	0,168
Home button	5,04%	3	0,1512	3	0,1512
Speakers	0,42%	4	0,0168	3	0,0126
Mic	1,68%	3	0,0504	3	0,0504
Front camera	1,05%	3	0,0315	3	0,0315
Score		78	3,1227	77	3,3002
Rank			7		4

Side slot		PBR		Flag		Lever		Modular		Swatch	
11	**0,605**	**8**	**0,44**	**14**	**0,755**	**10**	**0,55**	**11**	**0,59**	**11**	**0,605**
2	0,14	3	0,21	3	0,21	2	0,14	4	0,28	2	0,14
2	0,08	3	0,12	4	0,16	2	0,08	5	0,2	2	0,08
4	0,22	1	0,055	3	0,165	4	0,22	1	0,055	5	0,275
3	0,165	1	0,055	4	0,22	2	0,11	1	0,055	2	0,11
13	**0,603**	**11**	**0,504**	**12**	**0,495**	**13**	**0,531**	**14**	**0,63**	**14**	**0,657**
4	0,252	3	0,189	2	0,126	2	0,126	5	0,315	4	0,252
3	0,054	3	0,054	4	0,072	4	0,072	5	0,09	2	0,036
3	0,189	3	0,189	3	0,189	3	0,189	3	0,189	3	0,189
3	0,108	2	0,072	3	0,108	4	0,144	1	0,036	5	0,18
12	**0,78**	**16**	**1,04**	**13**	**0,845**	**15**	**0,975**	**17**	**1,105**	**14**	**0,91**
2	0,104	4	0,208	3	0,156	3	0,156	5	0,26	3	0,156
5	0,325	4	0,26	5	0,325	5	0,325	2	0,13	4	0,26
2	0,156	4	0,312	3	0,234	3	0,234	5	0,39	3	0,234
3	0,195	4	0,26	2	0,13	4	0,26	5	0,325	4	0,26
10	**0,3419**	**15**	**0,4758**	**15**	**0,4914**	**6**	**0,2119**	**20**	**0,65**	**11**	**0,3679**
3	0,1131	4	0,1508	4	0,1508	2	0,0754	5	0,1885	2	0,0754
3	0,1326	3	0,1326	4	0,1768	2	0,0884	5	0,221	4	0,1768
2	0,0572	4	0,1144	3	0,0858	1	0,0286	5	0,143	2	0,0572
2	0,039	4	0,078	4	0,078	1	0,0195	5	0,0975	3	0,0585
29	**0,7623**	**28**	**0,7581**	**28**	**0,7581**	**32**	**0,861**	**19**	**0,4977**	**32**	**0,861**
4	0,1176	4	0,1176	4	0,1176	4	0,1176	2	0,0588	4	0,1176
4	0,1344	4	0,1344	4	0,1344	5	0,168	2	0,0672	5	0,168
4	0,0924	4	0,0924	4	0,0924	5	0,1155	2	0,0462	5	0,1155
4	0,168	4	0,168	4	0,168	5	0,21	2	0,084	5	0,21
3	0,1512	3	0,1512	3	0,1512	3	0,1512	3	0,1512	3	0,1512
4	0,0168	3	0,0126	3	0,0126	4	0,0168	2	0,0084	4	0,0168
3	0,0504	3	0,0504	3	0,0504	3	0,0504	3	0,0504	3	0,0504
3	0,0315	3	0,0315	3	0,0315	3	0,0315	3	0,0315	3	0,0315
75	3,09228	78	3,21795	82	3,34453	76	3,12896	81	3,47271	82	3,40092

Appendix O

Assembly of Cog

This does not include the assembly for the locking mechanisms since they were not fully developed.



Place the back piece on a flat area

Put one middle arm and the cog wheel in position on the back piece

Attach the gear racks to the rack arms and place them in position in the middle arm. Make sure that they are equally far from the middle.

Attach the upper middle arm to the lower and snap them together using plastic clips or screws.

Attach the front back piece to the rear back piece and insert the screw into the hole in the front. Connect it to VCC’s interface.

Attach the little cap so that it covers the screw head

Take the outer frame parts.

Add the supports by pushing them onto the frame sections and bending them down into place.

Push the springs into place in the holes in the rear frame section using a long, narrow tool. Then insert the inner frame parts into the holes in the outer frame parts.

Mount the frame to the arms using bolts.

Done!